CHAPTER 8
Freshwater snails

Intermediate hosts of schistosomiasis and foodborne trematode infections

Many species of freshwater snail belonging to the family Planorbidae are intermediate hosts of highly infective fluke (trematode) larvae of the genus *Schistosoma* which cause schistosomiasis, also called bilharziasis, in Africa, Asia and the Americas. The infection is widespread, and although the mortality rate is relatively low, severe debilitating illness is caused in millions of people. It is prevalent in areas where the snail intermediate hosts breed in waters contaminated by faeces or urine of infected persons. People acquire schistosomiasis through repeated contact with fresh water during fishing, farming, swimming, washing, bathing and recreational activities. Water resources development schemes in certain areas, particularly irrigation schemes, can contribute to the introduction and spread of schistosomiasis.

The snails are considered to be intermediate hosts because humans harbour the sexual stages of the parasites and the snails harbour the asexual stages. People serve as vectors by contaminating the environment. Transfer of the infection requires no direct contact between snails and people.

Freshwater snails are also intermediate hosts of foodborne fluke infections affecting the liver, lungs and intestines of humans or animals.

Biology

Some 350 snail species are estimated to be of possible medical or veterinary importance. Most intermediate hosts of human *Schistosoma* parasites belong to three genera, *Biomphalaria, Bulinus* and *Oncomelania*. The species involved can be identified by the shape of the outer shell. Simple regional keys are available for the determination of most species. The snails can be divided into two main groups: aquatic snails that live under water and cannot usually survive elsewhere (*Biomphalaria, Bulinus*), and amphibious snails adapted for living in and out of water (*Oncomelania*). In Africa and the Americas, snails of the genus *Biomphalaria* serve as intermediate hosts of *S. mansoni* (Fig. 8.1). Snails of the genus *Bulinus* serve as the intermediate hosts of *S. haematobium* in Africa and the Eastern Mediterranean, as well as of *S. intercalatum* in Africa. In south-east Asia, *Oncomelania* serves as the intermediate host of *S. japonicum*, and *Tricula* as the intermediate host of *S. mekongi*. Among the snail intermediate hosts of trematodes, the species belonging to the genus *Lymnaea* are of importance in the transmission of liver flukes. *Lymnaea* species may be either aquatic or amphibious (Fig. 8.2).

Life cycle

All species of *Biomphalaria* and *Bulinus* are hermaphrodite, possessing both male and female organs and being capable of self- or cross-fertilization. A single

Fig. 8.1
Snail of the genus *Biomphalaria* (reproduced, with permission, from the *Bayer manual of pest control*).

specimen can invade and populate a new habitat. The eggs are laid at intervals in batches of 5–40, each batch being enclosed in a mass of jelly-like material. The young snails hatch after 6–8 days and reach maturity in 4–7 weeks, depending on the species and environmental conditions. Temperature and food availability are among the most important limiting factors. A snail lays up to 1000 eggs during its life, which may last more than a year.

The amphibious *Oncomelania* snails, which may live for several years, have separate sexes. The female lays its eggs singly near the water margin.

Ecology

Snail habitats include almost all types of freshwater bodies ranging from small temporary ponds and streams to large lakes and rivers. Within each habitat, snail distribution may be patchy and detection requires examination of different sites. Moreover, snail densities vary significantly with the season. In general, the aquatic snail hosts of schistosomes occur in shallow water near the shores of lakes, ponds, marshes, streams and irrigation channels. They live on water plants and mud that is rich in decaying organic matter. They can also be found on rocks, stones or concrete covered with algae or on various types of debris. They are most common in waters where water plants are abundant and in water moderately polluted with organic matter, such as faeces and urine, as is often the case near human habitations. Plants serve as substrates for feeding and oviposition as well as providing protection from high water velocities and predators such as fish and birds.

Most aquatic snail species die when stranded on dry land in the dry season. However, a proportion of some snail species are able to withstand desiccation for months while buried in the mud bottom by sealing their shell opening with a layer of mucus. Most species can survive outside water for short periods.

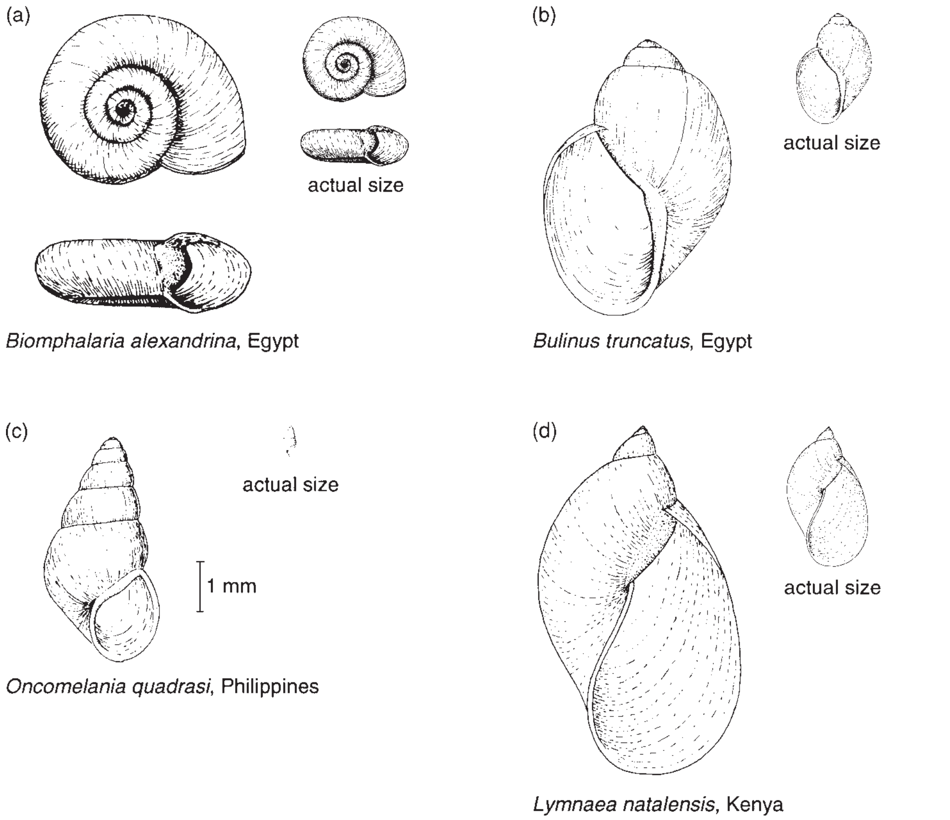

Fig. 8.2
Shells of the medically important snail genera: (a) *Biomphalaria*; (b) *Bulinus*; (c) *Oncomelania*; (d) *Lymnaea* (© WHO).

For reproduction, temperatures between 22 °C and 26 °C are usually optimal, but *Bulinus* snails in Ghana and other hot places have a wider temperature range. The snails can easily survive between 10 °C and 35 °C. They are not found in salty or acidic water.

In most areas, seasonal changes in rainfall, water level and temperature cause marked fluctuations in snail population densities and transmission rates. Reservoirs that contain water for several months of the year in Sahelian Africa can be intensive transmission sites of urinary schistosomiasis during a very limited period, because surviving *Bulinus* species rapidly recolonize the reservoirs after the rains start.

Oncomelania snails can survive periods of drought because they possess an operculum capable of closing the shell opening. In the temperate zone they can survive for 2–4 months, in the tropics much less. They live both in and out of water in humid areas such as poorly tilled rice fields, sluggish streams, secondary and tertiary canals of irrigation systems, swamps and roadside ditches. The vegetation in these sites is important in maintaining a suitable temperature and humidity. Their food is similar to that of aquatic snails but they also feed on plant surfaces above water.

Public health importance

Schistosomiasis

Schistosomiasis is one of the most widespread of all human parasitic diseases, ranking second only to malaria in terms of its socioeconomic and public health importance in tropical and subtropical areas. It is also the most prevalent of the waterborne diseases and one of the greatest risks to health in rural areas of developing countries.

In 1996 schistosomiasis was reported to be endemic in 74 tropical countries, and over 200 million people living in rural and agricultural areas were estimated to be infected. Between 500 and 600 million people were considered at risk of becoming infected.

As a mainly rural, often occupational disease, schistosomiasis principally affects people who are unable to avoid contact with water, either because of their profession (agriculture, fishing) or because of a lack of a reliable source of safe water for drinking, washing and bathing. As a result of a low level of resistance and intensive water contact when playing and swimming, children aged between 10 and 15 years are the most heavily infected. Increased population movements help to spread the disease, and schistosomiasis is now occurring increasingly in periurban areas.

Although most people in areas of endemicity have light infections with no symptoms, the effects of schistosomiasis on a country's health and economy are serious. In several areas (e.g., north-eastern Brazil, Egypt, Sudan) the working ability of the rural inhabitants is severely reduced as a result of the weakness and lethargy caused by the disease.

Major forms and distribution of schistosomes

Five species of the trematode parasite are responsible for the major forms of human schistosomiasis. In 1996 intestinal schistosomiasis caused by *Schistosoma mansoni* was reported from 52 countries in Africa, the eastern Mediterranean, the Caribbean and South America. Oriental or Asiatic intestinal schistosomiasis, caused by *S. japonicum* or *S. mekongi*, was reported to be endemic in seven Asian countries. Another form of intestinal schistosomiasis caused by *S. intercalatum* was reported from 10 central African countries. Urinary (or vesical) schistosomiasis, caused by *S. haematobium*, was reported to be endemic in 54 countries in Africa and the eastern Mediterranean (Figs. 8.3 and 8.4).

Life cycle and transmission

On reaching water, the eggs excreted by an infected person hatch to release a tiny parasite (a miracidium) that swims actively through the water by means of fine hairs (cilia) covering its body. The miracidium survives for about 8–12 hours, during which time it must find and penetrate the soft body of a suitable freshwater snail in order to develop further (Figs 8.5 and 8.6).

Once inside the snail, the miracidium reproduces many times asexually until thousands of new forms (cercariae) break out of the snail into the water. Depending on the species of snail and parasite, and on environmental conditions, this phase of development may take 3 weeks in hot areas, and 4–7 weeks or longer elsewhere. The fork-tailed cercariae can live for up to 48 hours outside the snail. Within that time they must penetrate the skin of a human being in order to continue their life cycle.

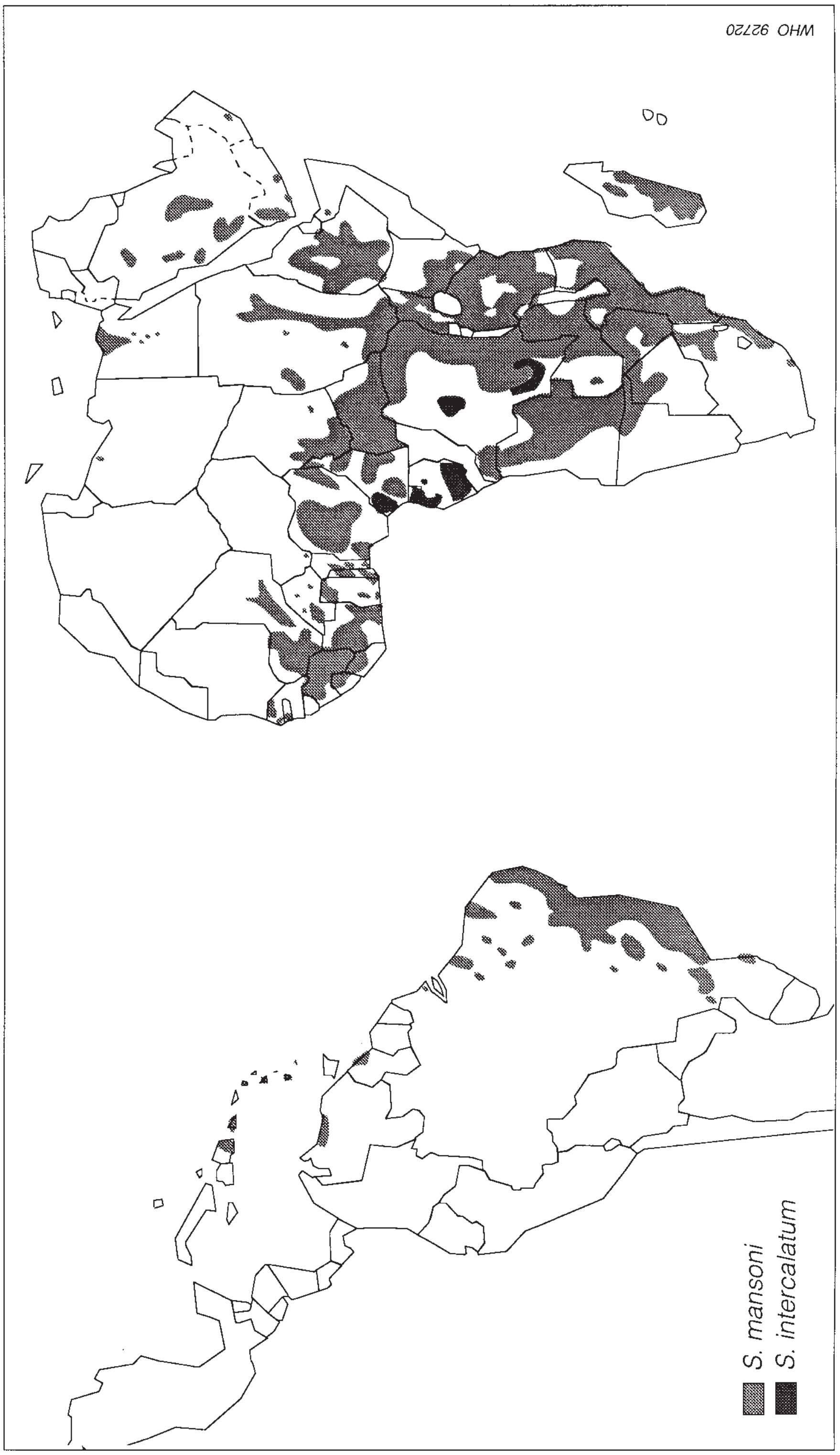

Fig. 8.3
Global distribution of schistosomiasis due to *Schistosoma mansoni* and *S. intercalatum*, 1993 (© WHO).

Fig. 8.4
Global distribution of schistosomiasis due to *Schistosoma haematobium*, *S. japonicum* and *S. mekongi*, 1993 (© WHO).

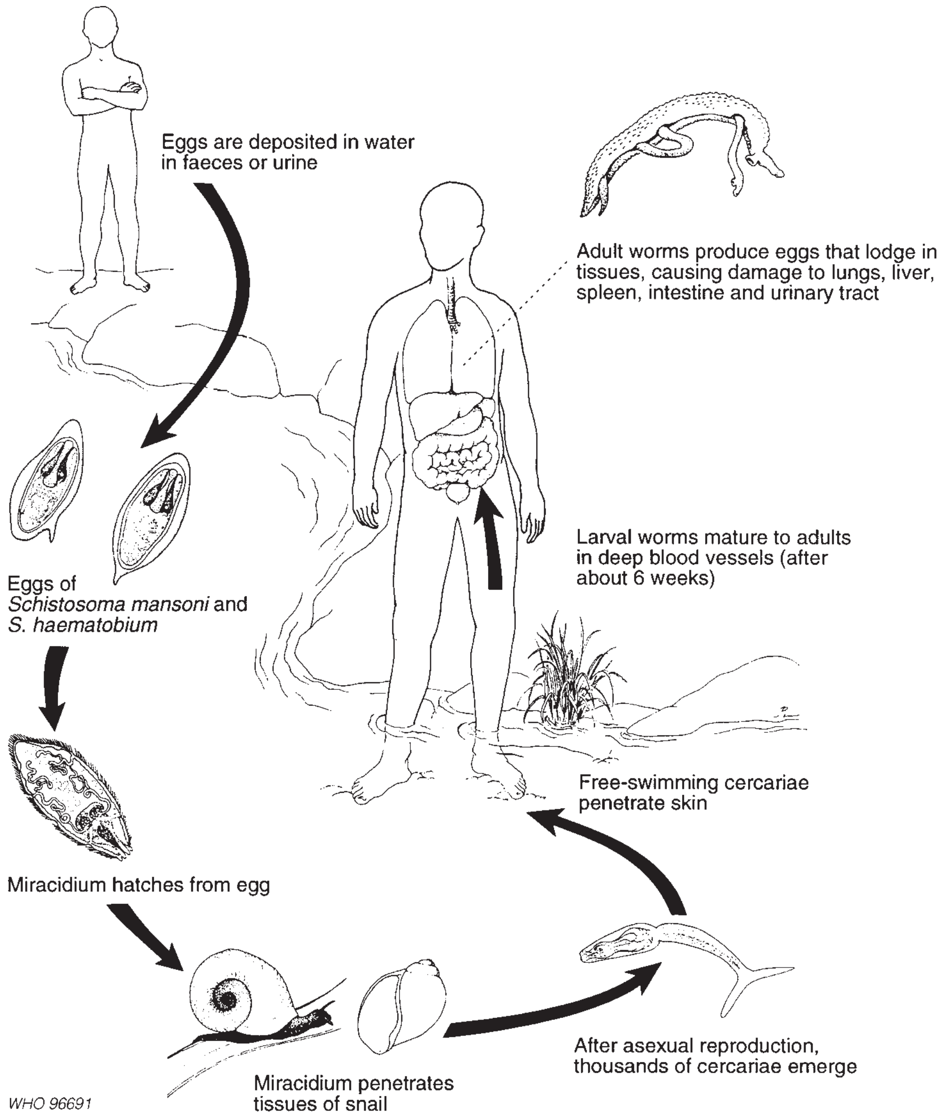

Fig. 8.5
Life cycle of schistosomes (by Taina Litwak for the United States Agency for International Development's VBC Project).

As the cercaria penetrates the skin, it loses its tail. Within 48 hours it penetrates the skin completely to reach the blood vessels. This process sometimes causes itching, but most people do not notice it.

Within seven weeks the young parasite matures into an adult male or female worm. Eggs are produced only by mated females. Male and female adult worms remain joined together for life, a period of less than five years on average but 20 years has been recorded. The more slender female is held permanently in a groove in the front of the male's body. Once eggs are produced, the cycle starts again.

In intestinal schistosomiasis the worms attach themselves to the blood vessels that line the intestines; in urinary schistosomiasis, they live in the blood vessels of

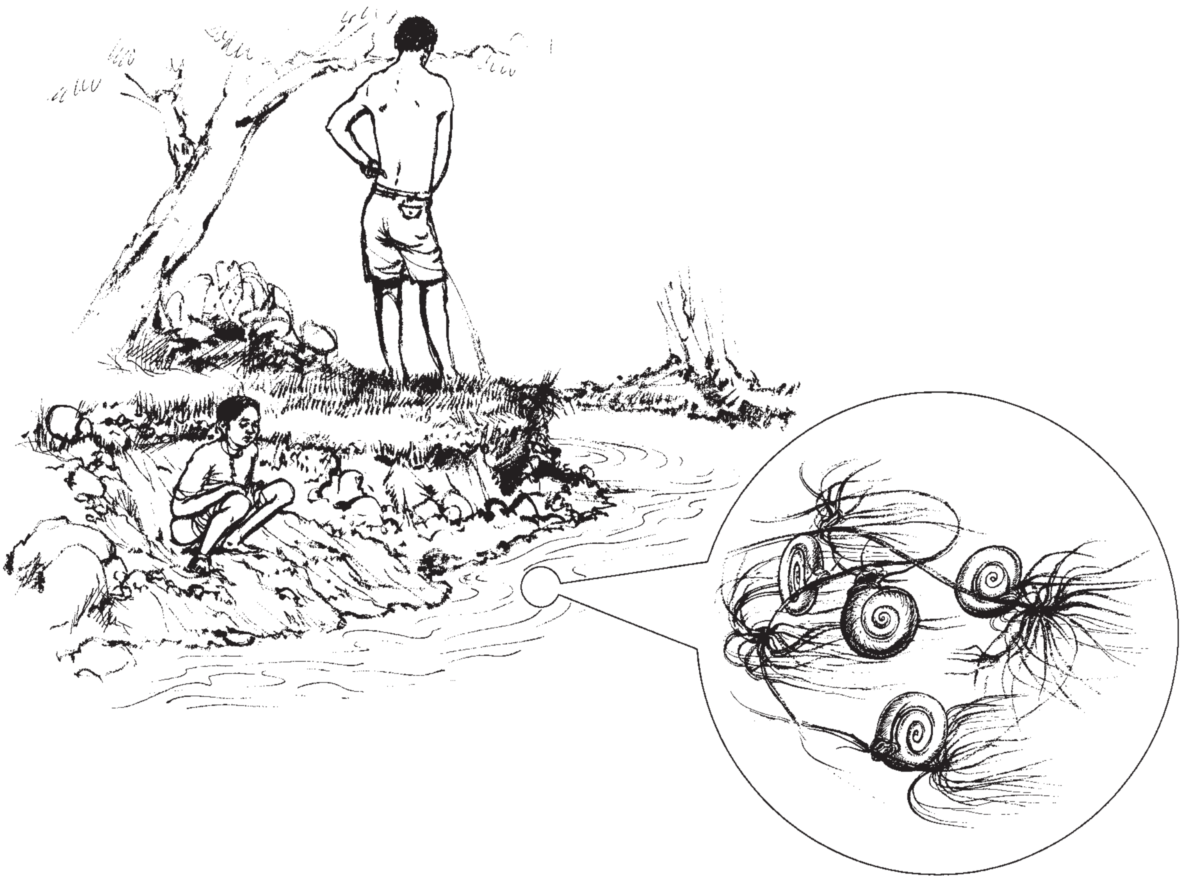

Fig. 8.6
Transmission of schistosomes. Eggs enter the water when infected people urinate in it or defecate on the water's edge. Freshwater snails are required for the development of the infective stage of the parasite which subsequently infects people entering the water.

the bladder. Only about half of the eggs leave the body in the faeces (intestinal schistosomiasis) or urine (urinary schistosomiasis); the rest remain embedded in the body where they cause damage to organs.

Clinical signs and symptoms

Reactions occur to schistosome eggs that are not passed out in the urine or stools but become lodged in body tissues. The symptoms are related to the number and location of the eggs.

In urinary schistosomiasis (caused by *S. haematobium*) the eggs cause damage to the urinary tract and blood appears in the urine. Urination becomes painful and there is progressive damage to the bladder, ureters and kidneys. Bladder cancer is common in advanced cases.

Intestinal schistosomiasis (caused by *S. mansoni, S. japonicum* and *S. mekongi*) develops more slowly. There is progressive enlargement of the liver and spleen (Fig. 8.7) as well as damage to the intestine, caused by fibrotic lesions around the schistosome eggs lodged in these tissues and hypertension of the abdominal blood

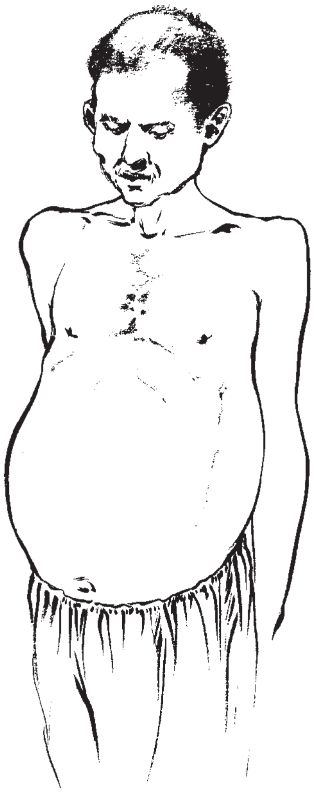

Fig. 8.7
Enlargement of the liver and spleen may occur in people with untreated intestinal schistosomiasis.

vessels. Repeated bleeding from these vessels leads to blood in the stools and can be fatal. *S. intercalatum* infects the lower intestinal tract.

Swimmer's itch

Human skin can be penetrated by cercariae that normally develop in birds. The larvae die in the skin causing an allergic reaction known as swimmer's itch. This problem is seen in many temperate areas, in people who bathe in fresh, brackish and salt water, where infected aquatic birds shed faeces in water populated by appropriate snail hosts.

Diagnosis

Modern techniques for detecting schistosome eggs under the microscope are simple and inexpensive. A simple syringe filtration technique (using filter paper, polycarbonate or nylon filters) is recommended for quantitative diagnosis of urinary schistosomiasis. This technique allows urinary egg counts to be performed on up to 130 samples per hour.

Researchers using this technique on children in Ghana, Kenya, Liberia, Niger, the United Republic of Tanzania and Zambia reported that children with more than 50 *S. haematobium* eggs per 10 ml of urine often have blood in their urine (haematuria). This sign is evidence of bladder disease caused by urinary schistosomiasis, and can be used by primary health care workers to identify children needing treatment. Urine sedimentation is also a simple and effective method for detecting *Schistosoma* eggs.

The diagnosis of intestinal schistosomiasis by counting the eggs in faecal specimens has also been simplified. A small amount of faeces, pressed through a fine nylon or steel screen to remove large debris, and placed under a piece of cellophane soaked in glycerol (Kato technique) or between glass slides (glass sandwich technique) can be quickly examined by trained microscopists.

Treatment

All people are susceptible to infection. Children have a higher rate of reinfection after treatment than adults.

Immunization is of great research interest but the probability of success is remote.

Three safe, effective drugs that can be taken orally are now available to treat schistosomiasis. Praziquantel, oxamniquine and metrifonate are all included in the WHO Model List of Essential Drugs (*1*). Praziquantel is effective in a single dose against all forms of schistosomiasis. Previously irreversible damage caused by *Schistosoma* infections can now be successfully treated with praziquantel.

Oxamniquine is used exclusively to treat intestinal schistosomiasis in Africa and South America, although *S. mansoni* is less susceptible to oxamniquine in Africa than in South America. Metrifonate, which was originally developed as an insecticide, has now proved to be safe and effective for the treatment of urinary schistosomiasis.

The fears of many doctors that reinfection would quickly eliminate any benefit from treatment have proved too pessimistic. Rapid identification and prompt treatment of infected people immediately reduce environmental contamination with parasite eggs. In some areas, a reduction in the number of cases is maintained for a year and a half without further intervention, but in areas of continuing transmission certain age groups (schoolchildren) may be reinfected within 4–6 months. Even if reinfection occurs morbidity may be reduced for a much longer time, because it usually results from prolonged infection with large numbers of parasites.

Prevention and control

Individual protection from infection (e.g. in travellers) can in principle be achieved by avoiding contact with unsafe water. However, this requires an understanding of the risk of contact with water and a knowledge of the sites where infected snails are likely to occur (Fig. 8.8). For people living in areas of endemicity, contact is often unavoidable (farmers in irrigated agricultural areas, fishermen) or difficult to prevent (playing children).

The control of the disease in known foci of transmission is possible by using one or a combination of the following measures: improved detection and treatment of sick people; improvement of sanitary facilities for safe and acceptable disposal of human excreta; provision of safe drinking-water; reduction of contact with contaminated water; and snail control.

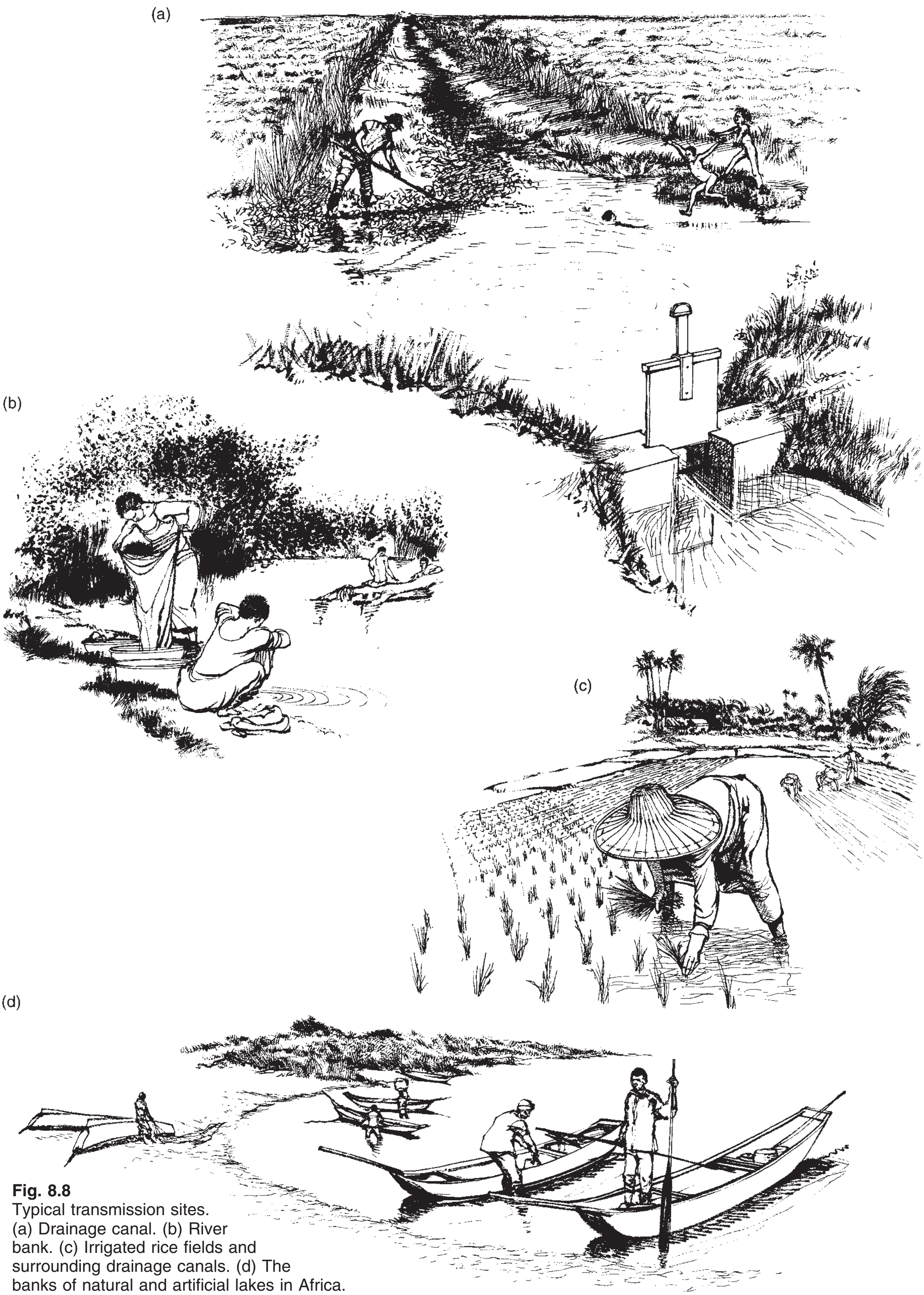

Fig. 8.8
Typical transmission sites.
(a) Drainage canal. (b) River bank. (c) Irrigated rice fields and surrounding drainage canals. (d) The banks of natural and artificial lakes in Africa.

In areas with low to medium prevalence of schistosomiasis and good health services, improved case detection and treatment of reported cases of illness may be the most cost-effective approach to control.[1] In areas where the disease is highly endemic, special schistosomiasis control campaigns, involving snail control measures, might be an additional cost-effective solution (*2*). Long-term sustainable improvements have to be based on safe water supply and improvements in sanitation and hygiene. Health education is essential for community understanding and participation in the proper use and continuous maintenance of sanitary and water supply facilities.

Schistosomiasis control in water resources development projects

The increasing numbers of water resources projects, essential for industrial and agricultural expansion in developing countries, are a matter of great concern to schistosomiasis experts. Water impoundments of all sizes, including man-made lakes and irrigation systems, provide excellent habitats for freshwater snails and encourage close and frequent contact between people and infected water.

Schistosomiasis and other waterborne diseases, whether introduced or spread by water development projects, can have a severe impact in economic terms (loss of labour, cost of treatment) and as regards the quality of life, and can delay the completion of projects if construction workers or the local population become infected. However, it is now possible to institute control measures from the moment such a project is planned. Examination and treatment of the population in the project area, of all employees of the development project and their families, and of potential migrant populations reduce the risk of schistosomiasis becoming a major public health problem. Good water management practices, where necessary supplemented by regular applications of molluscicide, may limit the distribution of snails. The lower the potential for transmission from the start, the smaller is the chance that serious disease will develop.

Foodborne trematode infections (*3*)

In 1993 at least 40 million people, largely in south-east Asia and the western Pacific, were reported to be infected by pathogenic flukes other than schistosomes. Fascioliasis, caused by *Fasciola hepatica* or *F. gigantica*, is an infection of the liver found throughout the world. Liver infections are also caused by oriental flukes in Asia (*Clonorchis sinensis, Opisthorchis viverrini* and *O. felineus*). Paragonimiasis, or lung fluke disease, occurs in Asia, West Africa, Ecuador, Peru and other South American countries. Intestinal fluke infections, caused by *Fasciolopsis buski* and many other species, occur in several Asian countries.

All trematode parasites occurring in humans are flat and leaf-shaped, ranging in size from 1 mm to 30 mm (up to 75 mm for *Fasciolopsis*). The adults deposit eggs that are excreted with the bile, sputum or faeces. On contact with water the eggs hatch and the larvae penetrate the appropriate snail intermediate hosts (*Fasciola* and *Paragonimus*), or the eggs are ingested by the snails and hatch inside (*Clonorchis, Opisthorchis*). Each parasite develops in a specific type of snail. Free-

[1] In areas where schistosomiasis caused by *S. japonicum* is endemic in south-east Asia and the western Pacific, control approaches should include the treatment of both infected persons and domestic animals because the parasite also occurs in populations of wild and domestic animals such as rodents, dogs, cats, pigs, water buffaloes, horses and cattle. Infected wild rodents may be a cause of continued transmission.

swimming cercariae emerge from the snail and attach to a specific second intermediate host (or substrate) to form a cyst. These hosts are usually a source of food for humans, i.e. watercress, fish and crustacea.

Prevention and control are possible through food safety measures (proper cooking and washing of fish, meat and vegetables) and avoidance of contamination of the environment with excreta. For example the fertilization of fish ponds in China with unprocessed night soil has been found to be a major cause of infection with *Clonorchis* and other flukes. Pretreatment of night soil in tanks to destroy eggs and other pathogens reduces the incidence of fluke infections significantly (*4*). Snail control measures are not cost-effective.

Praziquantel is the drug of choice for treatment of all human foodborne trematode infections except fascioliasis. *Fasciola hepatica* is described here in some detail because of its wide distribution and relative importance.

Fasciola hepatica

This fluke species occurs throughout the world and is a cause of serious economic loss in the animal husbandry industry. It is a common disease of ruminants, especially sheep, goats, cattle and buffaloes, although many other domestic and wild animals may also be infected. In comparison with animal infections, human infections are uncommon. Between 1970 and 1993, it was estimated that over 300 000 clinical cases may have occurred in more than 40 countries in Europe, the Americas, Africa, Asia and the western Pacific. The fluke is 2–3 cm in length, 0.8–1.3 cm in width, flat and leaf-shaped.

Life cycle and transmission

The adult worm lives in the human bile duct from where the eggs pass into the intestines and are excreted with the faeces. The eggs can remain viable in moist faeces for up to nine months or even longer. The larva (miracidium) hatches about two weeks after the eggs enter the water. It enters a snail and develops to produce large numbers of free-swimming cercariae which attach themselves to aquatic plants such as watercress and form cysts.

If the cysts are ingested by humans or animals, metacercariae emerge in the duodenum, penetrate the intestinal wall and reach the liver through the lymph or the body cavity where they remain for two or three months. Once they reach maturity, they migrate to the bile duct. The longevity in humans may be more than 10 years. Humans are infected by ingesting cyst-infested salads, eating raw liver or drinking water containing cysts.

Clinical signs and symptoms

Infection of the liver is difficult to diagnose because the symptoms are variable and resemble those of other diseases. A major symptom is chronic inflammation of the bile ducts. Bleeding of the bile duct can be a complication. People who have recently eaten raw liver may acquire infection of the pharynx, which is more easily diagnosed.

Diagnosis

Fasciola hepatica eggs can be detected by examination of faeces using a microscope (see p. 345).

Treatment and prevention

Treatment is possible with bithionol. Triclabendazole is being considered for registration by drug regulatory agencies in a number of countries. Infection can be prevented by not drinking unboiled or unfiltered water and by not eating raw liver and unboiled or unwashed vegetables. Snail control measures are not cost-effective.

Control measures

In addition to case detection and the treatment of sick people at first-line health facilities, measures should be taken to reduce or prevent transmission of schistosomiasis. The installation of a safe water supply is, in most areas, the most cost-effective control measure. Health education is essential to ensure community involvement in the construction and use of such facilities.

Avoidance of contact with snail-infested waters

It is important to provide water for drinking, bathing and washing clothes. Good village water supplies with pumps and pipes or pit-wells encourage people to stay away from streams and ponds that are infested (Fig. 8.9).

The health authorities should provide information on the safety of open waters. People should avoid swimming, wading, washing or bathing in water suspected of infestation. However, because detailed information is generally not available, it is safer to consider all freshwater bodies in endemic areas as potential transmission sites.

For agricultural workers at constant risk of infection, periodic examination and treatment may be the most feasible approach to disease control.

Improved sanitation

Defecation or urination in or near open waters should be avoided so that snails have less chance of becoming infected. Latrines or toilets should be constructed, and children should be taught to use them (Fig. 8.10). (For more information on latrines, see Chapter 1.)

Snail control

With the introduction of new and safer drugs for the treatment of schistosomiasis, and, in many places, improvements in water supply and sanitation facilities, snail control is perhaps employed less often as a means of combating the disease. However, it remains an important and effective measure, especially where transmission occurs to a significant extent through children playing in water. This type of water contact is not likely to be changed through health education and the provision of safe water supplies. Prior to undertaking snail control measures, health authorities should screen water for the presence of snail intermediate hosts.

Snails can be controlled indirectly by reducing their habitat or directly by removing them. Where these measures are not sufficient to eliminate snail populations the use of chemicals that kill the snails (molluscicides) may be considered.

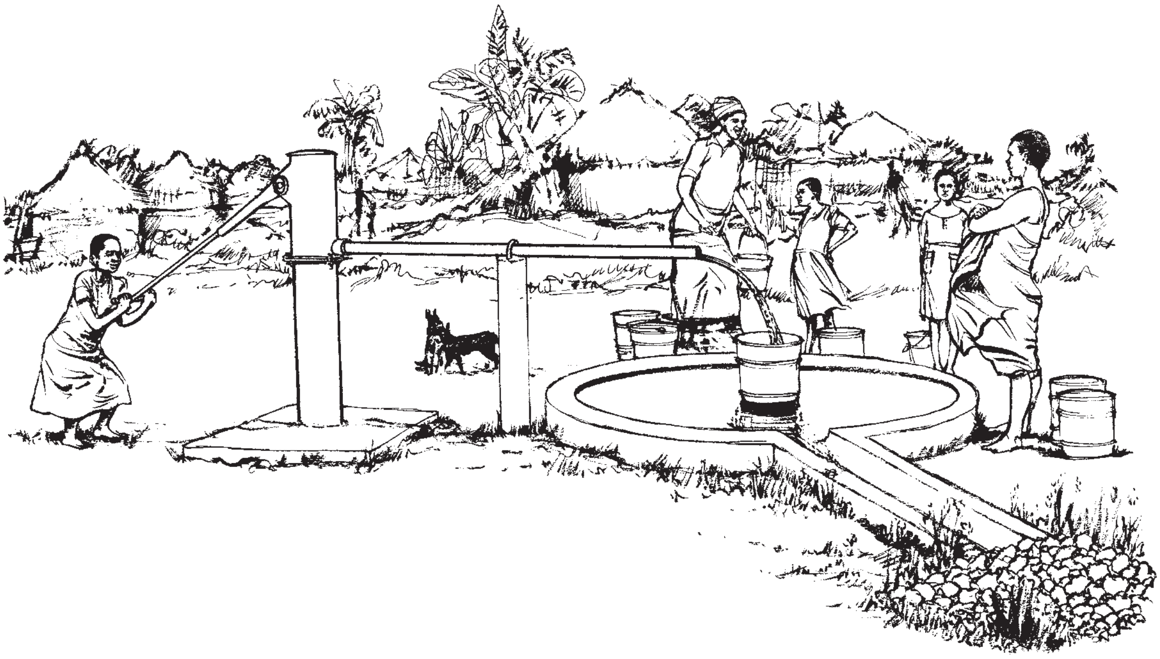

Fig. 8.9
A piped water supply with pumps, pit-wells and taps helps people to stay away from water that is infected.

Fig. 8.10
The use of pit latrines prevents the transmission of schistosomiasis.

The decision to do this, and the activity itself, must be the responsibility of technically qualified people.

The use of molluscicides has been and still is the most important method for controlling snail hosts. It is most effective against aquatic species of the genera *Bulinus* and *Biomphalaria*. Molluscicides are less effective against the amphibious *Oncomelania* species that transmit *S. japonicum*; environmental management measures are usually more cost-effective.

Snail control may be carried out by special teams or by primary health care personnel with some training in the epidemiology and control of schistosomiasis. Where transmission sites are well known, small in number and easily accessible, the community may also play an active role in control activities.

Environmental management

The methods of environmental management include drainage, filling in, and the lining of canals with concrete. These methods are generally expensive but long-lasting.

Reduction of snail habitats

Snails need vegetation for food, shelter and a substrate for their eggs. The removal of vegetation in irrigation ditches and canals reduces the number of snails. However, to clear manually, someone usually has to get into the water which is dangerous, while mechanical clearance is very expensive. The cleaning of canals may also help in the control of other diseases, including malaria, and may improve the effective use of irrigation water. A disadvantage of this method is the need for frequent repetition. Where sufficient resources are available, canals can be lined with cement to prevent or reduce the growth of vegetation. People can also remove plants from places where children swim or where clothes or dishes are washed. Under certain conditions the plant-eating Chinese grass carp (*Ctenopharyngodon idella*) may be suitable for the biological control of aquatic plants (see Chapter 1).

Alteration of water levels and flow rates

Where water quantity is not a limiting factor, raising and lowering water levels and increasing flow rates can disturb snail habitats and their food sources. Rapid complete drainage reduces the amount of vegetation and kills the snails by desiccation. This method may be of interest in areas with irrigated crops.

Elimination of breeding sites

Borrow-pits, small pools and ponds serving no special purpose may be drained or filled if they are found to be important sites for the transmission of schistosomiasis.

Removal and destruction

Snails can be removed from canals and watercourses with dredges and crushed or left to die of desiccation. This happens in irrigated areas of Egypt and Sudan as a beneficial side-effect of efforts to improve the flow of water by removing mud from canal bottoms.

Biological control

The possibility of controlling snails biologically has attracted some attention but cannot currently be recommended (*5*).

Chemical control

In the past, molluscicides were often applied on an area-wide basis. This costly and environmentally harmful method has been replaced by focal application (*6*, *7*). Studies are first carried out to identify sites and seasons of transmission, and only at such sites are chemicals applied periodically. Applications are usually restricted to places frequently used by the local population for swimming, washing, bathing and so on.

Currently only one chemical molluscicide, niclosamide, is acceptable for operational use in snail control programmes. Other molluscicides, including some of plant origin, are being evaluated. Because of its high cost, niclosamide is used only sparingly in a few local control programmes. At low concentrations it is highly toxic to snails and their egg masses. For practical use a concentration of 0.6–1 mg/l is recommended with an exposure time of eight hours.

The compound is safe to handle and after dilution is non-toxic to water plants and crops; however, it is very toxic to fish. Fish killed by the molluscicide can be safely eaten. When used focally and seasonally, molluscicide application should not cause any serious negative impact on the environment.

The use of molluscicides in general has a number of disadvantages:

- because of the need for repeated applications a long-term commitment is required;
- the chemicals are costly, and good supervision of application by trained personnel is essential;
- they have adverse effects on non-target organisms, particularly fish;
- snails are able to bury themselves or temporarily leave the water to escape the chemicals, necessitating repeated application.

For further information on the use of molluscicides, see reference *8*.

Application

Niclosamide is available as a 70% wettable powder or a 25% emulsifiable concentrate. The latter formulation spreads very well in standing water when mixed with diesel oil at a ratio of 8.5 parts of 25% emulsifiable concentrate to 1.5 parts of diesel oil. One gram of the active ingredient is contained in 1.43 g of the powder, or 4 g or 4 ml of the liquid.

In stagnant water

Where water is stagnant, such as in swamps and ponds and behind dams, applications are best carried out using a sprayer. The use and operation of a hand-compression sprayer are discussed in Chapter 9. Knapsack sprayers are also suitable. Mixtures of the wettable powder formulation for spraying should be constantly agitated.

Recommended dosages of niclosamide for stagnant water are 0.4 mg/l of the 25% emulsifiable concentrate formulation and 0.6 mg/l of the wettable powder formulation.

The amount to be sprayed on the water surface is calculated as follows. The volume of water in the pond is obtained by multiplying the average depth by the length and width. The depth can be estimated using a measuring stick weighted at the bottom and attached to the middle of a long string at the top. The stick stands upright from the bottom of the pond when the ends of the string are pulled from opposite sides.

In small ponds the molluscicide should be sprayed equally over the whole surface. In larger ponds only the margins need be treated.

Simple field equipment is available for measuring the concentration of the chemical in water to check whether applications have been made correctly.

In flowing water

Molluscicides introduced into flowing water are carried away immediately from the point of application. Because the chemical needs to be in contact with the snails long enough to kill them (preferably eight hours or more), it needs to be applied over a sufficiently long period. It is recommended that flowing water be treated for eight hours with a dosage of 0.6 mg/l of the 25% emulsifiable concentrate formulation or 1 mg/l of the wettable powder formulation.

The release of molluscicide into flowing water is commonly carried out by a drip-feed technique using a drum dispenser (Fig. 8.11), which delivers a constant

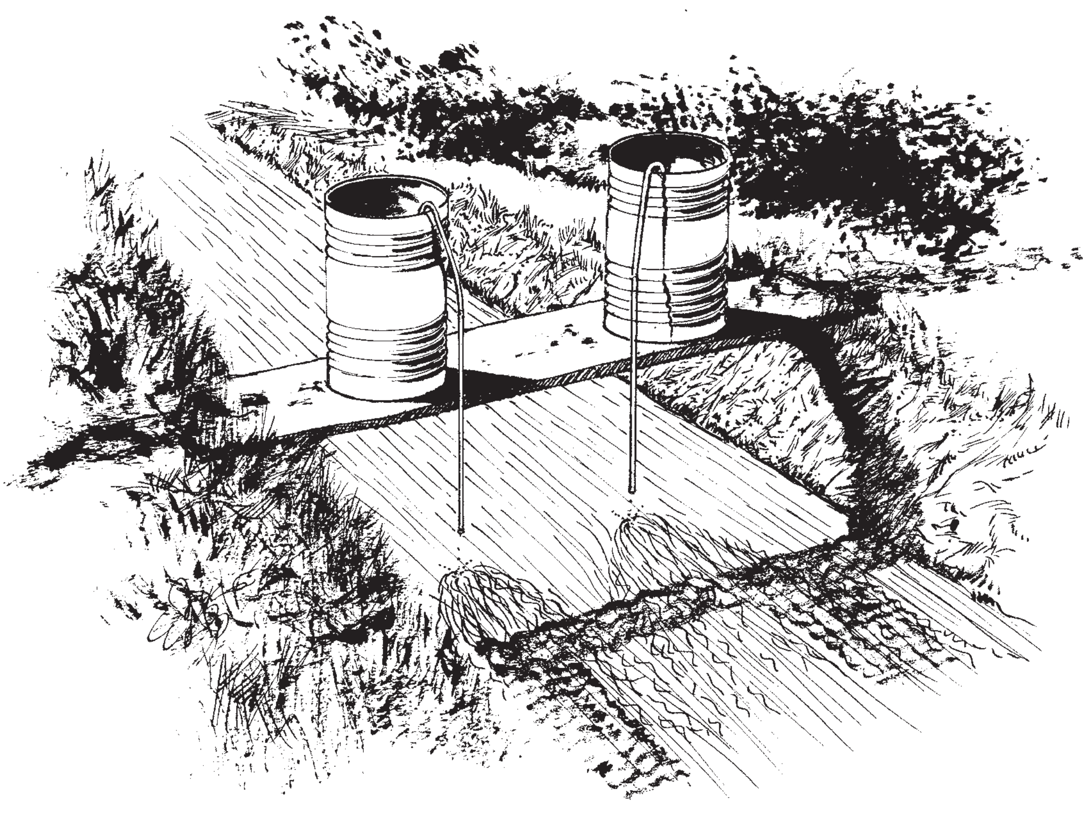

Fig. 8.11
Chemical control of schistosomiasis: molluscicide is slowly released from a barrel into flowing water.

flow for a number of hours. It should be set up at narrow or turbulent points in a stream or canal to ensure complete mixing of the chemical with the water. The chemical is carried away with the flow and distributed throughout the system. Sufficient chemical has to be introduced at the source to ensure that it is still of high enough concentration to kill the snails and their eggs at the end of the system.

In canals the water velocity can be estimated by recording the time for a floating object to travel a certain distance. In rivers and streams this method is inaccurate because of alternating sections of stagnant water and rapid flow. Further calculations to obtain the appropriate amount of chemical are shown in the box below.

Application of molluscicide using a constant-head dispenser

Niclosamide 70% wettable powder at 1 mg/l (active ingredient) is applied for eight hours:

1. Water volume to be treated per second (m^3/s): $Q = V \times D \times W$ where:

   V = water velocity in m/s
   D = water depth in metres
   W = width of canal in metres

2. Total amount of molluscicide (in grams) needed:

   $Q \times 100/70 \times 60 \times 60 \times 8$

3. Discharge from head dispenser: F litres/s
4. Mixing solution in head dispenser:

   $[Q\ (m^3/s) \times 100/70\ (g/m^3)]/F\ (l/s) = 100/70 \times Q/F\ (g/l)$

Note: the average water velocity in the entire cross-section of the canal is about 85% of the maximum flow velocity measured at the surface by observing a floating object. Therefore the amount of niclosamide in equation 2 needs to be multiplied by 0.85.

The drum dispenser should be filled with the amount of molluscicide mixture in water required for constant application over eight hours. The molluscicide is released from the barrel through a hose or tap. The correct quantity is obtained by adjusting the tap or by widening or narrowing the diameter of the hose with an adjustable clamp. If the suspension is prepared with a wettable powder formulation, frequent stirring is needed to prevent sedimentation of the chemical.

Focal application in a canal in Sudan

A slightly different application procedure was found effective in a village in Sudan, where transmission of schistosomiasis occurred along a nearby stretch of irrigation canal. One kilogram of niclosamide 70% wettable powder was mixed with 10 litres of water and applied 300 m upstream of the village. Application for 40 minutes resulted in a concentration of 2–3 g/m^3, which kept the stretch of canal free of snails for 4–6 weeks. After this time, the application had to be repeated.

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Selected further reading

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