Water and health in irrigated agriculture

E. Boelee

Health and Irrigation Specialist, International Water Management Institute (IWMI), Colombo, Sri Lanka

Abstract

Irrigation impacts on human health in many different ways. Often yields in irrigated agriculture are higher than in rainfed agriculture, thus making more food or income available to farmers. This may lead to better nutrition, making people more resistant to diseases. Increased welfare may also be spent on better health care and protective measures such as vaccines and bed nets. However, irrigation canals, drains and hydraulic structures can also become breeding sites for agents of disease, such as malaria mosquitoes and snail hosts of schistosomiasis. Other diseases, such as skin and eye infections, may be reduced by the introduction of irrigation, simply because more water is available for hygiene and sanitation. In fact, water destined for irrigation of crops is often used for all kinds of domestic activities, including consumption. Though the quality of irrigation water usually does not meet the standards for drinking, it may be the only water available in remote arid regions. In some cases, seepage from irrigation canals recharges the groundwater and provides fresh water pockets in an otherwise saline aquifer or dilutes chemical pollution from geological origin, such as fluoride. Consequently, investments in water resources development could be more cost-efficient if multi-purpose systems were conceived, catering for agricultural and domestic water needs.

Health benefits

Higher and more diverse food production in irrigated agriculture brings health benefits to farmer families in the newly irrigated areas. People may gain access to more varied and higher quality nutrition through increased income from cash crops, though this effect is not always very clear (Benjelloun et al. 2002; Parent et al. 2002a). The construction or rehabilitation of irrigation systems has other positive impacts on the human environment through increased employment possibilities, which would raise income and subsequently increase access to health services and education. However, an increased income is not always spent on health care. Access to health services, water supply and sanitation can be facilitated if with the planning of a new irrigation system these additional services are included. Irrigation can also influence the wider physical environment in a positive way and thus increase human well-being. For instance, seepage from earthen irrigation canals may improve the quality of the water as it filters into nearby wells.

Water-related diseases

Most of the reported impacts of irrigation development on health consist of water-related diseases. Generally, four groups of diseases are distinguished based on their way of transmission (Cairncross and Feachem 1993):

1. water-borne or faecal—orally transmitted diseases, such as cholera, typhoid and diarrhoea
2. water-washed diseases, such as louse-borne infections and infectious eye and skin diseases
3. water-based diseases with an intermediate host living in water, such as guinea worm and schistosomiasis and
4. water-related insect-borne parasitic diseases such as river blindness, filariasis and malaria.

Water-washed diseases may be reduced dramatically with the development of water resources. The availability of water, regardless of quality, enhances personal hygiene practices. This effect is especially widespread in arid and semi-arid regions, where irrigation systems may be the main source of water for all purposes. The use of irrigation water for cooking and consumption, despite its often questionable quality, may even diminish hygiene-related diarrhoeal diseases, as water quantity is believed to be more important than quality (van der Hoek et al. 2002).

Unfortunately, water-related diseases transmitted through vectors or intermediate hosts sometimes increase with irrigation development. Canals and drains may create ideal breeding sites for malaria mosquitoes or for snails, bringing both the vectors and the disease closer to people. Many field studies have described the influence of irrigation on the spread of these water-related diseases (for overviews see e.g. Oomen et al. 1988 and 1990; Bolton 1992; Hunter et al. 1993; Steele et al. 1997; HarmancioÈlu et al. 2001).

Specifically, many studies report on large-scale irrigation and malaria. Breeding sites for *Anopheles* malaria mosquitoes are found in clear surface water well available in irrigation systems and an increase in vectors usually leads to an increase in malaria. Wet rice fields are ideal breeding sites and rice field breeding *Anopheles* account for a great deal of the malaria transmission in rice-growing areas of the world (Gratz 1988). Irrigation often facilitates double or even triple cropping of rice, allowing for year-round transmission. As a result, mosquito abundance and density increases while the mosquitoes may live longer, allowing malaria parasites to complete their developmental cycle in the adult insect so they can be passed on to another host. Mathematical modelling has shown that these two factors together with possible changes in feeding habits, determine whether epidemics break out. Or it could lead from a situation of low and irregular transmission to a situation with continuous high transmission that will put a heavy toll especially on young children, who have not yet built up any resistance (Bradley 1995). The linkages between irrigated agriculture and malaria are complex: African case studies show that malaria transmission may increase, decrease or remain largely unchanged as a consequence of irrigation (Ijumba and Lindsay 2001). In West Africa for instance, intensified rice cultivation in the semi-arid savannah has led to an increase in *Anopheles* but with the high population densities, the life span of the mosquitoes was reduced and less mosquitoes were found infected with malaria. Moreover, mosquito abundance was high, creating a demand for bed nets, which farmers could afford through their improved income. Consequently, malaria transmission did not increase with irrigation development in several West African countries (e.g. Parent et al. 2002b). In Ethiopia, the construction of small dams in Tigray led to increased spread of malaria, even at higher altitudes. Seasonal transmission changed to year-round transmission because of the continuous availability of surface water. Children living near small dams had a 7–14 times higher risk of getting infected than children living further away (Ghebreyesus et al. 1999). However, this effect may be reduced over time as people benefit economically from irrigated agriculture and gain access to medication and preventive measures.

The high incidence and wider spread of disease resulting from an increase in vectors or intermediate hosts is observed for several water-related infections other than malaria. Mostly the mechanisms that play a role in increasing transmission rates are complex and dynamic. The farming system and subsequently the entire biological and human environment are often drastically changed with the introduction of irrigation. The process of mutual influences and interactions leading to disease transmission then becomes fundamentally different (Boxes 1 and 2).

Box 1. Complex health hazards of irrigation development in northern Senegal

In the lower Senegal river basin, the replacement of traditional earthen dams by large concrete dams in the 1970s influenced the hydrological and ecological situation in the valley. At the same time, the sugar factory in the town of Richard Toll expanded. Since the construction of the dams, a canal that had stable and high water levels replaced the Meandering River transporting water from Lake Guiers to the sugarcane fields. In the old riverbed, dead arms with plenty aquatic vegetation provided excellent breeding sites, massively invaded by *Biomphalaria* snails, intermediate host of *Schistosoma mansoni*. The sugar factory attracted thousands of labourers from all over the country. In twenty years, the population in Richard Toll increased more than ten-fold from 5000 to 60 thousand in 1994. Water supply and sanitation facilities for the booming population were inadequate and, as a consequence, river and irrigation canals were the only sewers and the main sources of water for many people. The entire health situation has deteriorated. Malaria was the most important public health problem in the area before the construction of the dam and the irrigation system. Now schistosomiasis has become an increasing burden to the local health system, with almost the entire population infected with very high worm loads. Other health problems that simultaneously increased are typhoid fever, cholera, rift valley fever, sexually transmitted diseases and malnutrition (Kongs and Verlé 1994; WASH 1994; Stelma 1997).

Multiple use of irrigation water

The use of irrigation water for non-agricultural purposes

In most open canal irrigation systems, water is used not only for agricultural purposes, but also for all kinds of agricultural, domestic, municipal, industrial and recreational purposes

Box 2: Malaria and schistosomiasis in Gezira, The Sudan

Oomen et al. (1988) gave extensive details on the history of malaria and schistosomiasis in The Sudan. Since the Gezira Irrigation System began in 1924, malaria has been closely linked to agricultural development. During the first 25 years reasonable malaria control was possible through good water management and larviciding. After 1950, when the irrigation system expanded and created more breeding sites, an intensification of cropping added water continuously to the larvae-producing minor canals. At the same time, large-scale applications of chemicals both against agricultural pests and for malaria control had caused pesticide resistance in malaria mosquitoes. Together this led to severe malaria outbreaks in 1973 and 1974. Later in the 1970s the communications and control systems in the main canals broke down. Combined with heavy aquatic growth due to inadequate maintenance, all canals had to be full to deliver water to the crops. Without precise regulation they were prone to overflowing. Another complicating factor was the large labour forces that come from malarious areas. These people were often outside health programmes and could easily bring infections into the area.

The Gezira irrigation systems have resulted in a similar increase of schistosomiasis. The same minor canals that favoured mosquito development also stimulated high snail populations most of the year. These canals with clear water and dense vegetation provided night storage and were close to villages, so water contact was high. Urinary schistosomiasis has increased from less than 1% before World War II to affecting almost a quarter of the adults and half of the children in the 1950s. Intestinal schistosomiasis rose even more from 5% in 1949 to 86% in 1973, in children of 7 to 9 years old, often the group with highest infection rates. Another vulnerable group consisted of the canal cleaners, who stayed daily for long hours in the infested water (Hunter et al. 1993).

(van der Hoek et al. 1999). These activities may influence the water quantity, quality or both (van der Hoek et al. 2001a). At river basin level, the allocation of water resources to different sectors in an approach of integrated water management is becoming common practice (e.g. Berkoff 1994; Heathcote 1998). Water from large dams and reservoirs is often used for hydropower, industry, municipal water supplies, and irrigation. In inter-sectoral negotiations over water, irrigation often comes after energy, municipal water supply and industrial supply, because of the low expected revenues from irrigated agriculture. This could change if all actual uses of water would be included in the calculation of economic benefits of irrigation (Meinzen-Dick and van der Hoek 2001).

Often, the multi-purpose use of irrigation water is not formally recognised and, for water quality reasons, perceived as a sensitive matter. An irrigation agency or water users association may ignore or even deny the *ad hoc* or systematic use of irrigation water for unplanned purposes. Other activities such as fishing in canals are hardly ever considered a problem because these normally would not interfere with the functioning of the irrigation system. The use of canals for laundry is usually tolerated too, or even facilitated through special steps that prevent damage to the canals. Water from irrigation canals can also contribute to the development of local economic activities, be it small-scale and informal such as butchers, car washing or market places, or medium-scale with formal water rights such as ice factories in Pakistan or brick factories in Morocco. These rural industries may contribute to regional income generation. Irrigation canals can also be sources of high quality protein and micronutrients in the form of aquatic plants, fish, crustaceans and snails. The presence of an irrigation system enables people, often women, to divert water to their home gardens. These gardens may have trees bearing nutritious fruit, giving shade and providing wood for fuel. Livestock rearing, be it cattle, sheep, goats or chicken, may depend directly on water from irrigation systems, in addition to profiting from the higher availability of fodder from crop stubble. In India and Pakistan for instance, milk production is significantly better when irrigation water is available than when saline groundwater is the only source (Meinzen-Dick 1997).

In semi-arid and arid countries, where irrigation systems are often the only available source of water for all purposes, tanks for community water supply may be fed directly from the irrigation system. In many villages in the Punjab of Pakistan and in Central Morocco, such tanks may be the only available source of water (Laamrani et al. 2000a; Ensink et al. 2002). The water taken from these tanks is sometimes treated at home, but often it is used for drinking, cooking or other household uses without any treatment or precaution (Jensen et al. 2002). When irrigation water is used for human consumption without any treatment, faecal-orally transmitted diseases such as diarrhoea, dysenteries, poliomyelitis and hepatitis-A may spread. Eggs or larvae of intestinal parasites are, in the absence of sanitation facilities, often excreted with faeces close to irrigation canals, especially when people use water for anal cleansing. Crops may be contaminated during irrigation or the water may be used further down the system for washing, cooking and drinking. Water contaminated with excreta increases exposure to schistosomiasis. Still, the higher availability of water, regardless of its sometimes-disputable quality, has a beneficial impact on children's health (van der Hoek et al. 2002).

Implications for planning and design of water resources development

Environmental control recommendations

In the literature, it has been argued that designing irrigation systems that avoid stagnant water could prevent negative health impacts of irrigation (see e.g. Speelman and van den Top 1986; de Weil et al. 1990; Tiffen 1991; Hunter et al. 1993; Slootweg 1994). However, few recent examples are available of actual implementation (Laamrani et al. 2000b; Laamrani and Boelee 2002). Measures for environmental control have been applied for ages in many countries till the first half of this century (Takken et al. 1990; Konradsen et al. 2002). With the introduction of DDT in the 1940s, environmental management seemed no longer necessary. Excessive spraying of fields, bushes, and houses replaced the inter-disciplinary co-operation and at that time almost eradicated malaria in some countries. In a similar approach, the snail host of schistosomiasis was attacked with molluscicides. Consequently, increased resistance of vectors to pesticides and unwanted effects on non-target organisms occurred. Drugs that are more efficient have been developed, but the distribution is difficult, re-infection is not prevented and parasites become resistant to the treatment.

Nowadays the health sector has come to rely on environmental management again as a part of integrated disease control approaches (Boelee 2003). Most of the recommendations are focused on preventive measures that can be incorporated into the design of new irrigation systems. Good construction practices are crucial in the implementation of a new irrigation system. Fields that are evenly laid out require less water than poorly prepared lands, while puddles and other breeding sites are less likely to form. Canals with the right elevation, size and slope will be less prone to erosion and can convey water at higher velocities without overtopping. For Ethiopia, this offers a great opportunity for integrated planning and design of water resources development projects. Apart from avoiding the characteristics that foster the development of vectors and intermediate hosts, the location of villages and drinking water supply are important factors. The distance between irrigation infrastructure and residences may determine how often and how intensely the population is exposed to vectors or infested water. For several mosquito and fly species, the flight range is known and when houses are located at a larger distance from the breeding sites, people will be less exposed to possibly infective bites.

In existing irrigation systems, the main options to control vector breeding and water-related diseases lie in maintenance and water management. Good cleaning and preventive maintenance of all irrigation infrastructures such as canals, structures and drains will reduce the breeding of vectors and intermediate hosts, and improve irrigation performance. The periodic removal of aquatic weeds from canals reduces friction and thus increases conveyance efficiencies, while it can significantly control vector mosquito larvae and aquatic snails as well. IWMI is currently evaluating the impact of rehabilitation of a natural canal on malaria mosquitoes (based on recommendations by Konradsen et al. 1998; Matsuno et al. 1999).

In Asia, where vectors are restricted to rice fields, a locally adapted farm water management system has been shown to reduce mosquito and snail populations (van der Hoek et al. 2001b). With the so-called intermittent irrigation method, exact water quantities are applied at field level. This requires accurate water deliveries from the canals and influences the organisation of water management up to system level (Mutero et al. 2000).

Adequate facilities should be provided to increase the safe use of irrigation water for other purposes and hence improve health. Especially in arid and semi-arid regions, separate drinking water supply may not always be feasible. In Ethiopia, the reverse situation also occurs, as sometimes overflow from drinking water systems are used for the irrigation of coffee plants. In both cases it could be considered to acknowledge and incorporate other water uses in irrigation systems. Instead of planning agricultural water systems separately from drinking water supply, the different sectors should work together at national and local level and plan for integrated multi-purpose systems. This would reduce overall investments and contribute significantly to improving the health of rural populations.

References

Benjelloun S., Rogers B.L. and Berrada M. 2002. Impacts économiques, alimentaires et nutritionnels des projets de développement agricole: le cas du projet d'irrigation du Loukkos au Maroc. *Cahiers Agricultures* 11:45–50.

Berkoff J. 1994. *A strategy for managing water in the Middle East and North Africa.* Directions in Development Series. World Bank, Washington, DC, USA.

Boelee E. 2003. Malaria in irrigated agriculture (Paludisme et l'agriculture irriguée). *Irrigation and Drainage* 52:65–69.

Bolton P. 1992. *Environmental and health aspects of irrigation*. OD/P 116, Hydraulics Research. Wallingford, UK.

Bradley D. 1995. Malaria's link with water resources development. *ODU Bulletin* 32:4–6.

Cairncross S. and Feachem R.G. 1993. *Environmental health engineering in the tropics. An introductory text*. Second edition, Wiley and Sons, Chichester, UK.

Ensink J.H.J., Aslam M.R., Konradsen F., Jensen P.K. and van der Hoek W. 2002. *Linkages between irrigation and drinking water in Pakistan*. IWMI Working Paper 14. IWMI (International Water Management Institute), Colombo, Sri Lanka.

Ghebreyesus T.A., Haile M., Witten K.H., Getachew A., Yohannes A.M., Yohannes M., Teklehaimanot H.D., Lindsay S.W. and Byass P. 1999. Incidence of malaria among children living near dams in northern Ethiopia: Community based incidence survey. *British Medical Journal* 319:663–666.

Gratz N.G. 1988. The impact of rice production on vector-borne disease problems in developing countries. In: *Vector-borne disease control in humans through rice agro-ecosystem management. Proceedings of the workshop on research and training needs in the field of integrated vector-borne disease control in riceland agro-ecosystems of developing countries*. IRRI (International Rice Research Institute), Los Baños, The Philippines. pp. 7–12.

HarmancioÈlu N., Alpaslan N. and Boelee E. 2001. *Irrigation, health and the environment: A review of literature from Turkey*. IWMI Working Paper 6. IWMI (International Water Management Institute), Colombo, Sri Lanka.

Heathcote I.W. 1998. *Integrated watershed management. Principles and practice*. John Wiley and Sons Inc, New York, USA.

van der Hoek W., Konradsen F. and Jehangir W.A. 1999. Domestic use of irrigation water: Health hazard or opportunity? *International Journal of Water Resources Development* 15:107–119.

van der Hoek W., Konradsen F., Ensink J.H.J., Mudasser M. and Jensen P.K. 2001a. Irrigation water as a source of drinking water: Is safe use possible? *Tropical Medicine and International Health* 6:46–54.

van der Hoek W., Sakthivadivel R., Renshaw M., Silver J.B., Birley M.H. and Konradsen F. 2001b. *Alternate wet and dry irrigation method of cultivating rice: Opportunities for water saving and control of malaria and Japanese encephalitis?* IWMI Research Report 47. IWMI (International Water Management Institute), Colombo, Sri Lanka.

van der Hoek W., Feenstra S.G. and Konradsen F. 2002. Availability of irrigation water for domestic use in Pakistan: Its impact on prevalence of diarrhoea and nutritional status of children. *Journal of Health, Population and Nutrition* 20(1):77–84.

Hunter J.M., Rey L., Chu K.Y., Adekolu-John E.O. and Mott K.E. 1993. *Parasitic diseases in water resources development. The need for intersectoral negotiation*. WHO (World Health Organization), Geneva, Switzerland.

Ijumba J.N. and Lindsay S.W. 2001. Impact of irrigation on malaria in Africa: Paddies paradox. *Medical and Veterinary Entomology* 15:1–11.

Jensen P.K., Ensink J., Jayasinghe G., van der Hoek W., Cairncross S. and Dalsgaard A. 2002. Domestic transmission routes of pathogens: The problem of in-house contamination of drinking water during storage in developing countries. *Tropical Medicine and International Health* 7(7):604–609.

Kongs A. and Verlé P. 1994. Human health and irrigated rice in the Sahel—Experiences in Richard Toll, Senegal. (Paper in preparation.)

Konradsen F., Matsuno Y., Amerasinghe F.P., Amerasinghe P.H. and van der Hoek W. 1998. *Anopheles culicifacies* breeding in Sri Lanka and options for control through water management. *Acta Tropica* 71:131–138.

Konradsen F., van der Hoek W., Amerasinghe F., Mutero C. and Boelee E. 2002. Engineering and malaria control: Learning from the past 100 years. In: Boelee E., Konradsen F. and van der Hoek W. (eds), *Malaria in irrigated agriculture: Papers and abstracts for the SIMA Special Seminar at the ICID 18th international congress on irrigation and drainage, Montreal, Canada, 23 July 2002*. IWMI Working Paper 47. SIMA Document 2. IWMI (International Water Management Institute), Colombo, Sri Lanka. pp. 5–14.

Laamrani H. and Boelee E. 2002. Rôle des paramètres de conception, de gestion et de maintenance des périmètres irrigués dans la transmission et la lutte contre la bilharziose au Maroc central. *Cahiers Agriculture* 11:23–29.

Laamrani H., Khallaayoune K., Laghroubi M., Abdelafid T., Boelee E., Watts S.J. and Gryseels B. 2000a. Domestic use of irrigation water: The Metfia in Central Morocco. *Water International* 25(3):410–418.

Laamrani H., Khallaayoune K., Boelee E., Laghroubi M.M., Madsen H. and Gryseels B. 2000b. Evaluation of environmental methods to control snails in an irrigation system in Central Morocco. *Tropical Medicine and International Health* 5(8):545–552.

Matsuno Y., Konradsen F., Tasumi M., van der Hoek W., Amerasinghe F.P. and Amerasinghe P.H. 1999. Control of malaria mosquito breeding through irrigation water management. *International Journal of Water Resources Development* 15:93–105.

Meinzen-Dick R. 1997. Valuing the multiple uses of water. In: Kay M., Franks T. and Smith L. (eds), *Water: Economics, management and demand*. E&FN Spon, London, UK. pp. 50–58.

Meinzen-Dick R.S. and van der Hoek W. 2001. Multiple uses of water in irrigated areas. *Irrigation and Drainage Systems* 15:93–98.

Mutero C.M., Blank H., Konradsen F. and van der Hoek W. 2000. Water management for controlling the breeding of *Anopheles* mosquitoes in rice irrigation schemes in Kenya. *Acta Tropica* 76:253–263.

Oomen J.M.V., de Wolf J. and Jobin W.R. 1988. *Health and irrigation. Incorporation of disease-control measures in irrigation, a multi-faceted task in design, construction, operation*. Volume 2. ILRI Publication 45. ILRI (International Institute for Land Reclamation and Improvement), Wageningen, The Netherlands.

Oomen J.M.V., de Wolf J. and Jobin W.R. 1990. *Health and irrigation. Incorporation of disease-control measures in irrigation, a multi-faceted task in design, construction, operation*. Volume 1. ILRI Publication 45. ILRI (International Institute for Land Reclamation and Improvement), Wageningen, The Netherlands.

Parent G., Zagré N-M., Ouédraogo A. and Guiguembé R.T. 2002a. Les grands hydro-aménagements au Burkina Faso contribuent-ils à l'amélioration des situations nutritionelles des enfants? *Cahiers Agricultures* 11:51–57.

Parent G., Poda J-N., Zagré N-M., de Plaen R. and Courade G. 2002b. Irrigation, santé et sécurité alimentaire en Afrique: quels liens? *Cahiers Agricultures* 11:9–15.

Slootweg R. 1994. *A multi-disciplinary approach to schistosomiasis control in northern Cameroon with special reference to the role of fish in snail control.* Proefschrift Rijkuniverstiteit Leiden.

Speelman J.J. and van den Top G.M. 1986. Irrigation and vector-borne diseases: A case study in Sri Lanka. In: *Annual Report 1985.* ILRI (International Institute for Land Reclamation and Improvement), Wageningen, The Netherlands. pp. 25–46.

Steele P., Konradsen F. and Imbulana K.A.U.S. 1997. *Irrigation, health, and the environment: A literature review with examples from Sri Lanka*. IIMI Discussion Paper 42. IIMI (International Irrigation Management Institute), Colombo, Sri Lanka.

Stelma F.F. 1997. *Immuno-epidemiology, morbidity and chemotherapy in a community recently exposed to Schistosoma mansoni infection. A study in northern Senega*l. Proefschrift Rijksuniversiteit Leiden.

Takken W., Snellen W.B. and Verhave J.P. 1990. *Environmental measures for malaria control in Indonesia: A historical review on species sanitation*. Wageningen Agricultural University Papers, Wageningen, The Netherlands.

Tiffen M. 1991. *Guidelines for the incorporation of health safeguards into irrigation projects through intersectoral cooperation with special reference to the vector-borne diseases*. PEEM Guidelines Series 1. PEEM Secretariat, WHO (World Health Organization), Geneva, Switzerland.

WASH (Water and Sanitation for Health). 1994. *Etude du plan directeur de santé pour le bassin du Fleuve Senegal.* Water and Sanitation for Health Project, Washington, DC, USA.

de Weil C., Alicbusan A.P., Wilson J.F., Reich M.R. and Bradley D.J. 1990. *The impact of development policies on health. A review of literature*. WHO (World Health Organization), Geneva, Switzerland.