HUMAN HEALTH IN WATER RESOURCES DEVELOPMENT

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Summary

Construction of dams and irrigation systems is undertaken to meet needs for food and energy. However, the development of water resources can have adverse effects on human health, especially through propagation of vectors that transmit diseases such as malaria and schistosomiasis. To prevent this happening it is essential to integrate health impact assessments into the formulation of water resources development policies, and into the planning of water resources development programs and projects. Water resources development can be used to implement environmental management measures for vector control. These include the alternate wet dry method of rice cultivation, improved drainage in canal irrigation systems and various other engineering and agriculture based interventions. Many of these methods were developed a long time ago but became less important when insecticides and effective drugs became available. Problems with resistance of vectors against insecticides and parasites against drugs have lead to renewed interest in water management methods to control vector borne diseases. An important issue in relation to the water resources development for expanding urban areas is the growing volumes of wastewater that have to be disposed of. Using this wastewater in a safe and productive way, for peri-urban agriculture, is a major challenge for developing countries that cannot afford wastewater treatment facilities. The

interactions brought about by water resource development activities, including environmental and social changes, and their combined impact on human health and natural resources are complex. To work out these linkages, substantial knowledge needs to be generated and operational disease control measures need to be developed in a collaborative effort between health and environmental specialists, agricultural experts and engineers.

1. Introduction

Water resources development refers to the infrastructure, governance, and management measures required to control fresh water to meet human and environmental needs. The development of water resources is especially important to meet demands for food and energy. The greater water security provided by irrigated agriculture, in particular, should translate into higher incomes, more nutritious diets, better housing and clothing, and greater access to and capacity for health care. Sound water resources development and management thereby is expected to improve health status and be a key to achieving the Millennium Development Goals that are at the centerpiece of the global development agenda for the period to the year 2015. The reality, however, is that dams and irrigation systems have long been associated with human ill health tied to water-related diseases, especially vector borne diseases such as malaria and schistosomiasis. The major reason is that the agricultural and water resources development sectors typically have focused on potential economic benefits in terms of food and energy production and employment, and not adequately addressed public health impacts. The adverse human health effects of water resources development is increasingly recognized, but there is little concerted action to mitigate these effects, either in the planning or implementation stages of these projects. The health sector is rarely consulted, and is thus unprepared to cope with the "unexpected" adverse health consequences when they occur. As human populations increase, the health implications of water availability and usage will assume greater importance.

A range of water issues essentially determines the health status of communities, and human health therefore cuts across the major sectors in water resources development and management. The crosscutting nature of human health through all water issues make health parameters the ultimate indicators of the success of water resources development. During and after water resources development both negative and positive health effects can occur. For example, irrigation can provide breeding sites for mosquitoes and snails that transmit diseases, but it has also been documented that the large quantities of water that become available for domestic use leads to reduced transmission of diarrheal diseases.

Studies in Africa and Asia show that especially the malaria - irrigated agriculture linkages are complex and situation-specific, with more or less malaria depending upon local conditions and mosquito vectors. Also, knowledge on water management and mosquito breeding has been used in the past to control malaria in irrigation systems, for example through drainage, stream and river manipulations, and the technique of intermittently wetting and drying rice fields. These types of interventions are expected to get renewed focus as an alternative to the more conventional control interventions based on the application of chemicals.

The present contribution focuses on health implications of water resources infrastructure such as large and small dams, irrigation systems and urban water supply and drainage systems. Institutional arrangements to control water-related diseases are also discussed. The important issue of water for domestic uses is discussed elsewhere and there the focus is on the lack of sufficient supplies of safe drinking water, and poor sanitation and hygiene practices, in relation to the transmission of diarrheal diseases and other gastro-intestinal infections.

2. The burden of water-related diseases

Health impacts of water resources development projects can only be assessed if relevant disease occurrence can be measured, before, during, and after project implementation. Apart from the basic epidemiological measures incidence and prevalence of disease, the Disability-Adjusted Life Year (DALY) has become an important measure to assess the disease burden associated with environmental exposures and to evaluate public health interventions. The DALY was developed under the Global Burden of Disease Study and was a major step towards rational information-based health policy. One DALY represents the loss of one healthy life year.

DALYs show the relative magnitude of health problems and can be combined with data on costs and effectiveness of interventions to establish which public health interventions would be most cost effective. This is a powerful tool for policy-makers in assisting decision making for prioritizing health projects. Therefore, the DALY is the measure of choice to monitor the burden of disease over time and across populations in relation to improvements in water supply and sanitation and to estimate overall impact on burden of disease of infrastructure development projects, such as dams and irrigation schemes.

Whether expressed in number of disease cases, number of deaths, or DALYs, water-related diseases continue to impose a large health burden especially in Africa and Asia. Diarrheal diseases are ranked 4th and malaria 8th in the global burden of disease causes. Diarrheal diseases and malaria thereby significantly contribute to the overall burden of disease, accounting for 4% and 3% respectively of DALYs lost and 1.8 and 1.3 million deaths in the year 2002. This burden is almost entirely concentrated in the under five year's age group. While the burden of diarrhea is concentrated in both Africa and South Asia, malaria is largely a burden for under fives in Africa. Africa accounts for more than half of the world's burden of onchocerciasis (97%), malaria (88%), schistosomiasis (78%), and trachoma (52%). The World Health Organization (WHO) Southeast Asian region accounts for more than half of the world's burden of dengue (62%) and lymphatic filariasis (56%). The WHO reports data on an annual basis in the World Health Report for over 100 disease causes including the most important water-related diseases, by age, sex, and for 14 epidemiological sub regions that are based on level of child and adult mortality.

Diarrhea and many other water-related diseases could eventually be controlled in a sustainable way by universal access to safe water and sanitation, improved hygiene, and by optimal water management practices. In the short term the control of many water-related diseases depends to a large extent on the health care delivery system, which is responsible for implementation of oral rehydration therapy to prevent deaths from diarrhea, insecticide treated bed nets to prevent malaria and individual or mass drug treatment for the various helminth infections. There are successful disease elimination programs against some important water-related diseases, notably Guinea worm disease, onchocerciasis, lymphatic filariasis, and trachoma. These programs, as well as programs to control intestinal helminths and schistosomiasis are based on mass treatment of at risk populations. Low-cost, safe, and effective drugs are available but problems are faced because of insufficient capacity of health delivery systems. This also applies to malaria, where prompt treatment of patients and promotion of insecticide-treated bednets is the backbone of the current control strategy. Unfortunately, health care systems especially in Sub-Saharan Africa are often fragile and fragmented and unable to effectively implement many of the evidence-based intervention strategies.

3. Vector borne diseases associated with water resources development

3.1. Malaria

Malaria remains one of the most important health problems at a global level, causing illness in 300 million people each year. Its share of the global burden of disease has increased over the past few years and now stands at 46.5 million DALYs, 3.1% of the world’s total. This is an increase of 23% compared with the year 1990. Mortality increased with 27% from 926,000 in 1990 to 1,272,000 in 2002. The majority of the burden of malaria is concentrated in Africa south of the Sahara. In many parts of Africa the population faces intense year-round transmission of malaria, resulting in a high disease burden especially among children below five years of age and pregnant women. In all malaria-endemic countries in Africa, on average 30% of all outpatients clinic visits are for malaria. In these same countries, between 20% and 50% of all hospital admissions are a consequence of malaria. International efforts to reduce the malaria burden are co-coordinated by the WHO-led Roll Back Malaria initiative, which was launched in 1998. The main strategy is to promote prompt diagnosis and treatment, and the use of insecticide-treated bednets.

In some parts of Africa and most areas of Asia and Latin America transmission is less intense, often seasonal in nature and associated with epidemics. In these low transmission areas, there is little natural immunity to malaria in the human population. Thus, both children and adults may be at risk of severe manifestations of the disease. Consequently, the pressures on the health care services are of a different nature than in intense- transmission areas. Epidemic preparedness is among the recommended strategies for malaria control in areas of seasonal transmission. Recently, it was estimated that in Africa more than 12 million malaria episodes and 155,000 – 310,000 malaria deaths per year are attributable to epidemics caused by abnormal climatic (rainfall) conditions. However, there is hardly any information on cost-effectiveness of preventive and control interventions in epidemic prone contexts and therefore planning and policy decisions in epidemic emerging situations are currently not supported by evidence.

The current malaria control strategy is hampered by a number of constraints. Carrier mosquitoes and parasites are, respectively, becoming resistant to insecticides and inexpensive drugs. Environmental and climate change, population movements and other shifts in social behavior have helped malaria gain new ground in many parts of the developing world. The difficulties of achieving a high coverage of insecticide-treated bednets among the vulnerable groups are a major issue especially in Africa. In addition, operational constraints limit effective reimpregnation of bednets. Most importantly, the countries facing severe malaria problems have an underdeveloped health care sector which is limited in its potential to implement the established strategies, particularly those related to ensuring early diagnosis and treatment, disease monitoring and community involvement in control activities.

Water resources development projects, especially irrigation systems, can provide breeding grounds for vector mosquitoes of malaria. However, the relationship between malaria and water resource development is highly situation specific, depending on the habits and efficiency of vectors, behavior of people and climate. The opportunities for malaria vector breeding are often associated with faulty irrigation design, maintenance or water management practices. In some places in Africa and Asia irrigation development has resulted in increased malaria transmission.

But several empirical studies from the same continents have shown the counter-intuitive result of no malaria increase, possibly because of improved socio-economic status of people in irrigated areas allowing them to live in better houses and purchase and apply preventive and control interventions. Studies in West Africa on rice irrigation and farmers' health showed that irrigation altered the transmission pattern but did not increase the burden of malaria. It was also documented that irrigated rice cultivation attracted young families, improved women's income, and affected treatment-seeking behavior by shortening the delay between disease and initiation of treatment.

The role of the water environment as an essential ingredient of malaria transmission was recognized long ago. Environmental management methods were used for malaria control, especially in Asia. Because of a lack of scientific evidence of effectiveness and uncertainty about the present-day feasibility of implementation, environmental management methods do not play an important role in present-day malaria control. More research is needed to identify specific environmental management measures for the reduction of vectors or people- vector contact.

In the absence of an effective vaccine, treatment of patients and promotion of insecticide treated bed nets will remain the main evidence-based control strategies for malaria control. In low transmission areas such as in many parts of Asia, environmental management could re-emerge as an important component of an integrated approach to malaria control.

In such areas it is also important that health impact assessments should be part of the planning process of infrastructure projects, in order to identify, qualify and possibly quantify adverse health effects at the earliest possible stage and suggest remedies. In rural areas of Africa where mosquito-breeding places are diffuse and various there might be little scope for environmental control measures. The situation is different in African cities. In urban and peri-urban areas breeding sites can be detected more easily than in rural areas and environmental management is proposed as a main feature for an integrated control approach. This can have an important impact on the overall malaria burden. According to different plausible scenarios an estimated 25 to more than 100 million malaria cases occur in African cities.

3.2. Filariasis

Worm diseases from the group of the filarial nematodes are transmitted by vectors such as small crustaceans in the case of Guinea worm disease, blackflies in the case of river blindness (onchocerciasis), and mosquitoes in the case of lymphatic filariasis. There are well-organized control programs for these conditions.

Guinea worm disease is unique in that it is the only communicable disease that is transmitted exclusively through contaminated water. Thus, it is the only disease that can be prevented entirely by protecting supplies of drinking water. Guinea worm is about to be eliminated by improvements in water supply. In Africa the number of cases declined from 3.5 million in 1986 to 35,000 in 2003. The majority of remaining cases is from Sudan, where many are inaccessible to eradication efforts because of the ongoing civil conflict.

Onchocerciasis has been reduced a lot in Africa by a large control program mainly consisting of mass distribution of the drug ivermectin and control of the blackfly vector with insecticides.

Lymphatic filariasis is rarely life threatening but causes widespread and chronic suffering, disability, and social stigma. Globally an estimated 119 million people are infected with 40 million suffering from severe chronic disease. More than 40% of people infected live in India and 30% in Africa. In India alone the disease causes losses of $1 billion annually. The current Global Program to Eliminate Lymphatic Filariasis is based on mass drug administration of the entire at-risk population. However, it has been argued that vector control is an essential supplement. Vectors of lymphatic filariasis breed in polluted urban waters such as blocked drains and sewers. An estimated 394 million urban dwellers without access to improved sanitation are at risk of lymphatic filariasis. Good sanitation and environmental management to minimize mosquito breeding places can play a major role in reducing the risk of the disease. In rural areas, an estimated 213 million people are at risk because of their proximity to irrigation schemes. However, while densities of the mosquito vector are often much higher in irrigated areas when compared to irrigation-free sites, there have been very few studies linking water resources development with filarial disease. In rural areas of Africa the vector of lymphatic filariasis is the same that transmits malaria. Therefore, vector control activities such as implemented under the Roll Back Malaria initiative can be expected to reduce the transmission of malaria and lymphatic filariasis. In India the vectors of lymphatic filariasis and malaria are different but vector control including breeding-site reduction and environmental management can have an impact on different vector species and both diseases. The lymphatic filariasis program provides significant opportunities for other disease control programs such as intestinal nematodes, malaria, and dengue, to deliver public health benefits on a large scale.

3.3. Schistosomiasis

Schistosomiasis (bilharzia) is contracted by humans through contact with water infested with the free-swimming larval stage of the worms (cercariae) that penetrate the skin and develop in the human body until maturity. Parasite eggs are released through urine or faeces, hatch in fresh water and infect snail hosts within which they develop into cercariae, which are, in turn, released into the water to infect new human hosts. Transmission can take place in almost any type of habitat from large lakes or rivers to small seasonal ponds or streams. Man-made water bodies, including irrigation schemes are particularly important, as the human population density is usually high around these. The disease occurs in 74 countries in Africa, South America and Asia with an estimated 200 million people infected, 85% of them in sub-Saharan Africa. Schistosomiasis is a chronic, debilitating parasitic disease, which may cause damage to the bladder or intestines, lowers the resistance of the infected person to other diseases, and often results in retarded growth and reduced physical and cognitive function in children. Recent estimates from sub-Saharan Africa indicate that 280,000 deaths can be attributed to schistosomiasis.

The key element in the current control strategy is the regular treatment of at risk populations, especially school children, with the drug praziquantel. This has to be combined with improvements in sanitation, which will prevent eggs entering the environment. Water contact with infested water has successfully been prevented by improving water supplies, providing laundry and shower facilities, and footbridges. It has been stated that linking schistosomiasis control to improvements in water supply and sanitation has the potential to ensure long-term control and, in many instances, elimination of the disease. Results from national control programs in endemic countries such as Brazil, China, and Egypt are encouraging. However, there is currently little or no schistosomiasis control in sub-Saharan Africa.

Introduction or spread of schistosomiasis has been documented in relation to the construction of large dams and irrigation systems. In these settings, it is important to combine mass chemotherapy and improvements in water supply and sanitation with snail control. Reductions in snail populations can be achieved by various engineering means, including proper drainage, canal lining, removal of aquatic vegetation from canals, regular flushing of canals, increasing the flow velocity, drying of irrigation systems, and changing water levels in reservoirs. In a number of cases irrigation and dam projects in Africa have increased schistosomiasis transmission; examples are the Volta Lake Project in Ghana, the Kainji Lake project in Nigeria and the Senegal River project. Several irrigation schemes have been implemented along with programs to control the snail population and to treat infected people with suitable drugs. However, the sustainability of such programs is highly dependent on the economical conditions in the country. Recessions have caused these programs to collapse followed by a substantial increase in snail proliferation and transmission of schistosomiasis. Another problem is the rapid re-infection of young children after drug administration. This puts a permanent stress to the effectiveness of such programs and increases the costs involved. Of even greater importance for schistosomiasis transmission in the future could be the thousands of small dams that are being built on the African continent for agriculture, livestock, and drinking water supply.

3.4. Japanese encephalitis

Restricted to the Asian region, Japanese encephalitis (JE) is closely associated with irrigated rice ecosystems in which pig rearing is practiced as a source of food and income generation. It is the leading cause of viral encephalitis in Asia with 30,000 to 50,000 clinical cases reported annually and an estimated global burden of 709,000 DALYs lost in 2002. Vaccination initiatives are the mainstay of control of JE outbreaks but water management methods have been used to control the mosquito vector, especially the alternate wet and dry method of cultivating rice, which will be discussed in more detail.

3.5. Dengue

Dengue ranks as the most important mosquito-borne viral disease in the world. In the last 50 years, incidence has increased 30-fold. An estimated 2.5 billion people are at risk in over 100 endemic countries. Up to 50 million infections occur annually with 500,000 cases of dengue hemorrhagic fever and 22,000 deaths mainly among children. Prior to 1970, only 9 countries had experienced cases of dengue hemorrhagic fever (DHF); since then the number has increased more than 4-fold and continues to rise. In 2001, the Americas alone reported 652,212 cases of dengue of which 15,500 were DHF nearly double the cases reported for the same region in 1995. Dengue and dengue hemorrhagic fever are present in urban and suburban areas in the Americas, South-East Asia, the Eastern Mediterranean and the Western Pacific regions and dengue fever is present mainly in rural areas in Africa. Several factors have combined to produce epidemiological conditions in developing countries in the tropics and subtropics that favor viral transmission by the *Aedes* mosquito vectors: rapid population growth, rural-urban migration, inadequate basic urban infrastructure (e.g. unreliable water supply leading householders to store water in containers close to homes) and increase in volume of solid waste, such as discarded plastic containers and other abandoned items which provide larval habitats in urban areas.

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Biographical Sketch

Wim van der Hoek is a medical doctor and epidemiologist who has worked for more than 10 years in several countries in Africa and Asia on public health projects. From 1997 to 2001 he was Research Leader of the Health & Environment Program of the International Water Management Institute (IWMI) based in Colombo, Sri Lanka. His main interest is the epidemiology of water related infectious diseases. Currently he is a consultant based in the Netherlands and external lecturer at the Department of International Health, University of Copenhagen.