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Putting Research Knowledge into Action

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Dams and Malaria in Sub-Saharan Africa

Dams bring many economic and social benefits. However, their construction often leads to an increase in malaria in nearby communities. Malaria transmission may very well increase due to planned acceleration of dam-building in the near future. Increasing temperatures as a consequence of climate change may exacerbate the effect of dams on malaria. Greater consideration of health impacts in dam planning and management can play a critical role in mitigating the transmission of malaria.

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Key findings

- As well as bringing numerous benefits, increased dam-building in Africa will also bring costs, which are often borne by poor people living close to the dams and the reservoirs created. One of the most lethal consequences of dams is increased malaria prevalence.
- A complex interplay of ecological, climatic and social factors determines the impact of any particular dam on malaria. Consequently, there is no simple solution to disease control around dams. Approaches that integrate a number of tools are needed for successful disease reduction.
- In the planning of large dams, formal Health Impact Assessments together with appropriate funding for mitigation, supported by intersectoral collaboration, ensure that malaria and other health risks are addressed systematically.
- For small, community-managed, reservoirs a Participatory Health Impact Assessment is an appropriate approach to identify and address malaria and other health issues.
- For large dams, the manipulation of reservoir water levels to reduce or disrupt mosquito breeding is one specific option that should be considered in appropriate circumstances.

Dams in Africa

Effective water resources development is crucial for sustainable economic growth and poverty reduction. Large dams are important to manage flood waters, to harness water for hydropower, to supply water to cities and for industry, and for irrigation. Currently, Africa has the lowest water storage of any continent and many countries have the lowest per capita water storage of any in the world. Of the estimated 45,000 large dams built globally, only about 1,700 are in Africa and half of these are in South Africa.

Small reservoirs, which are often created by simply mounding earth dams on streams, are vital for community well-being. The exact numbers are hard to come by, but in many places (e.g., in northern Ghana and Botswana) they provide the principal source of water for households, irrigation and livestock watering. Hence, by contributing to economic development and rural livelihoods, both large and small dams bring direct and indirect benefits for poor people.

Africa is the most vulnerable continent to the impacts of climate change. With little infrastructure and institutional capacity to support communities to adapt to more severe droughts and floods, the impacts of climate change are likely to be grave. It is imperative that more dams are built to contribute to economic development and help countries respond to the threats of climate change.

The World Bank, the African Development Bank, the European Union and China, and many African governments, are now investing heavily in large dams. Many dams are under construction and many more are planned. For example, in Ethiopia, several large dams are currently being built for hydropower and irrigation on tributaries of the Nile and other rivers. The number of small reservoirs is also increasing, with both governments and non-governmental organizations (NGOs) actively implementing programs to construct small dams in many countries to secure water supplies for rural communities.

Impacts of dams on malaria

Dams are built to bring social and economic benefits but, in common with almost any development endeavor, they are also associated with social costs. Amongst the most serious of these are the harmful impacts on peoples' health. As such, it is important that possible health consequences are carefully evaluated during the planning, construction and operation of dams, of whatever size.

Globally, between 300 and 500 million people are infected with malaria each year, and of these between 1.5 and 2.5 million die. Malaria is most intense - and one of the biggest killers - in Africa, where approximately 90% of the cases occur. Malaria transmission may increase under conditions resulting from climate change.

The link between the presence of reservoirs (small and large) and greater malaria cases in nearby communities is broadly established. Among the few studies conducted on dams and malaria in Africa, a common finding is higher incidence of the disease in communities living closer to reservoirs.

The increased malaria prevalence associated with dams is the result of complex interactions between people, their socioeconomic situation and mosquitoes. The high human population densities around dams often coincide with a rise in mosquito numbers as a result of increased breeding habitat created along the reservoir shore. In tropical areas, reservoirs hold great potential to increase malaria transmission as long as daily temperatures are warm enough (i.e., typically higher than 20 °C) to support the development of the aquatic stages of the mosquito life cycle as well as the development of the malaria parasite (Box 1).

Box 1. Malaria parasite life cycle and transmission.

Worldwide, there are approximately 3,500 species of mosquitoes. However, only females of one genus, *Anopheles*, transmit human malaria. Of the total 430 *Anopheles* species documented, 30 to 40 species are known to transmit malaria.

Mosquitoes go through four stages in their life cycle: egg, larva, pupa and adult. The first three stages live in water and last for 5 to 14 days in tropical settings, depending on the species and environmental factors. During the adult (flying insect) stage (which lives up to a month in favorable conditions) the female mosquitoes bite people in order ingest the blood they need to produce eggs. This provides the link between the human host and female *Anopheles* mosquitoes in the malaria parasite life cycle.

Malaria transmission involves interactions between the malaria parasite (i.e., *Plasmodium*) *Anophele*s mosquitoes and people. When a female *Anophele*s mosquito takes blood from a malaria-infected person, together with the blood she also swallows the *Plasmodium* parasite. Unwittingly, she will then host the *Plasmodiu*m parasite in her gut. Over a period of 2 to 4 weeks, large numbers of sporozoites (i.e., the infective stage of *Plasmodium*) are formed and migrate to the saliva gland of the mosquito.

Whenever this mosquito takes blood from a person, she injects her saliva containing the malaria parasites into the person's bloodstream. The person then gets infected. Within the person, the *Plasmodium* parasites multiply in red blood cells causing symptoms that include fever, chills, nausea, a flu-like illness and, in severe cases, coma and death. If this person is bitten by another mosquito then the cycle is repeated.

By increasing the amount of standing water, both large and small dams increase the abundance of larval breeding sites. This, in turn, gives rise to the breeding of greater numbers of mosquito eggs and larvae, and as a result a larger number reach adulthood and are available to transmit the disease. Whether or not there is actually an increase in disease transmission depends on a large number of factors, but in circumstances of seasonal transmission, they often do.

However, reservoirs do not always result in increased malaria transmission. In places where malaria is already present throughout the year, reservoirs may not increase the disease burden. In locations where malaria is a seasonal phenomenon, reservoirs may add significantly to the disease burden; by both increasing the number of cases during the malaria season and also extending the period of disease transmission. In any situation where a new dam is being built, it is currently impossible to predict (with numbers) the likely impact on neighboring communities.

A recent review concluded that approximately 9.4 million people in sub-Saharan Africa have a high risk of contracting malaria because they live close to large dams or formal irrigation systems[1], but there is little empirical information on the extent to which disease transmission has actually increased. No information is available on the continent-wide extent of increased risk arising from small reservoirs. Nevertheless, it is clear that large numbers of people are currently at greater risk of malaria transmission due to their proximity to large and small dams, and these numbers are likely to increase substantially in the future due to both high population growth rates and the aforementioned increase in dam-building.

A recent study, conducted by the International Water Management Institute (IWMI) and its partners in Ethiopia, is only one of a handful to have quantified the impact of a dam on malaria. The study conducted at the Koka Reservoir in central Ethiopia showed that cases of malaria increased as distance to the Koka Reservoir decreased (Figure 1). Although the area is known for its seasonal malaria transmission, it was found that there were more cases of malaria throughout the year in villages closer to the reservoir than those located further away (Figure 2). It was also found that both larval and adult *Anopheles* mosquitoes were much more abundant close to the reservoir.

The Koka Reservoir enhances the risk of malaria for people living close to it by providing suitable breeding sites for mosquitoes. Through the creation of habitat for mosquito larvae, the reservoir increases mosquito populations. Puddles along the shore of the reservoir - some forming naturally, others through human activities - and pools in the stagnant waters of the river channel immediately downstream of the dam, were found to provide ideal breeding habitats for *Anophele*s mosquitoes (Figures 3 and 4).

[1] Keiser, J.; Caldas de Castro, M.; Maltese, M. F.; Bos, R.; Tanner, M.; Singer, B. H.; Utzinger, J. 2005. Effect of irrigation and large dams on the burden of malaria on a global and regional scale. *American Journal of Tropical Medicine and Hygiene* 72(4): 392-406.

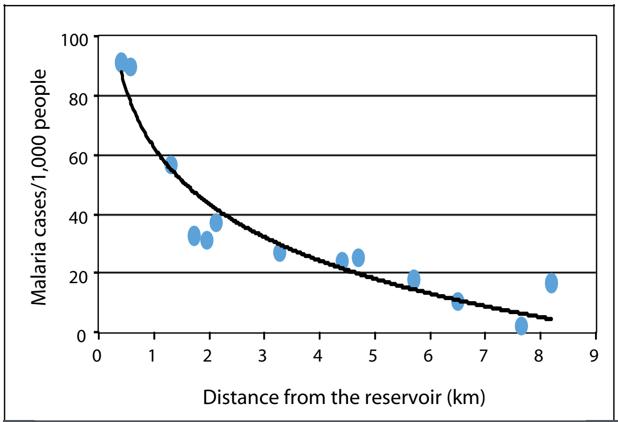

Figure 1. Relationship between the number of malaria cases and the distance from the Koka Reservoir in central Ethiopia.

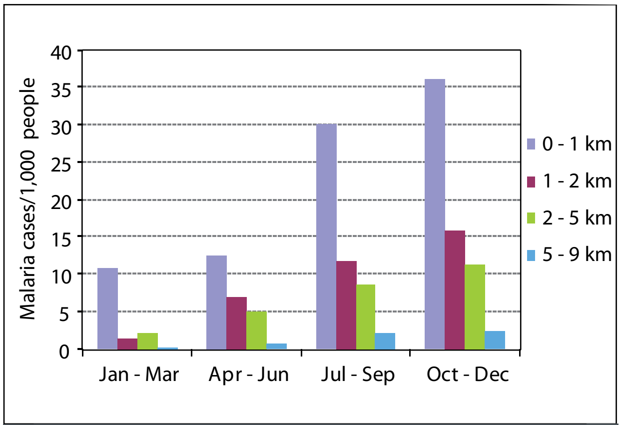

Figure 2. Seasonal malaria transmission around the Koka Reservoir in central Ethiopia.

Figure 3. Koka Reservoir shoreline: ideal mosquito breeding habitat. (Photo Credit: Jonathan Lautze)

Figure 4. Seepage pools downstream of the Koka Dam in Ethiopia: ideal mosquito breeding habitat. (Photo Credit: Amelework Tesfaye)

Malaria control measures

There is growing recognition that successful malaria control depends on combining a number of mitigation approaches. Current malaria-control strategies focus almost exclusively on early diagnosis, medical treatment of the disease, the use of bednets, and spraying pesticides inside houses to kill mosquitoes. There are many studies that demonstrate that these approaches, if properly implemented, can be very effective in reducing malaria. However, there are also examples showing that these approaches do not always work for several reasons: bednets are less successful where mosquitoes have changed their biting behavior to early in the evening and outdoors; the lack of money for medical and chemical control measures is a major constraint in many countries in sub-Saharan Africa; the effectiveness of pesticides and drugs is also reduced as a consequence of the increasing resistance of mosquitoes to pesticides and the malaria parasite to drugs; and in the case of pesticides, there are also concerns about the ecological implications of releasing them to the wider environment. Utilizing a combination of measures distributes the cost across sectors and, in general, leads to more environmentally conscious and sustainable methods for malaria reduction.

Health Impact Assessments

The most systematic way to address health issues in dam development is to carry out a Health Impact Assessment (HIA) as part of the project planning. For large dams, governments and donors often insist on an environmental impact assessment (EIA), but these rarely include a comprehensive evaluation of health issues. Public health agencies are hardly ever consulted and, if they are, their input is usually superficial. HIAs provide a systematic approach to screening, scoping, appraising and formulating management plans to address key public health issues associated with large dams (Box 2).

Box 2. Health Impact Assessment.

Practical approaches to a formal Environmental Health Impact Assessment (EHIA) or separate Health Impact Assessment (HIA) have been advocated by the World Health Organization and the Asian Development Bank. However, to date, rather than being integrated, the development of HIA has largely occurred in parallel with EIA approaches.

In relation to large dam projects, HIA is initially best conducted as an integral part of the project's feasibility study. However, if safeguards are to be effective, consideration of health issues is essential at all stages of the project life cycle, including dam planning, design and operation.

The formal HIA framework consists of several steps:

- Screening - should HIA be done?
- Scoping - how best to do it?
- Appraising - identifying/examining the best available evidence
- Formulating – making recommendations

These may be followed by further engagement with decision-makers on the implementation of recommendations, and monitoring and evaluation of the HIA process, impact and outcome.

For small reservoirs, formal HIAs are too expensive and impractical. Instead, a participatory approach should be used. Participatory Health Impact Assessments (PHIA) incorporate direct contributions from communities to identify health risks and options for disease reduction, including malaria (Box 3; Figure 5). Various steps in the PHIA approach have been applied in research, conducted by IWMI and its partners, on small reservoirs in Morocco, Burkina Faso and Ethiopia. The exact methodology used in each location was dictated by local circumstances and the priorities were identified by the different communities. As a result, the data collected varied in each case, and recommendations for improving the planning, design, and operation of small reservoirs also varied. At the Meskabet Dam in Tigray, Ethiopia, where malaria transmission had increased since dam construction, community-led interventions included the planting of trees near *Anopheles* breeding sites[2]. As well as shade that made the habitat less suitable for mosquitoes, the trees also provided benefits such as fruit and fodder.

Dam management – an option for malaria control?

Environmental management, which focuses on making the environment unsuitable for mosquitoes, is an age-old malaria control strategy, recently rediscovered as an option complementary to approaches commonly used by the health sector. Various studies have shown that, under the right circumstances, appropriate management of mosquito habitat can help suppress malaria.

Dam management, manipulating reservoir water levels to render habitats less favorable for mosquito breeding, is one form of environmental management that has been used (e.g., in the USA and India). In the south of the USA, such measures, used in the past by the Tennessee Valley Authority, helped eradicate malaria. The basic idea is to make the reservoir habitat unfavorable for mosquito larvae. This can, in turn, result in reduced numbers of adult mosquitoes and, hence, less malaria in communities living close to the reservoir.

Although the Koka Dam has not been operated with the objective of reducing malaria in the past, an IWMI study showed signs that this approach holds potential. Faster drawdown of the reservoir at the

Box 3. Participatory Health Impact Assessment.

The key aspect of a PHIA that is conducted for a small dam is the direct involvement of local communities. Otherwise, this has similar but not identical steps to an HIA:

- Scoping - which health issues should be assessed, where and with which partners; collection of secondary data.
- Participatory appraisal - community self-assessment of health issues related to small reservoirs.
- Biomedical studies - a targeted selection of studies to collect primary information for use by the health sector.
- Synthesis of location - specific information – using various indicators and mapping techniques.
- Development of practical options for reservoir design and operation.

If a small reservoir is planned in a malaria-endemic region, specific health questionnaires, entomological studies and, perhaps, even parasitological surveys should be included in the PHIA. These can help to identify options for risk mitigation at policy, institutional and technical levels. People involved in the PHIA should be local men and women, community leaders and decision makers, informal local organizations as well as NGOs, the dam constructors and managers, health officials and others who might be affected (e.g., pastoralists and fisherfolk who might only come to the reservoir infrequently or at particular times during the year).

[2]Yohannes, M.; Haile, M.; Ghebreyesus, T. A.; Witten, K. H.; Getachew, A.; Byass, P.; Lindsay, S. W. 2005. Can source reduction of mosquito larval habitat reduce malaria transmission in Tigray, Ethiopia? *Tropical Medicine and International Health* 10(12): 1274–1285.

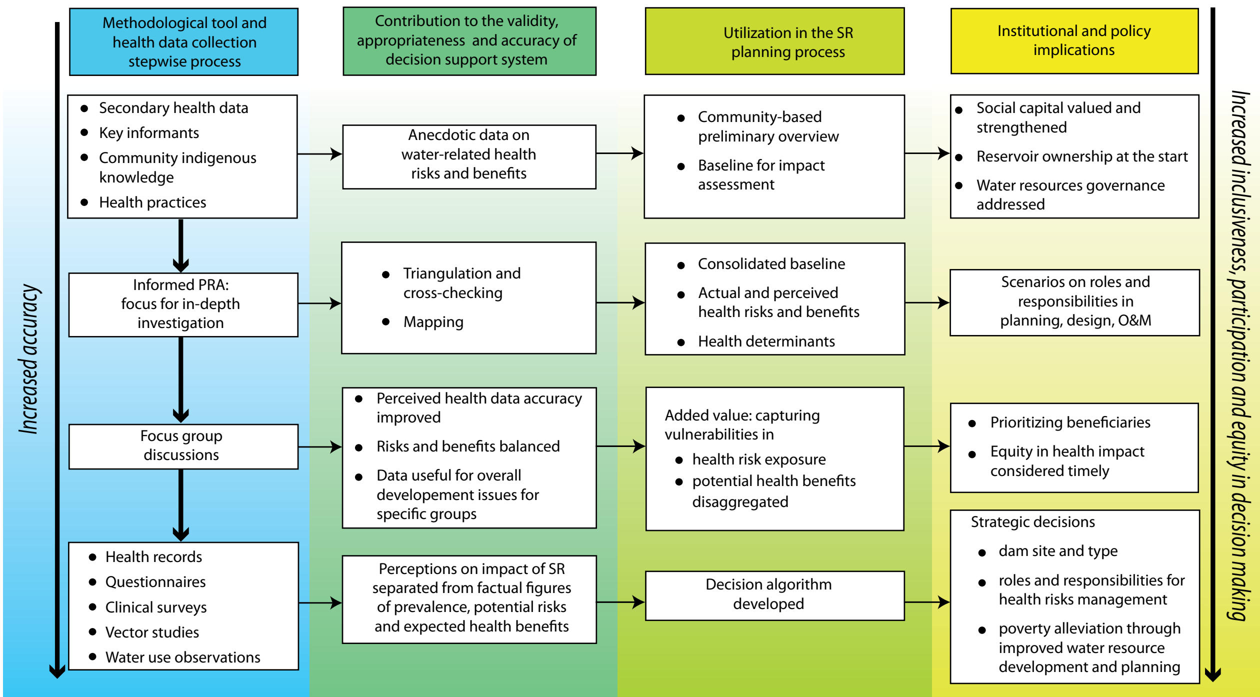

Figure 5. Diagram representing the links between various steps in the Participatory Health Impact Assessment. Note: PRA = Participatory Rural Appraisal; SR = Small Reservoir; O&M = Operation and Maintenance.

end of the wet season was found to dry out puddles along the reservoir shore, literally leaving the larvae high and dry! If this, in turn, translated into lower adult mosquito abundance and lower malaria then, clearly, reservoir management could play an important role in reducing malaria. Further research is needed to evaluate the implications of modified dam management on the incidence of malaria as well as on electricity production and irrigation, but the approach holds promise.

Key elements for any form of vector management, including reservoir management, which should be promoted through Health Impact Assessments, are:

- evidence-based decision-making;
- integrated approaches;
- collaboration within the health sector and with other sectors;
- advocacy, social mobilization, and legislation; and
- capacity building.

Concluding remarks

A great many dams, both large and small, will be built in Africa in the near future. As well as creating benefits, these dams will bring costs, including adverse health impacts, of which malaria is the most significant. Malaria and other health issues associated with dams need to be considered in the process of dam planning and management. HIAs and PHIAs provide a comprehensive, systematic approach for considering the health impacts as a result of dam development. There is also need for innovative approaches to malaria control. Dam management will not always be effective or appropriate, but in some circumstances it can be both, and should generally be given greater consideration as a component of integrated control strategies. More research is necessary to gain better insights into the role dams play in malaria transmission and the possible consequences of climate change.

Source

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Kibret, S.; McCartney, M.; Lautze, J.; Jayasinghe, G. 2009. *Malaria transmission in the vicinity of impounded water: evidence from the Koka Reservoir, Ethiopia*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 39p. (IWMI Research Report 132).

Lautze, J.; McCartney, M. P.; Kirshen, P.; Olana, D.; Jayasinghe, G.; Spielman, A. 2007. Effect of a large dam on malaria risk: the Koka Reservoir in Ethiopia. *Tropical Medicine and International Health* 12(7): 1-10.

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Related IWMI Publications

Open access (electronic version freely accessible via the internet)

Andreini, M.; Schuetz, T.; Harrington, L. (eds). 2009. *Small Reservoirs Toolkit*. Colombo, Sri Lanka: International Water Management Institute. www.smallreservoirs.org/full/toolkit

Boelee, E.; Cecchi, P.; Koné, A. 2009. *Health impacts of small reservoirs in Burkina Faso*. Colombo, Sri Lanka: International Water Management Institute. (IWMI Working Paper 136). www.iwmi.cgiar.org/Publications/Working_Papers/working/wp136.pdf

McCartney, M. P.; Boelee, E.; Cofie, O.; Mutero, C. M. 2007. *Minimizing the negative environmental and health impacts of agricultural water resources development in sub-Saharan Africa*. Colombo, Sri Lanka: International Water Management Institute. 41p. (IWMI Working Paper 117). www.iwmi. org/publications/Working_Papers/working/WOR117.pdf

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