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# Efficacy and Cost-Effectiveness of Environmental Management for Malaria Control

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# The Challenges of New Efforts to Control an Old Disease – Malaria

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Malaria is a devastating parasitic disease that has significantly increased over the last three decades, taking the lives of over 750,000 children under age 5 in sub-Saharan Africa each year. Since 1969 when the first global campaign failed to eradicate the disease, the goals of malaria campaigns have shifted from eradication to control. Attempts to find new drugs to combat malaria are underway, as are efforts to engineer malaria-resistant mosquitoes and to develop a vaccine. However, these efforts will take time, and history has shown that there is no "magic bullet." In the interim, an integrated approach to malaria control is recommended by many. An integrated approach combines multiple interventions, with a focus on early treatment, coordinated public health efforts, the cooperation and involvement of local organizations and government bodies, and environmental management, such as drainage of swamps and standing water and vegetation clearance near villages.

The authors of two Center for Health and Wellbeing working papers, **Efficacy and Cost-Effectiveness of Environmental Management for Malaria Control**, and **The Challenges of New Efforts to Control an Old Disease—Malaria,** examine the potential of environmental management by revisiting a malaria control program implemented from 1929-1949 at the Roan Antelope copper mine in Zambia. Based on extensive data maintained by the project, the authors estimate the number of deaths, malaria attacks, and disability-adjusted life years (DALYs) averted by the control efforts, as well as their cost-effectiveness. They find that an array of control measures, including vegetation clearance, management of water bodies, and using screens and bed nets, dramatically reduced the incidence, morbidity, and mortality of malaria.

**The Roan Antelope Copper Mine**

The Roan Antelope copper mine opened in 1927 in northern Zambia (then British colonial Northern Rhodesia). At that time, malaria was highly endemic to the area and likely the leading cause of death. The mine owners found it difficult to keep employees because workers expressed great fear of dying if they were to stay permanently. The mine owners took a systematic and integrated approach to control malaria that emphasized environmental management and detailed entomological surveys to understand the habitat of mosquitoes in the area. Environmental measures included reducing or eliminating unshaded standing water near the river and its tributaries where the *Anopheles gambiai* mosquito bred. Surveys showed that a second vector mosquito, the *A. funestus*, preferred the shaded banks of the river and flooded areas, which were common during the rainy season. Efforts were made to clear vegetation along the river and to remove man-made obstructions on the river, allowing the river to resume its normal, faster flow. Flooded areas and swamps were also drained, and oil was regularly applied to open bodies of water for further control.

In addition to control measures, water supply and sanitation facilities were improved and a hospital with basic diagnostic services was established. Additional control measures for European residents and some African mine employees included quinine treatments and sleeping under mosquito nets (as yet untreated with insecticide).

**Findings**

Extensive record-keeping at the project allowed the authors to determine both baseline incidence and mortality rates and improvements over the 20 years of program implementation. They find that the program was highly successful and cost-effective.

The incidence of malaria among African mine workers was halved in the first year, falling from 514 per 1,000 in 1929 to 263 per 1,000 in 1930. By 1931, the incidence had been cut in half again, to 151. Deaths due specifically to malaria among Europeans (the only available data) declined rapidly, falling by 70%–95% within five years. Within about three years, the incidence of malaria deaths declined from 10.3 per 1,000 in 1929 to 0.5.

Overall mortality fell as well, and the authors attribute the majority of the decline to falling malaria incidence and mortality. One year after interventions, the mortality from all diseases was cut in half. Mortality among Europeans in the immediate vicinity of the mine was 23.4 per 1,000 at baseline (1930), dropping to 13.2 per 1,000 in 1932. By 1939, overall mortality had dropped to 3.9 per 1,000. Among Africans, the mortality rate in 1930 was 32.3 per 1,000, falling to 3.5 in 1939.

The authors also estimate that the interventions averted roughly 4,173 deaths and 161,205 malaria attacks. The interventions are also estimated to have saved roughly 3,618 disability-adjusted life years (DALYs) during a three-year period (1934–1936), rising to nearly 11,000 years for 1947–1949.

Furthermore, the program was very cost-effective. The cost of the program over its 20-year span was approximately $3.6 million (in 1995 U.S. dollars). Initial costs, which included the in-depth entomological surveys and wages for the 300 workers to clear vegetation, were more than $1 million, or $167 per person. The annual maintenance costs ranged from $103,000–$190,000, or roughly $5–$23 per person.

The estimated costs per death averted were $858. Averting a malaria attack cost $22.20 over the entire implementation period. During the first 3–5 years of implementation, the costs per DALY averted were relatively high, ranging from $524–$591, largely owing to the high initial capital investment. Costs dropped significantly after the initial outlays, ranging from $92 for the first three-year period 1934-1936, and dropped to $22 for the last three years (1947-1949).

**Policy Implications**

Renewed interest in environmental management has emerged over the last 10-15 years, in part the result of the vector resistance to insecticides. As the malaria campaign shifts from eradication of the disease to control, much can be gained from looking back at past campaigns. Presently, there is heavy emphasis placed on research leading to high-technology solutions. In their paper, **The Challenges of New Efforts to Control an Old Disease—Malaria,** the authors argue that, based on an analysis of past interventions, a more effective strategy would be an integrated approach involving prompt diagnosis and treatment, insecticide-treated bed nets linked with agricultural development and water management.

Such environmental management strategies for malaria control have met with success elsewhere around the world. The experience of the Roan Antelope Mine in Zambia is just one example. In Borneo, limiting standing water near human settlements has achieved impressive results without unnecessary defoliation. Construction sites are especially fertile breeding grounds for mosquitoes, and eliminating standing water is essential. Water management strategies, however, must pay heed to local agricultural needs. In Southeast Asia, for example, timed drainage of rice paddies is particularly effective. Intermittent irrigation cycles of 5 wet and 2–4 dry days demands less water, controls malaria, and increases yield and rice quality. This technology is especially important as more rice cultivation gets underway in Africa.

The success of these various malaria control programs can be characterized by the following features: (1) an integrated approach with multiple interventions; (2) active participation of local communities; (3) monitoring and adaptive tuning of the intervention package; (4) allowing 3-5 years for outcomes to emerge; and (5) multidisciplinary program staff with expertise in epidemiology, entomology, clinical aspects of malaria, and hydrology.

The authors propose four main building blocks for malaria-control programs, including strengthening and promoting health systems to tailor programs to local settings; employing local personnel to implement the strategies; linking land and water management with health; and ensuring dependable power and water at local health care facilities. Critical to all campaigns is the need for committed, local participation operating within well-organized national control programs. The recent examples of partnerships between national governments, private foundations, networks of nongovernmental organizations, research institutions, and the corporate sector are encouraging.

The Center for Health and Wellbeing (CHW) and The Research Program in Development Studies (RPDS) are research centers in the Woodrow Wilson School of Public and International Affairs at Princeton University. Information about CHW can be obtained from its web site, at www.wws.princeton.edu/~chw, or by sending e-mail to chw@princeton.edu. Information about RPDS can be obtained from its web site, at www.wws.princeton.edu/~rpds, or by sending e-mail to rpds@princeton.edu.