and maintenance. In addition, the development of resistance to the synthetic pyrethroids used in targets is being anticipated with research to identify safe alternative insecticides, including insect-growth-regulating hormones and insect pathogens.

Tsetse control specialists have long demonstrated an awareness of the potential adverse environmental impacts of their health programs so they included environmental assessments and monitoring in their programs. As a result, control technologies continued to get safer and more sustainable, as well as more effective. Ground and aerial insecticide spraying led to severe acute effects on non-target animals and/or widespread contamination of wildlife with insecticide residues. In contrast, targets are relatively selective, non-polluting, and safe for workers. They reduce the hazard, persistence, and amount of insecticide used, as well as its contact with the environment and non-target species.

The Okavango Delta's cloth targets have another advantage that increases their sustainability: they lend themselves to production, deployment, and/or management by communities and the private sector. Surveys of tour operators and communities in 1996 found that large majorities of each group were willing to contribute to tsetse fly control, given appropriate compensation. Since human resources and transportation have historically been key limiting factors, these offers are potentially quite helpful. Mutually beneficial public-private partnership arrangements, involving rewards such as tax relief for tour companies and employment for community members, are under study.

Onchocerciasis Control in West Africa[7]

West Africa : Onchocerciasis control without DDT

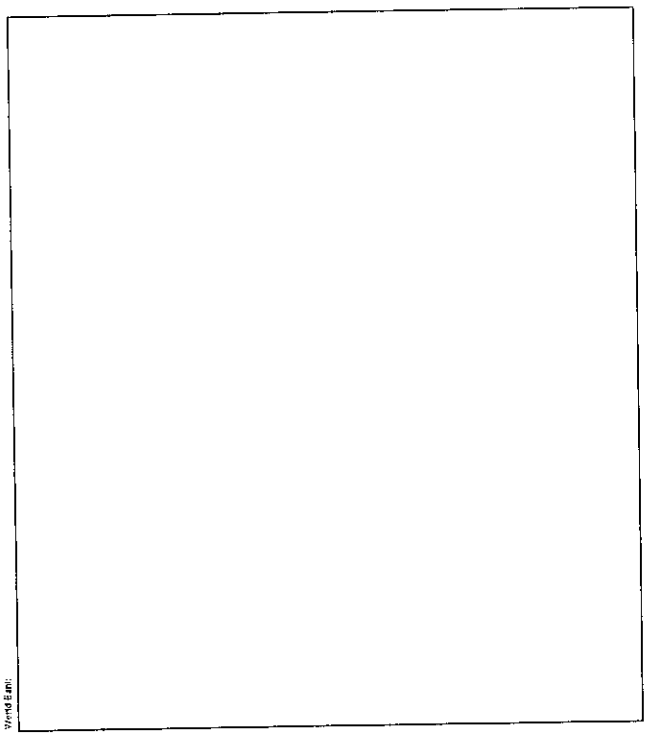
Starting in 1946, and for nearly 30 years after, DDT was applied weekly to some West African rivers to kill larvae of blackflies in the genus Simulium which transmit onchocerciasis or "river blindness," a debilitating disease caused by the parasitic nematode Onchocerca volvulus. The Onchocerciasis Control Programme (OCP), started by a group of seven West African countries in 1974, is now achieving disease control with aerial application of much smaller amounts of alternative insecticides, combined with ivermectin, a drug treatment for infected people. The OCP, a multilateral project implemented by the WHO, was ultimately financed by a consortium of 21 donors, and expanded stepwise to cover 1.3 million square kilometres and 50,000 kilometres of rivers in 11 countries. Representatives of the WHO, the World Bank, FAO, and UNDP constitute the Committee of Sponsoring Agencies that oversees the project.

The OCP rejected DDT because of the risk of bioaccumulation and hazard to non-target species. The insecticide of choice, temephos, has a very low toxicity to

mammals and fish and a good selectivity for blackflies. However, by 1989 the blackflies had developed temephos resistance over most of the project area. Presently, resistance is managed by using temephos in rotation with other organophosphates, pyraclofos and phoxim, the carbamate carbosulfan, the synthetic pyrethroids permethrin and ethofenprox, and the biocide Bacillus thuringiensis (B.t.). The pattern of rotation is determined by roving testing teams that constantly monitor blackfly sensitivity. Resistance to temephos has regressed, and sensitivity to the other insecticides remains generally unchanged.

Applied research that cuts operational costs and maximizes results has been an integral part of the OCP. Among other things, it has helped ensure that insecticide applications are made in a way that minimizes impacts on non-target aquatic life. Since the beginning of the program, a network of 100 solar-powered water monitoring stations has transmitted information on stream depth via satellite to a ground station that uses computers to forecast water flows. This information is used to choose appropriate insecticides and dosages and to plan the most cost-effective spraying routes. Application efficiency is improved even further by computerized spray equipment in the aircraft that helps the pilot apply the larviciding specifications and nozzles that are best suited to the insecticide used, the habitat, and the amount of chemical to be discharged. This precision insecticide application prevents costly and toxic insecticide overdosing, as well as excessively low doses that can promote the development of insecticide resistance.

Specially equipped helicopters apply insecticides to West African rivers which are breeding sites for blackflies that transmit "riverblindness."



From the beginning of the project, formally designated panels of expert advisors studied the environmental impact of the insecticides applied, approving or rejecting them for use by the program and making recommendations for environmental protection. A surveillance network was established to monitor aquatic life in the watercourses to be treated. All the insecticides chosen by the OCP degrade rapidly, have low mammalian toxicity, and do not kill fish or crustaceans at the doses and discharge rates at which they are used. B.t., the most-used insecticide, has almost no non-target effects. A 1990 external review found no evident long-term effects on aquatic fauna.

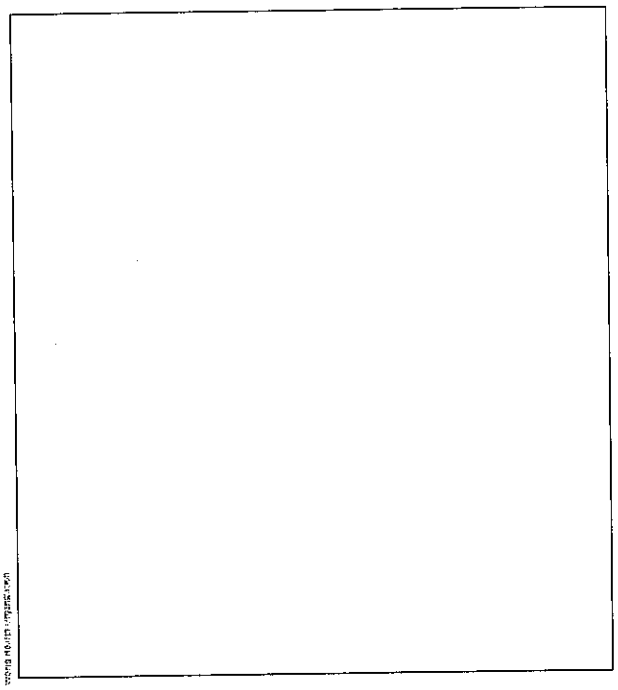
That review also found that river blindness has ceased to be a public health threat in the original project zone, and vector control operations have ended in most of that area.

Over 34 million people are protected from the disease. Children born since 1975 no longer face the risk of blindness, and the disease has been halted in older persons. The program is now entering a five-year phase-out period (1998-2002), after which lasting control of the disease throughout the extended program area is expected.

A cost-benefit analysis using conservative assumptions, and with the benefit of additional agricultural output due to labor and land made available through onchocerciasis control, concluded that the OCP is a highly productive program. The economic rate of return of the OCP is about 20 percent, one of the better economic returns among World Bank projects in any sector over the years. OCP officers consider their project to be a model of global partnership where donors, international agencies, and participating countries unite to make the most of the comparative advantages of each. The success of the OCP also underlines the advantages of attacking disease problems regionally.

Ecological Malaria Control in Kheda District, Gujurat, India[8]

Using larvae-eating fish such as Gambusia is one non-chemical method of managing malaria vectors.



India's National Malaria Eradication Programme has long depended on house spraying with DDT, HCH, and malathion for vector control. The resulting widespread insecticide resistance, environmental pollution, and citizen refusal of house spraying are ongoing problems. From 1983-1989, however, the Malaria Research Centre, an autonomous research organization under the Indian Council of Medical Research, implemented an Integrated Disease Vector Control (IDVC) pilot project in Kheda District, Gujarat, which enlisted community participation for implementing an integrated, ecological malaria control strategy that eliminated insecticide use altogether.

Kheda District is rural and dominated by irrigated agriculture, with no conservation areas. Irrigation canals and channels are the most important breeding sites of the main malaria vector. The IDVC project protected up to 700,000 people living in Nadiad subdivision, which had the highest malaria incidence in Gujarat State. It did so by combining several non-chemical vector control methods with aggressive (weekly) village-level disease surveillance that ensured early-case detection and prompt treatment.

Health education was important for consciousness raising and eliciting community participation. Community members eliminated mosquito breeding habitats by

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71. IBID

72. A full report on the development and run results of the mass balance model for indoor exposures, prepared by Katie Feltmate, Dr. Don Mackay, and Eva Webster is available from WWF.

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Part C

1. A full report on the projects briefly profiled here, prepared by Dr. Patricia Matteson and co-authors associated with the various projects, is available from WWF.

2. In particular, Brazil has reduced malaria in the Amazon region by integrating intensified diagnosis and treatment, health education, and environmental management; see The Malaria Control Program in Brazil, presentation by Carlos Cateo Prates at the UNEP/IFCS Subregional Awareness Raising Workshop on Persistent Organic Pollutants (POPs), Cartagena, Colombia 27–30 January, 1998.

3. Unpublished documents, Servicio de Erradicacion de la Malaria de la Secretaria de Estado de Salud Publica y Assistencia Social, Dominican Republic.

4. Gambia implemented a national impregnated bednet program on the basis of a pilot study described by B. M. Greenwood and H. Pickering, A malaria control trial using insecticide-treated bednets and targeted chemoprophylaxis in a rural area of The Gambia, West Africa, Transactions of the Royal Society of Tropical Medicine and Hygiene 87, Supplement 2:3–11 (1993).

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   a. Village-level production in coconuts of B. thuringiensis israelensis for larviciding of malaria mosquitoes in Peru, in Of Mosquitoes and Coconuts, IDRC Reports, Vol. 19(1):17–19 (April, 1991);

   b. Integrated malaria control including biological vector control with marketable fish as a source of local income in Pondicherry, India, P. K. Rajagopalan and K. N. Panicker, "Vector Control: How to Gain Acceptance and Support from the Community", WHO Chronicle 40(5):184-187 (1986);

   c. Malaria control in Pudukuppam, Pondicherry, India through environmental management – algae cleared from ponds was used for village-level manufacture and sale of art paper, K. N. Panicker and P. K. Rajagopalan, A Success Story of Community Participation in Malaria Control (Pondicherry, India: Vector Control Research Centre Miscellaneous Publication No. 18, 1990);

   d. IVC using bacterial larvicides and the selective spraying of vegetation as a successful alternative to altering Venezuelan wetlands for malaria control, R. H. Zimmerman and J. Berti, The Importance of Integrated Control of Malaria for the Preservation of Wetlands in Latin America, in Global Wetlands: Old World and New, W. J. Mitsch, ed. (Elsevier Science B. V., 1994).

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8. R. K. Khawere and P. Kumar, "Malaria Control in Kheda District, Gujurat, India," in P. C. Matteson, ed., Disease Vector Management for Public Health and Conservation (Washington, D. C.: World Wildlife Fund, 1998, in preparation).

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10. Lengeler et al, 1996.

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15. M. en C. J. Carabias Lillo, G. Quadri de la Torre and C. Cortinas de Nava, Programa de Gestión Ambiental de Sustancias Tóxicas de Atención Prioritaria (Mexico City: Instituto Nacional de la Ecología, 1997).