Larval Source Management in Khartoum, Sudan

Malaria was the major cause of outpatient attendances, admissions and deaths in Khartoum in the 1980s and 1990s. This led to the launch of the Khartoum Malaria Free Initiative (KMFI) in 2002 by the State and Federal Ministry of Health, in collaboration with the World Health Organization (WHO), with the aim of reducing malaria incidence in Khartoum State by 80% between 2002 and 2008, to less than 0.5 cases per 1000 people per annum [1] and to demonstrate the potential of modern malaria control interventions in order to attract funding for malaria control in the rest of the country [2]. The KMFI has three main components: (1) diagnosis & treatment, (2) prevention and (3) epidemic surveillance [2]. Larval source management is an essential component of the malaria prevention program. This document outlines the structure of the KMFI and its impact.

Background

- **Site characteristics:** Khartoum state is located on the southern fringes of the Sahara, at the junction of the Blue Nile, White Nile and River Nile, 400m above sea level (Fig. 1). The state consists of seven localities [3].

- **Climate:** There are four seasons: winter (mid-November-March); a hot, dry summer (March-July); a rainy season (July-September) and a short, hot transitional season (September-November). Temperatures ranges from 12-45°C and average annual rainfall is 110-200mm [4].

![Figure 1. Khartoum state](image)

- **Primary vector:** Anopheles arabiensis.

- **Main type of breeding sites:** Irrigation canals, pools created from leakage of water pipes, water basins, storage tanks, rain pools and river bed pools [2].

- **Malaria transmission:** Transmission is low and seasonal. Plasmodium falciparum accounts for 95% cases. Plasmodium vivax and P. ovale are also prevalent.

The larval source management program

Structure of the control program: The Khartoum Malaria Free Initiative (KMFI) divides Khartoum State into 7 localities, which are further divided into 26 administrative units, then sectors (areas of 7-10km² with a one week working load) and finally sub-sectors (areas of 1-1.5km² with one day working load (six per sector)). The program aims to protect a population of 2,073,300 in urban areas, 3,201,021 in peri-urban areas and 640,672 in rural areas [3]. The KMFI employs 14 trained medical entomologists, 60 public health officers, 31 sanitary overseers and squad leaders, 360 assistant sanitary overseers and 705 spray men [3]. Each public health officer is supported by the sanitary overseers and assistant sanitary overseers and supplied with the necessary equipment [1]. In 2002, WHO commissioned experts from the Oman malaria elimination program to give the program technical support [1].

- **Baseline mapping:** Both potential and actual vector breeding sites have been identified and mapped and target areas classified into the following epidemiological zones: urban, peri-urban, rural riverine, and rural non-riverine (pastoral) [2, 5].

- **Larval source management:**
  - Repair of broken water pipes and the removal of water basins by law (Fig. 2): the KMFI collaborates with the Water Corporation Department (WCD) to repair broken water pipes. KMFI is responsible for surveillance, reporting and transportation and the WCD provides engineers and equipment. By 2004,
3,818 metres water pipes had been replaced and 6,104m repaired [2].

- Intermittent irrigation: regular drying of irrigated fields, which reduces vector breeding, is compulsory in both government and private irrigation schemes. This initiative is supported by the Farmers Union and the Ministry of Agriculture. 98.2% irrigation schemes were dried for at least 24 hours during 2011 [3]. Leakages from irrigation canals are also repaired and vegetation around canals is cleared in conjunction with the Ministries of Irrigation and Agriculture [2].
- Larviciding with temephos: In addition to the KMFI workforce, 405 schools and 287,000 pupils are involved in treating breeding sites with temephos [3].
- Biological control with Gambusia fish: Gambusia fish have been added to 317 permanent breeding sites, mainly irrigated canals and pools from leakage of drinking water pipes [3].
- Public involvement: Efforts to involve the public in the KMFI have been intense (Fig. 4), through the distribution of information leaflets, regular radio broadcasts and television coverage, health education in schools in collaboration with the Ministry of Education, the organisation of an annual ‘Khartoum State Malaria Day’, public meetings and the establishment of malaria control committees and societies [2].
- Clinical surveillance: Since 1998, annual cross-sectional surveys have been undertaken in random samples of residential blocks every September. Between 1998 and 2009, 256 clusters across 203 samples were surveyed; a total of 128,510 slide examinations [6].
- Entomological surveillance: Fortnightly entomological surveys are conducted at 24 sentinel stations by a medical entomologist and entomology technicians. Data are compiled and reported to localities and the state malaria control program using a standard form [2].
  - Larval surveillance: At each sentinel site, all known breeding sites within the vicinity are sampled, with 3-10 dips taken with a 0.5L dipper. The average number of larvae per dip is calculated. Larvae are classified according to stage and species. In 2004, 12,360,284 breeding sites in Khartoum State were inspected by 705 mosquito collectors [2].
  - Adult mosquito surveillance: Pyrethrum spray catches are conducted in seven rooms at each sentinel site, between 6.00am and 8.00am, and the average number of anophelines per room per station calculated. All mosquitoes collected are classified according to physiological status as unfed, fed, half gravid and gravid [2].
- Funding: Government of Sudan; United Nations. The annual cost of the KMFI in Khartoum State is US$0.10 per person protected per annum [3].
- Other malaria control interventions: Strengthening of case management through the improvement of microscopy, staff training and provision of antimalarial drugs through the ‘revolving drugs fund’ [1]. Indoor residual spraying (IRS) and long-lasting insecticidal net (LLIN) distribution are not conducted in Khartoum, however LLINs are exempt from import tax in order to encourage private sector sales [2]. Nonetheless, in the northern states of Sudan, the national malaria control program distributed nearly 0.6 million LLINS between 2006 and 2009 [7].

Impact
Clinical outcomes: Overall parasite prevalence increased from 2.5% in 1999 to 3.2% in 2000 and fell to <1% in all subsequent years to 2009. >90% of all surveyed clusters reported no infections between 2006 and 2009. However notable clusters of malaria infection remained in 2009 at the confluence of the White and Blue Nile rivers [6]. Total confirmed and unconfirmed malaria
cases, as a proportion of total outpatient attendances, declined from 40% in the 1990s to <20% in 2004 (however diagnosis simultaneously improved) [1]. Total malaria deaths (confirmed and unconfirmed) declined by almost 75% from 1,070 in 1999 to 274 in 2004 [1].

It is not possible to directly attribute the decline in malaria to the KMFI, however there is a strong temporal association between the two. It is unlikely that changes in rainfall can explain the trend [6]. Data on the distribution and coverage of KMFI control activities is not available at a sufficiently fine spatial scale to allow attribution to changes in parasite prevalence recorded with the cross-sectional surveys. Travel history data were not collected during these surveys, so local and imported cases cannot be distinguished [6].

**Entomological outcomes:** The total number of breeding sites under surveillance increased from 1,854,856 to 12,360,284 between 2001 and 2004. The percentage of breeding sites producing anopheline larvae and the overall mean larval density did not alter between 2001 and 2004. The average density of adult mosquitoes per room recorded declined from 1.6 mosquitoes/room in July 2001 to 0.4 mosquitoes/room in July 2004 [1].

**Factors contributing to success**
- Public support is high and KMFI has a high profile due to good public relations [2].
- Technical support from the Oman malaria elimination program [1].
- Strong political support for the control program at both State and Federal level [2].
- Sustaining funding [2].
- Improving entomological surveillance [1,6].
- New agricultural schemes and new construction sites create more breeding sites [3].
- Emergence of P. vivax in parts of Khartoum State [3].
- Two decades of conflict have weakened the health system.

**References**

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Figure 4. Raising public awareness of the Malaria Free Initiative (Photo courtesy of KMFI)