وزارة الصحة
Ministry of Health

World Health Organization

Progress Toward Malaria Elimination in the Kingdom of Saudi Arabia

A Success Story

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Foreword

After approval by the Royal Court, the Government of Saudi Arabia, represented by the Ministry of Health, took the initiative to adopt a national malaria elimination policy with the strategic objective of total interruption of local malaria transmission from all parts of the Kingdom in accordance with strategies of the World Health Organization (WHO) by the year 2020. Vector borne diseases department at the Ministry of Health, in collaboration with the vector borne diseases centres and units of the Health Affairs Directorates in the regions, have developed and adopted effective control plans and strategies since 2004 to achieve malaria-free status in the Kingdom with the support of WHO. In the first year (preparation phase) of the project, many of the requirements for control activities and adequate facilities, including insecticides, drugs, devices, equipment and vehicles, were secured. In this regard, the various epidemiological elements of the programme have been strengthened following WHO recommendations.

The Government continued its interest in and sponsorship of this project and has provided, and continues to provide, all the needed resources to carry out the different activities of the planned malaria elimination phases. In the past decade, much has been achieved in the malaria elimination project and only a few steps are left to be completed.

The Saudi Arabian Ministry of Health is proud to present this success story. We were very honoured to have been identified by the WHO and its regional office as one of the countries eligible to report its achievements in malaria elimination. We have seen a positive impact as a result of the vigorous and committed implementation of our malaria policies detailed in the country's National Malaria Control Policy. We assure our commitment to achieving the goal of malaria elimination in Saudi Arabia by 2020, and I am very confident that through the efforts of the Government and its partners, malaria can be eliminated in our country.

I would like to acknowledge the efforts undertaken by the WHO Regional Office for Eastern Mediterranean and the experts who contributed to this case study. In addition, special appreciation is due to the General Director of Disease Vectors and Zoonotic Diseases and his team members of our National Malaria Elimination Programme, Ministry of Health. I hope that you will find this report useful and that WHO Member States, international agencies, academia and other stakeholders will make use of the information available in this report and positively benefit from it.

Dr Tawfig Alrabiah

Minister of Health, Kingdom of Saudi Arabia

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Thanks and particular appreciations are conveyed to all current and previous officials and staff in the malaria departments in the vector-borne disease control units of all regions of the Kingdom of Saudi Arabia

Contents

Summary

The Kingdom of Saudi Arabia made significant progress toward elimination of malaria from the late 1940s through to the early 1980s. Malaria remained entrenched in the south-western regions of the country and epidemics plagued these regions during the 1990s. As a result of these epidemics, a concerted effort was again made to eliminate malaria from the country.The Government of Saudi Arabia has made an outstanding political and financial commitment to a malaria elimination strategy since 2000 within the framework of the national plan for socioeconomic development of south-western regions.

The Technical Strategy of Malaria Elimination provided the actions and activities needed to maintain the malaria-free status in northern, eastern and western regions and, in the southwestern regions, to reduce malaria incidence to the lowest possible level and to work towards elimination of malaria in the residual foci, in order to eliminate malaria from the whole country. The elimination strategy emphasizes: strengthened case management, including improved, quality-assured laboratory confirmation of all cases; the provision of free artemisinin-based combination therapy to all patients; adult vector control (indoor residual spraying, insecticide treated nets), space spraying and larviciding; and vector control linked to a strengthened casebased surveillance system including the epidemiological investigation (and classification) of all passive and active cases detected. Special attention was paid to the threat posed by crossborder movement between Yemen and the Kingdom of Saudi Arabia through the establishment of a network of border malaria health posts, financial assistance to carry out simultaneous vector control activities on both sides of the border and exchange of information between the two countries with regular biannual meetings. In malaria-free areas,screening of expatriate workers from endemic countries was strengthened to prevent reestablishment of transmission.

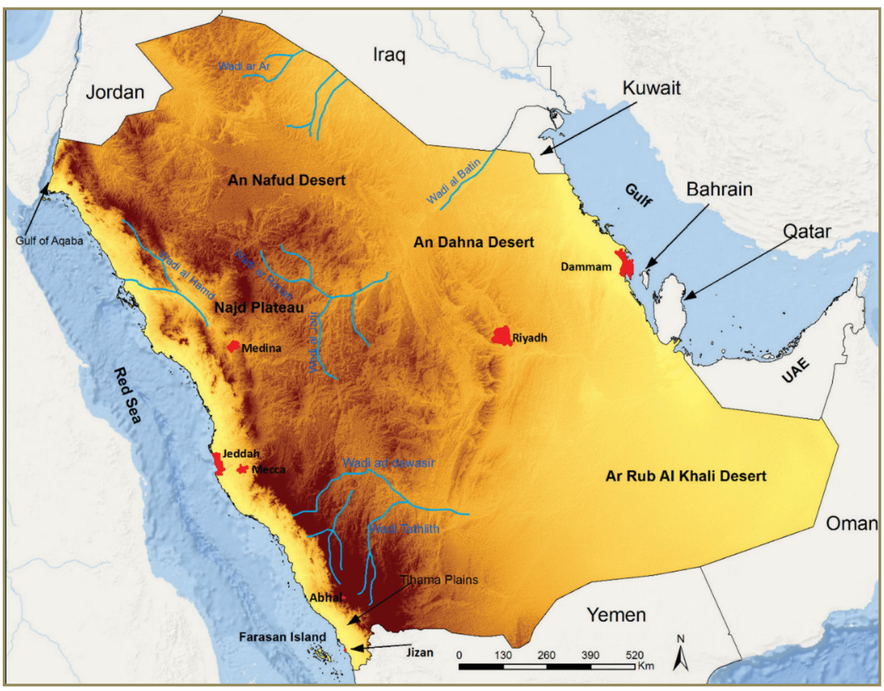
An allocation of US$ 25-30 million a year has been made to the programme by the Government since 2004, and by 2009 malaria was considered a negligible public health problem with a total of about 100 indigenous cases. Up to 2015, indigenous cases did not exceed this number. Significant success has been achieved towards malaria elimination in the Kingdom. The number of local malaria cases is at a very low level and active malaria transmission is confined to limited foci on the border between Saudi Arabia and Yemen. However, the malaria elimination programme is facing some challenges that might allow these foci to remain. The main challenge is the population movements across the Saudi border with Yemen, particularly those who cross illegally and come from highly endemic countries such as Ethiopia, Eretria, Yemen and Sudan. The ongoing conflict in Yemen has resulted in cessation of collaboration between the malaria departments in Saudi Arabia and Yemen as well as discontinuation of the Malaria-free Arabian Peninsula Project which was initiated in 2005. The malaria control operations financed by the Saudi Ministry of Health, which were carried out about 10 km inside the Yemeni border, stopped at the first war between 2009 and 2010. In 2015, the situation has been further complicated by suspension of malaria control activities at the Saudi border with Yemen and the evacuation of all the bordering villages for security reasons because of the ongoing war. Despite these challenges, Saudi Arabia is committed to achieving the malaria elimination target by 2020, with the support of the World Health Organization’s (WHO) regional malaria control and elimination programme and guided by the global technical strategy for malaria,2016–2030 The Kingdom of Saudi Arabia’s experience and its path towards malaria elimination provides a valuable case study for countries attempting a similar journey. This case study also provides a documented account of malaria elimination for the institutional memory of the Kingdom.

Country context

Location, topography and climate

The Kingdom of Saudi Arabia is in the south-west corner of Asia, at the crossroads of Europe, Asia and Africa. The Kingdom is bounded by the Red Sea on the west, borders Yemen and Oman in the south, the Gulf coast, the United Arab Emirates and Qatar in the east, and Jordan, Iraq and Kuwait in the north (Fig. 1). It occupies about four-fifths of the Arabian Peninsula, with a total area of approximately two million square kilometres. This large expanse has a wide range of climatic and ecological conditions.

Fig. 1: Location, topography and major wadis (valleys)1



Due to a subtropical high-pressure system, the country is generally extremely hot in summer and cold in winter. The west and the south-western parts of the country have a more moderate climate and the coastal areas have high temperatures and humidity. Most parts of the Kingdom usually receive little rain throughout the year, but the Red Sea coast has seasonal rainfall between October and January.

[1] The extents of the major listed megacities were digitized using Google Earth and ArcMap 10.1 (ESRI, Redlands, California). Elevation is shown in increasing shades of brown from 56 m below sea near the Oman border to 2995 m above sea level in Aseer Province (http://gdem.ersdac.jspacesystems.or.jp/search.jsp). Other features were digitized using on-line sources (http://www.ezilon.com/maps/asia/saudi-arabia-physical-maps.html)

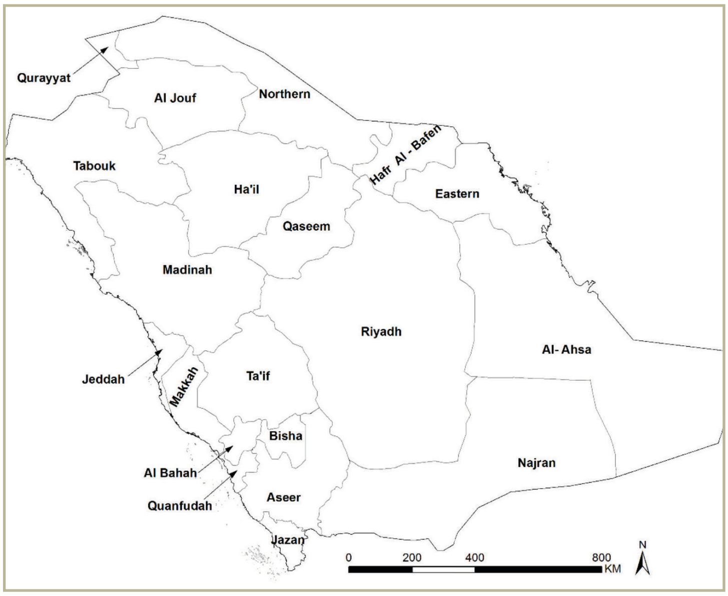
Population

In 2010, the total population of Kingdom of Saudi Arabia was 27.14 million, including 18.71 million Saudi nationals2. Today, 84% of the population lives in urban areas compared with 38% in 19653. There are several large cities in the Kingdom (Fig. 1): Riyadh, the capital, location of the headquarters of the Gulf Cooperation Council and centre of high-tech commerce; the holy cities of Makkah and Madinah; Jeddah, the commercial capital on the Red Sea; Dammam, the capital of the Eastern Province, and location of all the country's oil and gas and the largest port on the Gulf; and smaller but rapidly expanding cities in the southwest including Jazan and Abha (Fig. 1).

Administrative boundaries

The Kingdom of Saudi Arabia is divided into 13 administrative regions. Each region is divided into several governorates, and each governorate is divided into centres linked administratively to the governorate itself resulting in 20 health administrative regions that implement national policies and report directly to the National Malaria Control Programme of the Ministry of Health (Fig. 2).

Fig. 2: Administrative health regions used by the National Malaria Control Programme, Ministry of Health



[2] Central Department of Statistics & Information, Kingdom of Saudi Arabia; 2011. Population statistics database (http://www.cdsi.gov.sa/english)
[3] World urbanization prospects: the 2014 revision. New York: Department of Economic and Social Affairs, Population Division, United Nations; 2014 (http://esa.un.org/unpd/wup/CD-ROM/)

Health system

The Ministry of Health has a well-defined, decentralized organizational and administrative structure. The Ministry supervises regional directorates-general of health affairs in various parts of the country. Each regional health directorate has many hospitals and health sectors and every health sector supervises many of primary care centres. The role of these directorates includes: implementing the policies, plans and programmes of the Ministry of Health; managing and supporting the Ministry's health services; supervising and organizing private sector services; and coordinating with other government agencies and relevant bodies. Health service provision is based on the primary health care centre strategy and application of a referral system through three tiers of health care providers under the Ministry of Health. Primary health care centres provide both preventive and curative services and the number of centres has grown considerably since the mid-1980s. Over this time, primary health care centres have been increasingly used to support malaria control activities. Using a structured referral system, patients that require advanced care are referred to the second level of care (public hospitals), and those that need more complex or specialist levels of care are transferred to the third level of health care (referral hospitals). In addition, private sector providers play a key role in providing quality health care services in the Kingdom.

Table 1 Number of malaria centres and units in the administrative health regions

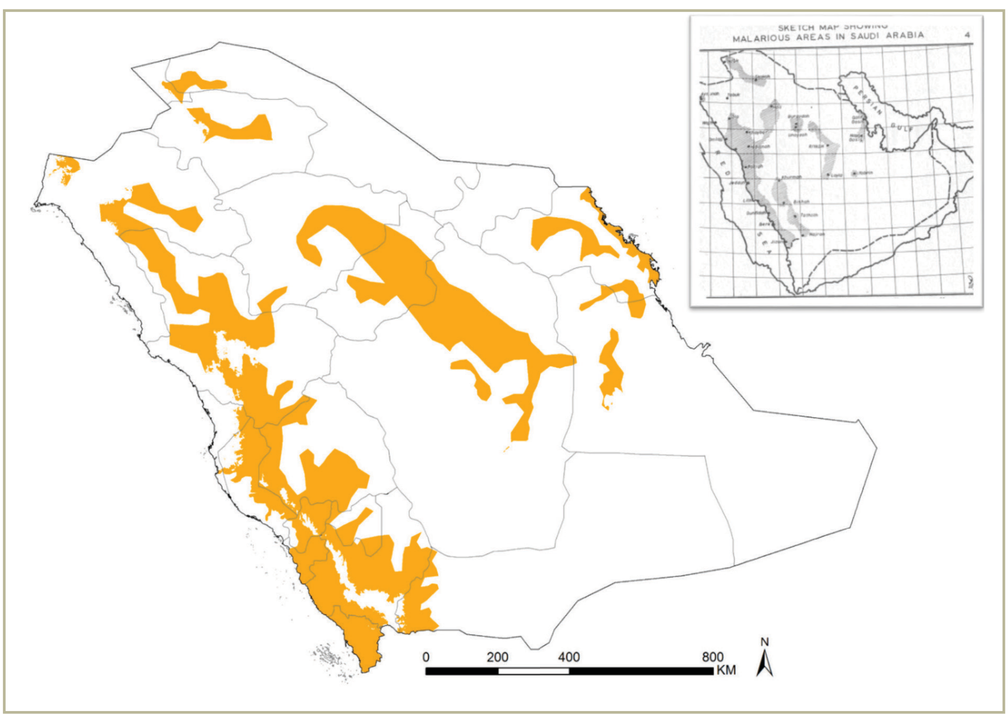
Administrative health regions	No. of malaria centres	No. of units
Jazan	9 and 9 malaria sub-centres	13 border units
Al Baha	9	
Eastern region	1	
Hafr Albaten	1	
Aseer	17	6 border units
Taif	1	
Alhassa	1	
Northern Province	1	
Najran	2	
Jeddah	1	
Al Jouf	1	
Riyadh	1	
Qunfudah	3	4 units
Makkah	1	
Hayil	1	
Tabuk	1	
Madinah	1	
Alqurayat	1	
Bisha	1	
Qaseem	1	

Malaria epidemiology

Natural limits of malaria transmission

Writings from travellers to the Arabian Peninsula in the 19th and 20th centuries refer to periodic fevers and deaths from fever at oases and in the inhospitable Tihama region on the western border with the Red Sea. It is thought that during the Prophet Mohammad's (peace be upon him) migration from Makkah to Madinah in the year 622 there was an epidemic of Yethrib fever among his followers; Yethrib, subsequently named Madinah, was regarded as a dangerously unhealthy place. Deserts, human settlement, ecology and dominant vector species all combine to define the natural limits of transmission of malaria in Saudi Arabia. Crude approximations of the spatial limits of malaria transmission in the country were provided between 1930 and 1968. In 1962, the Ministry of Health developed a map showing the main areas of malaria risk, which required planned efforts to control and eliminate transmission. This was based on expert opinion and was the most informed map developed of the extent of malaria in the country. To show the limits of risk, data on factors that are likely to decrease malaria transmission (obtained from meteorological data, remotely sensed data on land cover, altitude, and composite maps of malaria risk boundaries developed between 1930 and 1960) were combined to provide a more up-to-date and accurate picture of the natural extent of malaria transmission in the Kingdom (Fig. 3).

Fig. 3: Probable natural extent of malaria (coloured areas) in the Kingdom of Saudi Arabia (Ministry of Health 1962 map shown in insert for comparison)



Malaria vectors

A total of 17 *Anopheles* species have been recorded, four of which are known to be competent malaria vectors in the Kingdom: An. *arabiensis,* An. *sergentii*, An. *stephensi* and An. *superpictus.* The distribution of the dominant vectors has largely defined the success in eliminating malaria across the country; the less efficient vectors in the east (Indo-Iranian region, An. stephensi), central and west (Afro-Arabian region, An. *sergentii*) and northern (Mediterranean region, An. *superpictus*) are rapidly susceptible to vector control compared with the intransigent and more efficient vector *An. arabiensis* in the south-western Afrotropical region. An. sergenti is the most common vector across the country and has been implicated in transmission in the south-west. An. arabiensis is confined to the south-west but has a greater ecological range than is suggested by maps of the Afro-tropical ecological zone.

Other species, not implicated in malaria transmission in the Kingdom but sampled since 1931, include *An. azaniae*, *An. cinereus*, *An. coustani* s.s, *An. coustani* var. *tenebrosus*, *An. culicifacies, An. d''thali*, *An. fluviatilis*, *An. multicolor*, *An. pharoensis*, *An. pretoriensis*, *An. pulcherrimus*, *An. rhodesiensis*, *An. rupicolus*, *An. subpictus*, *An. tenebrosus* and *An. turkhudi*. Most blood meals identified among *An. arabiensis* females in the south-west of the country are not of human origin. This vector feeds and rests both indoors and outdoors, making vector control methods targeting households, such as indoor residual spraying and insecticide treated nets, or long-lasting insecticidal nets, insufficient as the only method needed to reduce transmission.

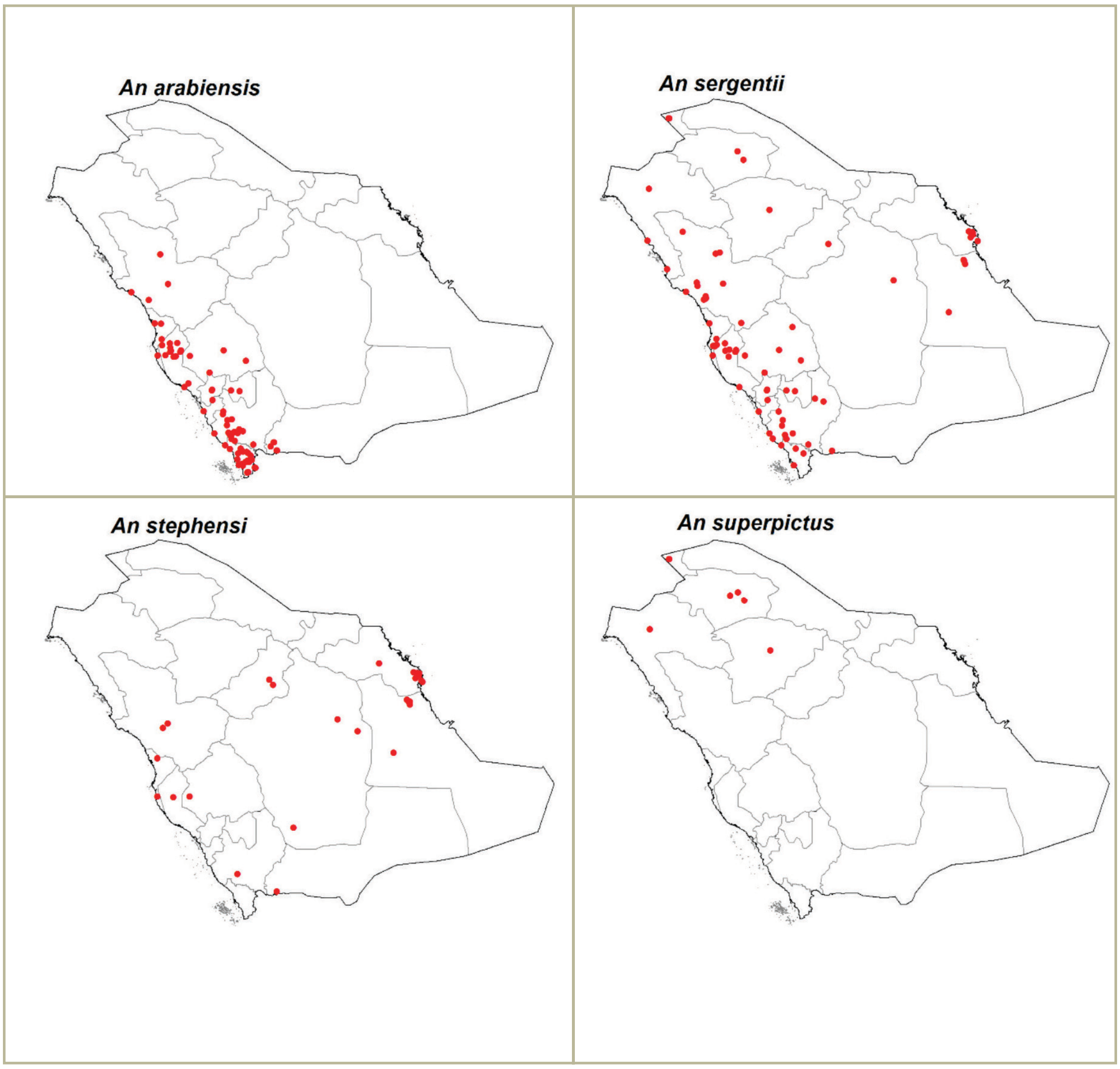
Table 2 shows the characteristics of the four dominant malaria vectors in the Kingdom and

Fig. 4 shows their locations documented in 181 survey sites since 1931

Table 2 Characteristics of the four competent Anopheles malaria vectors in the Kingdom

Characteristic	Variable		An. arabiensis	An. sergentii	An. stephensi	An. superpictus
Distribution	Spatial		South-western regions (Jazan, Aseer, Al Baha, Qunfudah)	Western and south-western regions	Eastern regions	Northern regions
	Seasonal	Peak	Winter	Autumn	Autumn, Winter	
		Low density	Spring, Autumn	Spring, Summer	Spring, Summer	Autumn
		No density	Summer	Winter		Spring, Summer, Winter
Adult behaviour	Biting behaviour		Both endophagic and exophagic	Exophagic, rarely endophagic	Exophagic	NA
	Resting behaviour		Mainly endophilic (in human dewellings)	Exophilic(outdoor resting)	Zoophilic (inside animal shelters)	NA
	Host preference		Both anthropophagic and zoophagic	Mainly zoophagic	Mainly zoophagic	NA
	Sporozoites rate		0-0.7	NA	NA	NA
Larval environment	Habitat types		Natural habitat (wadis, rain pools), sometimes domestic water containers	All types but mainly manmade (drinking water tanks, cement pools, etc.)	Manmade water collections (agricultural water catchments, water canals, etc.)	NA
	Water depth		Shallow water	Deep water	Deep water	NA
	Water pH		7-9	7-9	NA	NA
	Water salinity		1-2 mS/cm	1-2 mS/cm	NA	NA
	Turbidity		Turbid fresh water, sometimes clear fresh water	Clear water, rarely turbid	Clear water, sometimes turbid	NA
	Vegetation		No or low vegetation preferred	No vegetation preferred	No to high vegetation	NA
	Density of algae		None to medium	Low to high	Non to medium	NA
Current malaria transmission status			Local transmission in border areas with Yemen	Role in local transmission has not been clarified	Interrupted local transmission since 1970	NA
Associated anopheline species	With larvae		An. d`thali, An. multicolor, An. pretoriensis, An. turkhudi	An. rupicolus, An. d`thali	An. fluviatilis, An. sergenti, An. d`thali, An. multicolor	NA
	With adults		An. d`thali, An. sergenti	An. d`thali, An. arabiensis	An. pulcherrimus, An. d`thali	NA

Fig. 4: Dominant Anopheles Malaria vector species documented in 181 survey site locations since 1931[4]



[4] Historical archives and published sources were used to find entomological data collected in the Kingdom of Saudi Arabia. From each identified report, the data extracted included whether a species was identified at a given site, methods used to capture adults or larvae, and methods used to identify the species of each anopheline collection. The database is one of species presence, not absence and/or proportional presence of various vectors. Where An. gambiae complex was described before adequate identification techniques, we assumed these to have all been the sibling species An. arabiensis. A total of 199 site locations were identified from the data search where malaria vectors had been sampled; 18 sites could not be located geographically. The remaining 181 survey locations were surveyed between 1931 and 2010.

Vector control

Vector control milestones

1948 Annual indoor residual spraying (IRS) with dichlorodiphenyltrichloroethane (DDT) began and continued until the late 1950s in Arabian-American Oil Company (ARAMCO) project areas of Qatif and Alhassa

1952 Larvivorous fish, *Aphanius dispar*, introduced in Al-Kharj in the Najd

Larviciding using diesel oil, and sporadic IRS with DDT the following year, until 1958 in Wadi Fatma, between Jeddah and Makkah

1953 Larviciding in Jeddah and El Lith

IRS with DDT around Jeddah at Hada Sham interrupted transmission but malaria reappeared in 1958

1954 Deildrin replaced DDT for IRS in Qatif and Alhassa

1955 IRS with DDT, three annual rounds, started in Najran, Tathleeth, Tibala and Bisha valleys

1957 Pilgrimage routes of Madinah and Khayber protected with larviciding: Paris green (copper acetoarsenite) and IRS with DDT

1961 Increased efforts to protect pilgrimage routes of Makkah and Jeddah using larviciding: Paris green and IRS with DDT

1965 Larviciding began at Al Jouf, Sikakaand and Alqurayat, northern regions, where transmission was maintained by An. superpictus, followed later by IRS with DDT

1970 Malaria eliminated in northern and central regions mainly through the use of IRS with DDT and dieldrin in foci around oases. An. superpictus disappeared in the north

Continued surveillance (active and passive case detection) and mapping operations to support larviciding with Paris green, kerosene and diesel oils, in eastern regions

Resistance to both DDT and dieldrin, in regions under attack phase, prompted a change in attack methods that increasingly included larval control and mass drug administration using chloroquine

1971 Temephos (Abate) replaced Paris green for larviciding

Reported use of limited larviciding in Jazan Region

1973 Limited IRS with DDT, often only a single round per year, in Aseer, Jazan, Al Lith, Mohayil

1976 and Bisha with low coverage

Compulsory testing, radical treatment and monthly follow-up of labourers from endemic

1978 countries in eastern and northern provinces, and continued vector surveillance and larviciding with Abate or diesel oil

1981 Biannual IRS with DDT began in Qunfudah Region; reverted to one round per year over the next three years and discontinued in 1984

1982 An. superpictus reappeared at Doumat Al-Jandal oasis in Al Jouf; aggressive larviciding and case detection ensured that no local transmission occurred by 1984

1983 IRS with DDT in Aseer (annual) and Jazan (biannual) regions restarted
covering 110 000 households, weekly larviciding and ultra-low-volume space spraying with
Reslin IRS with DDT suspended in the western region and the pilgrimage routes of Makkah,
Madinah and Jeddah because ineffectual against An. sergenti; replaced with focal larviciding
Breeding habitat spraying using temephos became the principle method for mosquito
control across the Kingdom

1984 Foci mainly in south-western regions targeted with IRS, larviciding with temephos and

1985 occasional ultra-low-volume space spraying with Reslin

1987 DDT replaced by biannual fenitrithion for IRS in Aseer and Jazan regions

1990 Free insecticide-treated nets become available through the public sector butnot widely

1991 distributed until 2004
Trial of lamda-cyhalothrin treated nets in Khoba, Jazan Region showed decline in malaria
infection risks

2002 IRS done three times a year in Jazan and twice a year among communities located below
2000 m; in Aseer, IRS only done in targeted foci defined by previous years' case history

2004 Abate temphos 50 EC was stopped in Jazan and replaced with biological control using Bacillus
thuringiensis israelensis, insect growth regulators diflubenzuron (25%) and pyriproxyfen
(0.5%) and to a lesser extent chemical control using pyridafenthion for larviciding 460 000
insecticide-treated nets distributed across Aseer and Jazan regions

2007 Cross-border initiative signed with Yemen including spraying activities within a 10-km
range of the border in Yemen and the establishment of 22 border malaria posts offering free

2008 screening and treatment
250 000 long-lasting insecticide-treated nets distributed, mainly in Jazan

2012 About 750 000 long-lasting insecticide-treated nets distributed mainly in border areas with
Yemen and foci in Jazan Region

2015 About 500 000 long-lasting insecticide-treated nets distributed mainly in Jazan Region,
including distribution to military personnel

Mosquito larval control

Larval control has been a key to vector control in areas in the attack phase of elimination and areas working to remain malaria-free and prevent the reintroduction of malaria. Interventions to reduce mosquito larval populations are a key component of Saudi Arabia's malaria vector control and elimination programmes. In 1984 ,breeding habitat spraying became the main method for mosquito control across the Kingdom, particularly in the main wadis; temephos was the larviciding agent used

Mosquito larval control programmes adopted since 1984 used one or more of the following measures

1. Mechanical or environmental operations: breeding places are eliminated or reduced by mechanical means, e.g. piling or drying of unwanted ponds, and opening and cleaning of water courses in wadis to remove debris and grasses to allow water to run.
2. Chemical larviciding: this intervention method was more effective, produced better results and was easier to operate for the spraying teams. Temephos was used for more than 30 years, at which time resistance of larvae was detected in Jazan and Aseer regions and it was stopped.
3. Biological larviciding: bacterial larviciding replaced Abate in 2004 in Jazan and Aseer regions. This had technical difficulties when used by the spray teams and was gradually replaced by insect growth regulators, diflubenzuron wettable powder for spraying and pyriproxyfen as a granular product. The natural existence of the larvivorous fish Aphanius dispar in all wadis in the south-western regions and elsewhere in the country played an important role in larvae and pupae control. From field experience, all water collections with this species of fish were devoid of mosquito larvae and pupae.
4. Larviciding plant oil: mosquito larviciding and pupiciding products of plant origin were recently introduced because of the poor efficacy of insect growth regulators. Other insecticides used in Aseer and Jazan have included pyrethroids used in treated bed nets, and those used during ultra-low-volume space spraying.

Space spraying

Since 1983, routine application of space spraying, both indoors and outdoors, has been carried out. Ultra-low-volume aerosol spraying has been used only in emergency situations. It is applied to treat houses found to have cases of malaria, neighbouring houses and suspected potential outdoor resting places of vectors during case and/or focus investigations in non-sprayed areas, or in the active malaria foci when the vector density becomes high. In some areas, the use of ultra-low-volume spraying is minimal, while in other areas it is used routinely in situations where efficient malaria vectors and/or malaria cases are permanently present. Each team is allocated several villages at malaria risk to be covered within a week. Pyrethroidal insecticides are used for space spraying activities, mainly emulsion concentrates.

Although, space spraying has been implemented in the Kingdom for more than 30 years and is known to help reduce malaria incidence, its impact on malaria transmission, particularly in endemic foci, has not yet been studied.

Insecticide resistance

Insecticide resistance in malaria vectors has become a major concern for public health authorities and national malaria control programmes in Saudi Arabia, as the prevention of this disease relies heavily on the use of pesticides for the control of its mosquito vector populations.

Resistance to DDT was detected in *An. stephensi* in the Eastern Province in 1955. Deildrin resistance was detected in same vector in the same locations in 1957. According to Reffly, in 1953, the fifth year of a malaria control programme with DDT in eastern Saudi Arabia, the resting of An. stephensi on recently sprayed surfaces suggested the development of resistance to DDT in this species; this suspicion was confirmed by tests carried out from 1955 to 1958. DDT was replaced by dieldrin in 1955 and malaria rates, which had been rising, were again reduced. No resistance to dieldrin has been found in local *An. stephensi* strains and no *An. stephensi* have been collected from treated villages since the widespread use of dieldrin. While An. pulcherrimus, *An. coustani* var. *tenebrosus*, *An. fluviatilis* and An. sergenti were susceptible to DDT, the first two showed resistance to dieldrin. *An. pulcherrimus* was rarely collected before and during the use of DDT but has become increasingly frequent since the introduction of dieldrin. Deildrin resistance was detected in *An. stephensi* at the same locations in 1957.

By 1970, resistance to both DDT and dieldrin had appeared in regions in the attack phase of elimination (central and northern regions). In 1971, the use of DDT was stopped in the northern regions. DDT was last used in Aseer Region in 1979 and in Qunfudah Region in 1984. In 1986, 86% mortality was reported among adult An. arabiensis to DDT in Khoba, Jazan Region, and the use of DDT was stopped in 1987. From 1987 fenitrithion was used in both Aseer and Jazan regions.

In 1990, malathion was used for two seasons in Jazan, between 1992 and 1994, primiphos methyl was used for IRS in Aseer and Jazan and then replaced by lambd cyhlothrin between 1995 and 2001. From

2002 to 2011, deltamethrin was used for IRS in Jazan, and since then lambdcyhlothrin and deltamethrin have been used. In Aseer, only deltametrhin has been used. In 2012, 100% mortality from deltamethrin was recorded during bioassays among reared adult *An. arabiensis* populations.

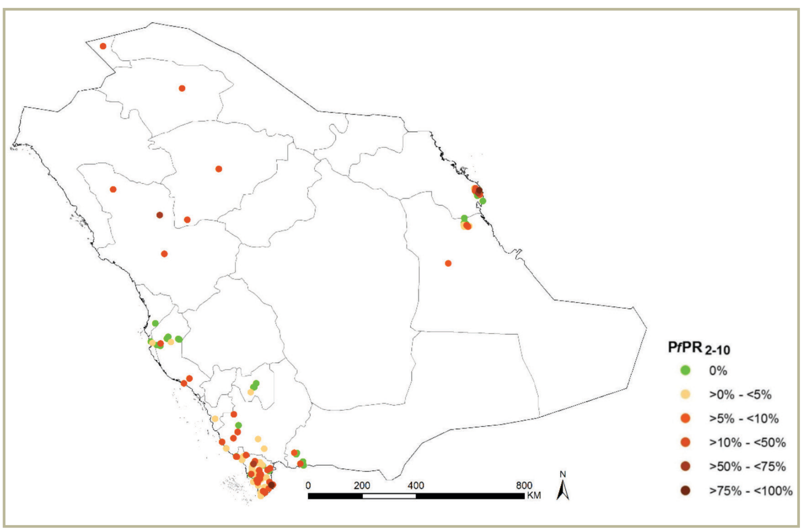
In 1971, temephos (Abate) replaced Paris green as the mainstay of chemical larval control. In 1987, 100% mortality was reported among exposed *An. arabiensis* larvae to temephos (Abate) in the Jazan Region. Resistance to temphos among vector larvae for Rift Valley fever, *Culex tritaeniorhynuchus*, was detected. In 2004, temephos was stopped and replaced by biological control using *Bacillus thuringiensis israelensis*, insect growth regulators diflubenzuron (25%) and pyriproxyfen (0.5%), and, to a lesser extent, chemical control using pyridafenthion. In 2006, resistance to temephos by *An. multicolor* and *An. d'thali* larvae was confirmed by the vector control department of Aseer Region. However, in 2012, An. arabiensis and An. sergenti larvae from Tihamat Qahtan (Aseer) were tested and showed 100% susceptibility to temephos.

Parasites

The presence across the country of established human red cell polymorphisms, protective against malaria, such as haemoglobin S and glucose-6-phosphate dehydrogenase deficiency, suggests a long-term selective pressure because of a significant malaria burden.

Data have been collected from published and unpublished sources on parasite prevalence in the Kingdom between 1948 and 1985 from community-based cross-sectional surveys. Overall, the intensity *of Plasmodium falciparum* transmission was at hypoendemic levels where these survey data were documented (Fig. 5; Table 3). P. falciparum was the predominant parasite recorded during cross-sectional surveys in all regions except those in the eastern part of the country where *P. vivax* was common. *P. malariae* has also been recorded in most regions.

Fig. 5: Location of 248 age-corrected1 Plasmodium falciparum infection prevalence surveys undertaken between 1947 and 1985 (showing highest values at any location on top). PfPR2-10 = Plasmodium falciparum parasite rate



[5]Smith DL, Guerra CA, Snow RW, Hay SI (2007). Standardizing estimates of the Plasmodium falciparum parasite rate. Malar J. 2007 Sep 131 :6;25 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2072953/)

Table 3: Results of cross-sectional parasite prevalence surveys where parasite species were documented: 1947- 1985

Region	Number of surveys (dates)	Total examined (% P. species falciparum)	Percentage of all infections where species was recorded: P. falciparum, P. vivax, P. malariae
South-western			
Jazan	123 (1977-1984)	668/10 201 (6.5%)	Pf (91%), Pv (0%), Pm (9%)
Aseer/Bisha	21 (1977-1984)	87/965 (9.0%)	Pf (95%), Pv (2%), Pm (3%)
Qunfudah	2 (1984)	1/136 (0.7%)	Pf (100%), Pv (0%), Pm (0%)
Najran (southern part)	7 (1954-1977)	13/142 (9.2%)	Pf (100%), Pv (0%), Pm (0%)
Makkah/Jeddah	24 (1952-1985)	187/5738 (3.3%)	Pf (89%), Pv (11%), Pm (0%)
Western			
Madinah	5 (1951-1977)	62/324 (19.1%)	Pf (28%), Pv (0%), Pm (71%)
North central			
Alqurayat	1 (1957)	6/100 (6%)	NA
Al Jouf	1 (1958)	12/100 (12%)	NA
Hail	7 (1976 - 1984)	32/263 (12.2%)	Pf (50%), Pv (50%), Pm (0%)
Eastern			
Eastern region	35 (1947 - 1977)	274/7114 (3.9%)	Pf (60%), Pv (25%), Pm (14%)
Alhassa	21 (1947-1977)	45/4245 (1.1%)	Pf (36%), Pv (32%), Pm (32%)

Because there were few data, they are not representative of any time, nor were they always documented before the scale up of interventions. Nevertheless, they give an idea of the approximate pre-1985 ranges of endemicity nationwide, but cannot be used to define relative pre-intervention receptivity between regions.NA = not available.

Antimalarial drug use and parasite resistance

Chloroquine was used as treatment in Saudi Arabia after the Second World War. As well as treatment, during the final phases of elimination in the Eastern Province in the 1960s, chloroquine was used as part of mass drug administration and was repeated in the northern regions in the 1970s. In 1985, a single dose of primaquine was introduced as gametocidal treatment for *P. falciparum* and as a radical cure of P. vivax following glucose-6-phosphate dehydrogenase deficiency testing; however, it was not widely used.

In 1988, the first cases of chloroquine resistance were documented in Jazan. By 1992, increasing chloroquine treatment failures were reported in Aseer and Jazan regions and about 20% of in vitro test results showed resistant isolates. By 1998, chloroquine resistance in vivo was widely established. In 2005, the first reports of resistant mutations to sulfadoxine-pyrimethamine were documented in Jazan Region, and by 2008 double mutations associated with dihydrofolate reductase in *P. falciparum* infections, which conferred resistance to sulfadoxine-pyrimethamine, were found in over 70% of infections in Jazan.

In 2007, chloroquine and sulfadoxine-pyrimethamine monotherapy was replaced in the national treatment guidelines with artesunate and sulfadoxine-pyrimethamine for first line treatment of P. falciparum malaria and artemether-lumefanthrine for treatment failures, while chloroquine plus 14-day treatment using primaquine was retained for the treatment of *P. vivax* malaria. For severe malaria, the first line of treatment is intravenous/intramuscular artesunate, the second is intramuscular artemether and the third is intravenous quinine. The recommended prophylaxis for travellers is mefloquine, while malarone is recommended for military personnel.

Malaria epidemics

Epidemics have been a characteristic feature of malaria in the Kingdom since before the first concerted attempts at elimination. These include two possible cycles, where information has been documented, in the 1950s and the 1990s. A malaria epidemic in Jeddah recorded 3717 cases in 10 weeks between December 1950 and February 1951. In 1952, a major epidemic was reported in Makkah and Madinah regions during the Hajj. In 1958, another major epidemic was reported in the mountainous valleys about 250 km north of Jeddah and Makkah.

In 1992, an outbreak of locally acquired *P. vivax* infection in Al Hassa, which had been declared malaria-free in the 1970s, was documented and there followed repeat epidemics in 1994 and 1995 before it was fully contained. During the same period, other epidemics were reported in south-western regions. In 1996, epidemics occurred in the south-west including a notable outbreak in Al Baha, Jazan Region that led to over 400 cases of *P. falciparum* malaria within a few months. As with many other countries, the El Nino rains in 1998 led to epidemics with over 31 000 cases reported in the south-west, with 65% of these from Jazan Region.

Malaria epidemiological stratification for elimination (2004)

The details and peculiarities of the epidemiology of malaria in various parts of the Kingdom, as described above were the basis of the development of the technical strategy for malaria elimination in 2004. The aim of the malaria programme in the northern, eastern and western regions was to maintain their status as malaria-free areas. In the southern regions, the aim was first to reduce malaria incidence to the lowest possible level and second to work towards elimination of malaria in the residual malaria foci, which would result in elimination of malaria from the whole country. A concept of malariogenic stratification was developed based on the distribution of malaria foci within well-defined physiogeographical zones—coastal, plains, hills, mountains valleys. Epidemiological intelligence was used based on entomological observations and the seasonal pattern of malaria incidence in each defined malariogenic zone. The aim was to provide a framework for cost-effective control measures, and operational information on the timing and frequency of their application.

The Kingdom was divided into malaria-free areas and areas remaining at risk of local malaria transmission.

Malaria-free areas

These covered about 80% of the total territory of the Kingdom and encompassed interrupted malaria transmission over vast spaces of the northern, central, eastern and western regions. The main malaria vector in these areas is *An. sergenti* and all detected cases, which include both P. falciparum and *P. vivax* malaria, are imported from various malaria endemic countries, particularly from Sudan, Pakistan, Bangladesh and India.

Areas at risk of malaria

These included the south-western and southern regions of the Kingdom and these were further stratified into the following malaria ecotypes.

- Coastal areas: in the past, these areas were subject to periodic malaria epidemics, normally during severe floods. Rainfall is erratic and seldom reaches over 100 mm per year. Seasonal transmission is mainly by *An. arabiensis* with a single peak during the winter lasting no longer than 3 months.
- Low land plains/plateaus: in the past, malaria probably reached a mesoendemic peak in this area with cyclical epidemic outbreaks. This area is also the most densely populated and has important agricultural activity supported by traditional flood irrigation and wells; these provide, in addition to stream pools in wadis, the main breeding sites for *An. arabiensis*, with *An. sergentii* playing a secondary role in some areas. Rainfall is variable between 100 and 300

mm per year and malaria transmission is characterized by well-defined seasonality which varies in length between 6 and 9 months with transmission stopping during the summer months. Importation of malaria occurs from Yemen on quite a large scale.

- Foothills/mountains below 2000 m: these were the most significant malaria endemic areas with An. arabiensis maintaining perennial transmission. Rainfall is considerably higher and more regular than elsewhere and between 400 and 800 mm per year. The terrain is very irregular, communication was not always easy and the local population was mobile, including migrants from Yemen who stay for a short period time on their way to find employment elsewhere. Malaria transmission had previously not responded well to the control measures applied.
- Border malaria: this malaria ecotype is found mostly along the Yemeni border in Jazan and Aseer regions, where, until recently, malaria transmission was almost uncontrolled in Yemen. This ecotype, irrespective of the geographic terrain (whether on the foothills/mountains or the plains), had had the highest malaria incidence since the beginning of the malaria control programme. Transmitted by An. arabiensis, malaria incidence varied according to the flow of immigrants.
- These malariogenic strata were used in 2004 to develop a series of tailored interventions best suited to the ecology and characteristics of each stratum (Table 4).

Table 4: Implementation of malaria-related activities in the Kingdom from 2004

Activity	Malaria free areas	Coastal areas	Plains/plateaus	Hills/ mountains	Border areas
Case detection/treatment	+	+	+	+	+
Foci investigation/classification/ inventory	–	+	+	+	+
Chemical/biological larviciding	If indicated only	All year around	All year around	Seasonal	Seasonal
Larvivorous fish	+	+	+	+	+
Indoor residual spraying	–	1 round	2 rounds	3 rounds	rounds 2–3
Insecticide-treated nets	–	(+)(–)	+	+	+
Ultra-low-volume spraying/fogging	(+)(–)	+	+	-	(–)(+)
Entomological monitoring	+	+	+	+	+
Population movement monitoring	+	+	+	+	+
GIS (mapping)	–	+	+	+	+
Reports/returns	+	+	+	+	+
Training (various categories of staff and the private sector)	+	+	+	+	+

+ = carried out: – = not carried out: (+)(–) = partially carried out.

GIS = geographical information system.

Changing incidence and range of malaria in the Kingdom

National incidence of locally acquired cases

Malaria was made a notifiable disease in 1957. Passive case detection has formed the basis of malaria reporting since the 1970s. However, from as early as the 1960s, active case detection was used to identify residual foci of infection in the Eastern Province as part of elimination efforts. Between 1971 and 1979 only total cases, whether confirmed through microscopy or not, and combined as imported and locally acquired cases, were reported to WHO. In 1980, efforts were made to distinguish between presumed cases and those parasitologically confirmed. Annual reports of the Malaria Control Service distinguished between parasite species but these summaries were hard to interpret without knowing the species compositions among imported and local cases. In addition, as new malaria reporting centres expanded across the west and south-western regions, increasing numbers of local cases were identified that would have previously been unreported because of poor health service coverage. Furthermore, with an expansion of mass blood surveys and epidemiological special surveys, asymptomatic cases among semi-immune populations began to be reported from Jazan and Aseer regions.

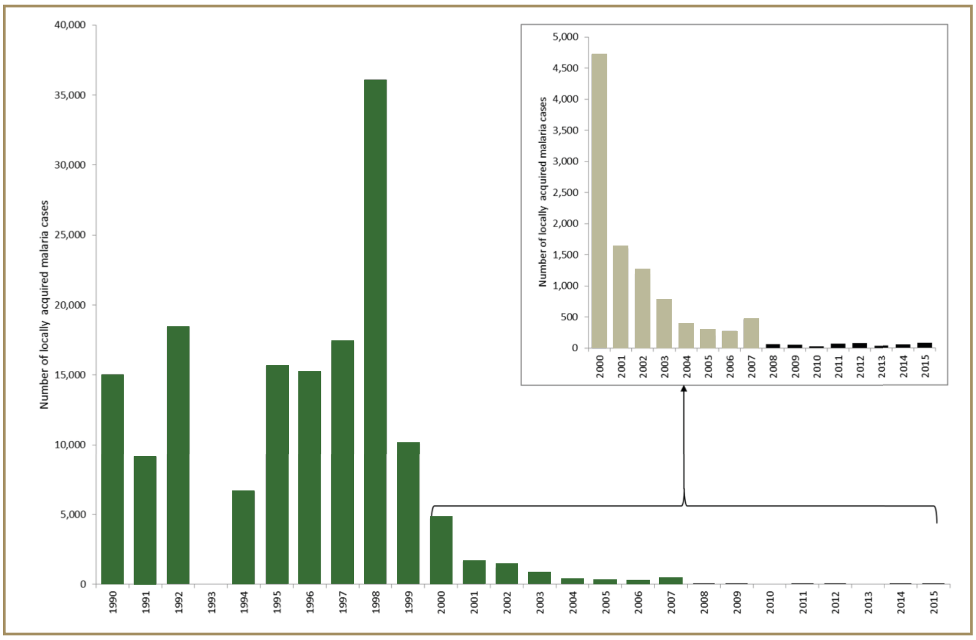
It was not until 1990 that a distinction was made between parasitologically confirmed imported and local infections. Malaria case detection systems have been steadily strengthened since 2000, following the increased national commitment stimulated by the large epidemic in 1998 and the start of the Roll Back Malaria partnership in 1999.

During the 1930s and 1940s, malaria accounted for 35% of all outpatient attendances in Jeddah and clinical attack rates were as high as 160 per 1000 population per year in the Eastern Province. From 1971 to 1981, between 2000 and 6000 total malaria cases (imported and local) were reported each year by the Malaria Control Service; in 1982 this number doubled to about 15 000 cases, and averaged between 10 000 and 18 000 cases each year until 1989.

During the early 1990s, local case incidence averaged 1 per 1000 population. In 1998, a major outbreak of locally acquired malaria occurred, in which the total number of confirmed cases in the country reached 36 139 (Fig. 6); this outbreak occurred mostly in the Qunfudah, Aseer and Jazan regions.

By 2000, local malaria was confined mostly to only two regions, Aseer and Jazan, with some residual foci in Qunfudah. In 2004, 308 local *P. falciparum* cases were identified in Aseer and Jazan regions; through passive and active detection of foci and case investigation, the numbers of local cases declined to 29–83 annually between 2008 and 2015.

Fig. 6: Locally acquired cases reported nationwide, 1990 - 2015. Data for 1993 did not distinguish imported versus local cases



Changing case incidence in Aseer and Jazan regions

Since 2000, the main focus of control and subsequent elimination has been in the two regions of Aseer and Jazan in the south-west of the country. These two historically endemic areas border Yemen and, for the many years of national elimination, were under-developed, rural areas with many inaccessible communities. Following the Jeddah treaty that ratified a commonly agreed border with Yemen, economic growth in this region has accelerated, coinciding with large increases in Government support for malaria control following the 1998 epidemic.

Both regions have seen a steep decline in locally transmitted malaria incidence since 2000, which accelerated after 2004, except for an epidemic in 2007 in Aseer Region associated with exceptional rainfall that also led to an epidemic of Rift Valley fever. The regions had different malaria disease burdens from the start, with Jazan having a considerably higher burden than Aseer. However, both had achieved very low case numbers by 2008. The two regions differ also in their rates of imported malaria. Jazan, with a longer border with Yemen, and more rapid growth in the building and development sectors, had far higher numbers of imported malaria cases than Aseer. However, despite the constant influx of new infections from outside the region, these do not appear to have contributed significantly to local case incidence (Figs 7 and 8).

Fig. 7: Locally acquired (top panel) and imported cases (bottom panel) per month in Jazan Region, January 2000 to December 2015

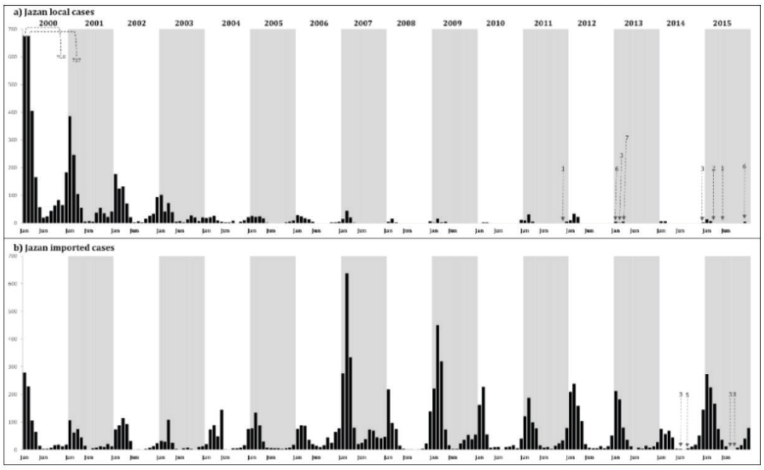
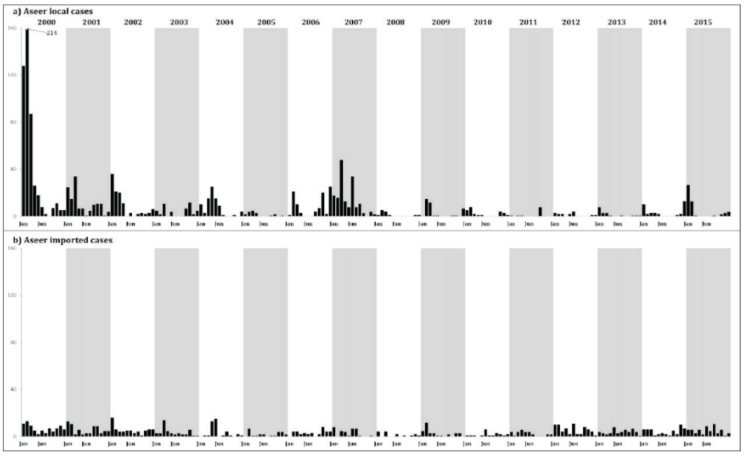


Fig. 8: Locally acquired (top panel) and imported cases (bottom panel) per month in Aseer Region, January 2000 to December 2015



Changing spatial range

From the natural extent of malaria shown in Fig. 9, it is possible to construct from Ministry of Health reports how this systematically changed over decades of planned elimination in different parts of the country (Table 5). In brief, in 1971 the last foci of malaria in the Eastern Province was at Awwamiyah and the region was declared malaria-free in 1972/ 1973. By 1980, malaria elimination had largely been achieved in the western regions, with risks confined to south-western regions of Kingdom (Lith, Qunfudah, south-west Najran, Aseer and Jazan). By 2005, only four local cases were reported in Qunfudah from three active foci of transmission, and local transmission was identified at only two foci at Wadi Al Furra, outside of Madinah, which resulted in six cases. By 2007, foci of local malaria outbreaks in Qunfudah led to rapid responses to eliminate these and the last local case of malaria reported in Qunfudah was in 2009. By 2010, active local malaria transmission was limited to only Aseer and Jazan regions.

Fig. 9: Changing spatial range of active malaria transmission from its natural range to 2015

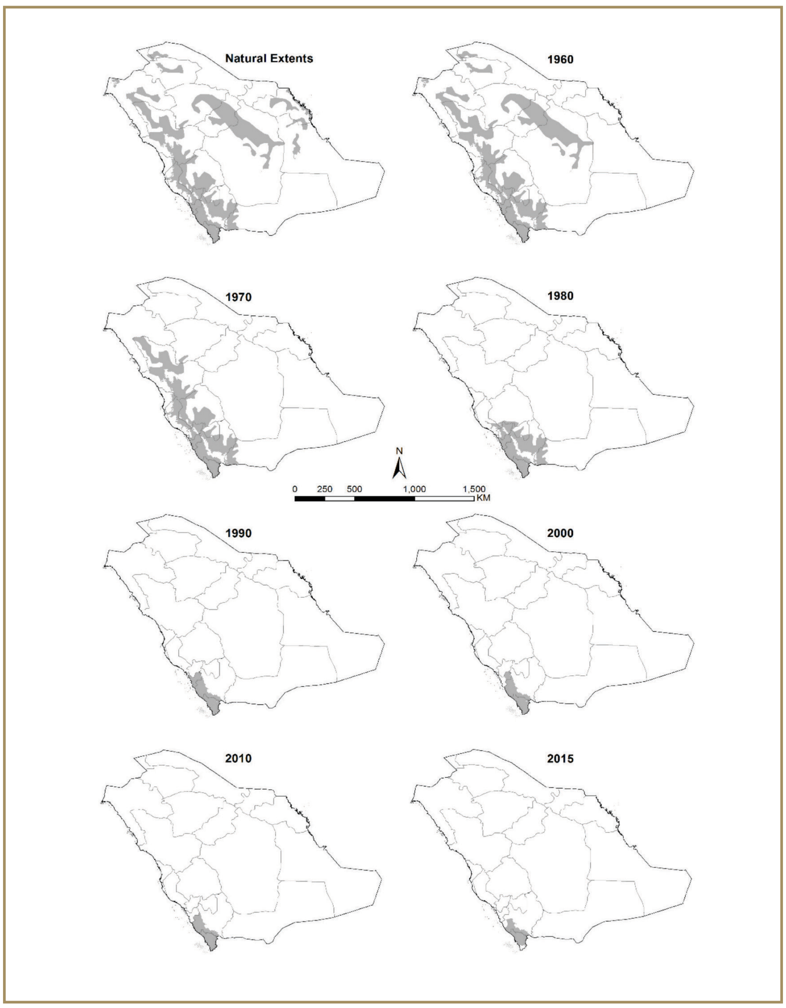


Table 5: Elimination of malaria from the Kingdom

Region	Last locally acquired malaria cases	Number of cases	Location	Parasite type
Eastern Province*	1972	7		Plasmodium vivax
Hayil	1997	1	Al-Haid	P. vivax
Taif	2002	1	Wadi Showqab ((Belharth	P. vivax
Najran	2002	1	Najran city	P. vivax
Al Baha	2003	1	Al Rumaidah ((Qilwah	P. falciparum
Makkah	2007	2	Al Manqah	P. falciparum
Madinah	2007	3	Wadi Alsafra ((Badr	P. vivax
Bisha	2008	2	Bisha	P. falciparum
Qunfudah	2011	1	Sheia Village ((Hulay	P. falciparum

* An isolated mini outbreak has occurred in the Eastern province in 1996 where 16 cases were reported as local.

Surveillance and notification since 2004

Combinations of passive and active case detection have been adopted through networks of primary health care centres and notifications from the private sector. Cases are notified to malaria centre teams within 24 hours by facsimile, WhatsApp or a 977 SMS text messaging service. These are linked to the Ministry of Health's Integrated Disease Notification System and Health Management Information System that feed into a web-based malaria surveillance database system.

Case investigations occur within three days of notification by teams based in malaria reporting centres. Teams investigate the origins of the infection through case and travel histories, screen community members within a radius of 500 m of the index case, which is maintained for a period of five weeks (reactive active case detection). All positive cases are taken to the nearest health facility by mobile teams for treatment according to the malaria drug policy of the Kingdom. In addition, entomological investigations are undertaken within the neighbourhood, followed by vector control measures to ensure 100% coverage by appropriate adult and larval stage targeted control. Details of the case and community investigations are recorded on an investigation form

(Annex 1), which is sent by facsimile or e-mail to the malaria department in the Ministry within 72 hours of notification. This is reviewed by teams of laboratory technologists, clinicians and vector specialists to define whether the case is an imported or locally acquired infection, and a detailed report is produced.

In Jazan, but not Aseer, the areas where locally acquired infections are recorded are classified as foci for mass blood survey investigations the following year. These surveys are used to examine residual transmission and may identify additional cases that are then classified as either imported or locally acquired.

Reporting

1- Immediate reporting

After the confirmation of a positive case in any health centre, government or private hospital, a notification form is sent immediately by facsimile or telephone to the Directorate of Health Affairs and vector-borne diseases unit (malaria department) in the region. They then send an immediate facsimile to or telephone the Malaria Department in the General Department of Disease Control at the Ministry of Health. This process is intended to expedite the decision-making for any measures to tackle the disease.

2- Weekly reporting

The statistical weekly statement using a specially designed form is sent from all health centres, and government and private hospitals to the Health Affairs Directorate in all regions. After that, the directorates send the information by facsimile or email to the Head Office of National Malaria Elimination Programme in the Ministry of Health in Riyadh.

3- Monthly reporting

A specially designed form for monthly reports which includes all recorded cases during the month at health centres, and public and private hospitals, is sent from the Directorates of Health Affairs to the Malaria Department at the General Department of Disease Control at the Ministry of Health.

Imported malaria

Pilgrims

During the earliest phases of malaria elimination in the Kingdom it was recognized that there was a duty to protect pilgrims from malaria in the Makkah and Madinah areas. In the 1950s, pilgrims arrived by land and sea, less so by air. In 1954, there were approximately 56 000 pilgrims during the Hajj. Today, there are about two million.

As early as 1952, vigorous attempts to control *An. sergentii* in this area using DDT had varied success, but *An. sergentii* was largely eliminated by the late 1980s through increased use of larviciding. As control became more successful, the emphasis changed to pilgrims as a potential source of reintroduced transmission, and the adverse effect of this on elimination efforts. In 1985, for example, it was estimated that at least 3% of pilgrims from across the world were asymptomatic carriers of malaria infection.

Of the approximately two million foreign pilgrims that undertake the Hajj today, the highest numbers are from Pakistan, Bangladesh, Indonesia, India and Africa (notably Nigeria) where malaria remains endemic. Because of development in the area, changes in the ecology of the area, and better surveillance including entomological surveillance and control, it is reasonable to assume that pilgrims no longer pose a threat to onward transmission in and around the area of the Hajj. However, pilgrims from endemic areas require case management should they develop clinical symptoms while on their pilgrimage from infections acquired at home. In 2000, at Ajyad Hospital in Makkah, which provides free medical services to pilgrims during the Hajj, 25 cases of malaria were treated between February and March, including six from Sudan, five from Pakistan, five from Yemen, three from India, one each from Kenya, Malawi, Nigeria and Indonesia, and two from Saudi Arabia. Between 2008 and 2011, there were 388 imported cases recorded in Makkah Region[2], of which 108 (34%) were from Pakistan, 53 (17%) from Nigeria, 37 (11%) from India, 17 (5%) from Yemen, 12 (3%) from Sudan, and the remaining cases largely from Africa (Mauritania, Mali, Ethiopia, Niger, Guinea, Chad, Comoros, Somalia, Ivory Coast, Benin, Senegal, Tanzania and Burkina Faso), with fewer cases from Afghanistan and Bangladesh where active transmission still occurs. Most infections (64%) were P. falciparum malaria with 32% showing evidence of *P. vivax.*

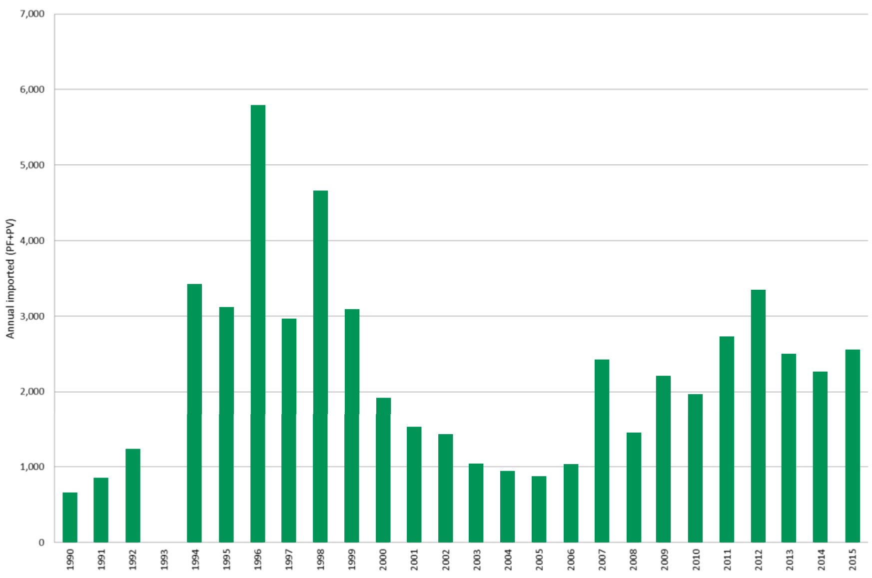
Economic migrants

Recruitment of foreign nationals to work in the service and construction industries began in the 1940s in the Eastern Province during the expansion of the oil industry, but escalated during the 1970s. In 2013, there were approximately 9.7 million non-Saudi residents in the Kingdom, providing most of the labour force in construction (26%), other service industries (23%), domestic service (17%), and nursing, teaching and academic positions (7%)3. Most of the economic migrant work force (accounting for over 7 million people) are from India, Pakistan, Bangladesh, Egypt, Philippines, Sudan and Yemen4. As such, many of the immigrant work force come from countries where malaria has not been eliminated.

The number of imported malaria cases rose during the mid to late 1990s, which coincided with a growing global malaria epidemic. Interestingly, the incidence of imported malaria cases decreased from 1999 to 2006, which might reflect a declining malaria risk in countries outside of the Kingdom.

However, the number of imported cases rose from 2007, although the numbers for imported malaria are hard to interpret without accurate annualized denominators. Figure 10 shows the number of imported cases recorded nationwide between 1990 and 2015 (data for 1993 did not distinguish between imported and locally acquired cases).

Fig. 10: Number of imported cases recorded nationwide between 1990 and 2015 (data for 1993 did not distinguish between imported and locally acquired)



6Memish ZA, Alzahrani M, Alhakeem RF, Bamgboye EA, Smadi HN (2014). Toward malaria eradication in Saudi Arabia: evidence from 4-year surveillance in Makkah. Ann Saudi Med, 34: 153-158 (http://www.annsaudimed.net/index.php/vol34/vol34iss2/683.html)

7 http://gulfmigration.eu/media/pubs/exno/GLMM_EN_2014_01.pdf

8 http://esa.un.org/miggmgprofiles/indicators/files/SaudiArabia.pdf

Cross-border risks

Yemen has been a constant source of imported infections into the Kingdom. Over the three years 1981– 1983 in the Eastern Province, 14% of the 1287 imported cases were from Yemen, the third largest source of imported cases after Pakistan and India; these two countries account for 56% of all imported infections.

In 2007, there was a large cross-border migration of people fleeing conflict in Yemen, and, of the 2397 imported cases recorded in that year, 1718 (72%) were from Yemen. Between 2006 and 2009, of the 774 cases of malaria recorded in the Samthah malaria reporting area in Jazan Region, which shares a border with Yemen, 450 (58%) cases were among Yemenis.

In 2007, an agreement was signed to implement coordinated efforts aimed at regularizing bi-annual spraying, shared mapping exercises, increased screening at border posts, and mass blood surveys undertaken either side of the border, and increasing the joint planning meetings that began in 2001.

Families who live close to the border with Yemen have close relatives living on the opposite side and there remains frequent movement, in both directions, across this border. It is estimated that about 3000 illegal migrants cross this border every day, and around 20000 Saudis spend weekends in Yemen. The area has become insecure since the beginning of the civil war in Yemen in 2015. However, population movement and the numbers crossing the border are not at the level as the 2007 conflict.

Conclusions and lessons learnt

Summary of progress toward malaria elimination

The Kingdom was able to shrink the malaria map through a concerted elimination strategy from the 1960s (Fig. 9). In the 1970s, the global strategy shifted towards a more integrated response to malaria control based on primary health care. This led to a change in emphasis in the Kingdom, away from a defined elimination strategy to one based on disease control.

By the 1980s, active malaria transmission was confined to the south-western regions of the Kingdom. This area had been largely neglected in the economic and social development initiatives enjoyed by the rest of the Kingdom since the 1970s. These regions also have an ecozone similar to the African continent and as such they are home to some of the most efficient malaria vectors, such as *An. arabiensis.*

A rapid increase in *An. arabiensis* populations following exceptional rainfall, escalating drug resistance and a reduction in funds for specific malaria control activities all contributed to a series of epidemics in the late 1990s, the worst being during the 1997 / 1998 El Nino rains (Fig. 6). This epidemic served to redefine the need for malaria control investment globally through the Roll Back Malaria partnership, and led to a renewed commitment by the Government of the Saudi Arabia to invest, expand and reorientate its ambitions for the south-west of the country.

By 2004, with the assistance of the WHO Regional Office for the Eastern Mediterranean, a strategic plan was formulated for malaria elimination, based upon a staged effort to reduce the malaria incidence to the lowest possible levels and proceed to elimination, while maintaining the malaria-free status of areas in the north, east and west of the country. It was hoped that by 2015 malaria would be eliminated from the entire country. This received the very highest political support in the Kingdom. This was part of a broader ambition for a malaria-free Arabian Peninsula articulated in 2007 by the WHO Regional Office for the Eastern Mediterranean and regional partners. From 2008 to 2015, there was exceptional progress in reducing locally acquired cases with fewer than 100 cases recorded in that time in the south-west of the country.

Evolution of the malaria programme

- **1948** The ARAMCO oil fields areas of Qatif and Alhassa began annual IRS with DDT which continued through to the late 1950s.
- **1950–51** Malaria reconnaissance visit by WHO consultant Dr MA Farid to advise on stratification of malaria ecology.
- **1952** Malaria control programme initiated in the Eastern Province in collaboration with WHO, with Qatif selected as a demonstration area.
- **1955** Malaria centre established in Jeddah.
- **1956** Malaria Control Service established, designed to target malaria-endemic areas throughout the country with a focus on protecting pilgrims visiting Makkah and Madinah in the west.
- **1963** Nationwide malaria plan launched in collaboration with WHO, with national headquarters in Riyadh; the plan was geographically staggered with stratified phases for preparation, attack, consolidation and maintenance.
- **1966** Malaria demonstration area established at Qatif.
- **1974** Malaria eradication programme launched with support from WHO. Malaria station opened at Abha, Aseer Region.
- **1977** National programme for elimination changed to one aimed at control that was integrated into plans for expanded primary health care.
- **1978** Launch of second five-year plan of action for malaria control through to 1982;

the focus was on priorities in endemic areas and areas where lack of socioeconomic development created vulnerability to malaria.

- **1980** Malaria station opened at Qunfudah Region.
- **1981** National malaria training centre established in Jazan, supporting eight sub-regional reconnaissance centres.
- **1985** Malaria control fully integrated into the expanded primary health care system with a focus mainly on south-west regions with IRS, foci-targeted larviciding with temephos and occasional ultra-low-volume space spraying using Reslin.
- **2004** National malaria elimination strategy launched with the goal of achieving elimination by 2015, and specifically to prevent reintroduction of local transmission in areas where it had been interrupted (eastern, northern and central regions), to reduce the number of indigenous cases by 50% between 2005 and 2007 and then by 100%, and thereafter to mount a maintenance phase to ensure the country remains malaria-free.

Lessons learnt for other countries aiming for malaria elimination

There are some important lessons to be learnt from the Saudi Arabian experience.

1- Vectors:

Successful shrinking of the spatial range and reduction in local case incidence in the south-west has been achieved with *An. arabiensis,* which in this area feeds indiscriminately on humans and livestock, indoors and outdoors, and rests outdoors. For these reasons, IRS and long lasting insecticidal nets would have not been successful alone had there not also been an effort to target larvae. Larval control has contributed considerably to the reduction of malaria in the south-western areas of the Kingdom.

2- Primary health

care versus vertical malaria programmes: It is often said that the global integration of malaria control into the less specialized management of fevers through primary health care marked the end of elimination during the 1970s and 1980s. This may be true when case-management alone becomes a primary care responsibility. What Saudi Arabia has demonstrated, however, is that the primary health care system can provide a valuable entry point also to disease prevention. The expansion of primary health care centres in Aseer and Jazan since 2004 has coincided with the declining case incidence. These primary care units are the basis of case-detection, which has led to the identification of active foci requiring intervention, and all are linked to malaria reference centres across both regions.

3- Economic development:

It was not until the mid-1980s that paved highways in Aseer and Jazan regions improved the connectivity to other areas of the Kingdom, asphalted road networks improved within these regions connecting villages to major towns, the construction of the Jazan dam provided irrigation for agricultural development, and the electrification of towns and major villages began. Since 2000, economic and social development has increased further, following the reconciliation of the borders with Yemen, and today there is almost universal primary education, including for girls (children are collected from homes to attend school), health service access is largely free, electrification of the most remote rural areas is complete and there is no longer a requirement for water storage in households as most now have piped water. This development has been most pronounced in recent years in Jazan which, as part of Saudi Arabia's Economic Cities Agency 2020 vision[9], aimed to invest US$ 27 billion and create 500 000 new jobs through an industrial park, re-investment in the agricultural sector and creation of the largest sea port on the Red Sea and one of the largest new universities in the Gulf. Compared with 1980, the entire landscape of Jazan has changed, suitability for An. arabiensis breeding has changed, people's ability to reach health services and receive treatment has changed, and levels of primary education of the population have changed. This region is no longer a receptive ecology for malaria as it was 20, or even 10, years ago. The elimination strategy in the Kingdom has been tied to a national framework of socioeconomic development to improve the living standards of local populations, and the rate of growth has matched the rate of decline of malaria. Given the substantial impact of economic development on malaria elimination in Saudi Arabia, there are potential lessons for other regions aiming for elimination, and this approach deserves more detailed analysis.

4- Imported infection versus local transmission:

To highlight the likely effects of combined, aggressive control linked to case and foci detection and economic development in changing the receptive landscape, it is notable that, especially in Jazan, the constant influx of new cases from outside the region has not led to as many locally acquired cases as might have been thought. This suggests that it is harder now than before for F2 generations of infections (indigenous cases) to become established. If this were confirmed, it would have implications for how elimination is defined in the Kingdom. More broadly, there is a need to better define the balance between receptivity and vulnerability, which in some cases may be overstated.

Challenges to a malaria-free Kingdom

Despite the remarkable progress toward a malaria-free Kingdom, there continue to be challenges.

1. Migration: The economy and labour markets in the Kingdom and the presence of pilgrimage sites mean that malaria cases will be imported into the country. For much of the country this poses little threat of onward transmission and the aim will always be to maintain zero deaths among foreign nationals from endemic countries. This requires constant review of the treatment protocols and appropriate medicines given the threat of artemisinin resistance. At the same time, there remains a constant threat of sustained transmission among migrants and visitors across the border with Yemen. This has been less common than one might have expected, which might be a direct result of a changing malaria landscape. Nevertheless, for this region to be free of such risks, there is a continued need for cross-border collaboration. Yemen remains the single largest contributor to the malaria burden on the Arabian Peninsula. Despite ongoing conflicts and civil strife, it has maintained a constant communication with and support from the National Programme in the Kingdom. This example of common ambitions in health that rise above politics must continue if Saudi Arabia is to achieve and maintain malaria elimination and for Yemen, with time, to achieve a similar status.
2. Climate: The south-western region of the country was most affected by climate anomalies in the 1990s. Malaria transmission in this region is acutely seasonal and has been driven by the extent to which unusually high annual rainfall has led to a proliferation of vectors. This has affected other vector-borne diseases, most notably Rift Valley fever. Climate and vector-borne diseases will continue to challenge disease elimination programmes and constant vigilance and preparedness is needed. It seems unlikely that the vectors will be eliminated, but their vectorial capacity could be substantially reduced through more general development as seen in other parts of the world.
3. Sustained investment: Economies are as volatile as climate but sometimes less predictable. The political support enjoyed by the malaria elimination strategy in the Kingdom was matched by considerable financial support to achieve this ambition. However, the price of oil and the regional conflicts have meant that the Saudi Arabian economy could face challenges in meeting its social and health development aims.

Economic, social and malaria agendas are linked and maintaining the business case for investment in all three is critical.

4. Documentation: As malaria elimination in the eastern provinces in the 1960s progressed, very detailed geographic reconnaissance became an integral part of the operations. With the launch of the most recent elimination strategy in 2004, spatial mapping of foci has been the only way to tackle residual transmission in the south-west. Regional malaria reference centres in Aseer and Jazan, and their district-level reporting centres have adopted this foci-orientated approach using case data, case investigations, documentation and mapping. Despite the speed of case investigations, data are not always verified immediately, nor are they available soon enough in a digital format for the national programme to verify information provided at the periphery. For elimination certification to become a reality, this will need to be upgraded in the coming years.
5. Human capacity and institutional memory: There are several common features of successful malaria elimination programmes that have maintained malaria-free states. First, there is a constant turn-over of staff in control and elimination programmes worldwide. This serves to weaken leadership, continuity and institutional memory. New managers take time to become familiar with a new role and they often do not have access to the resources assembled over many years. One purpose of the present study was to formalize the documented history and progress for new staff involved in malaria elimination. The most successful elimination campaigns have had a dedicated staff and leadership for many years. Second, ending malaria and being certified malaria-free does not mean an end to malaria control programmes. Staff involved in the elimination and consolidation phases are required to sustain new activities, based on accumulated experience, to prevent reintroduction and re-establishment of transmission. These staff have skills in vector-borne disease surveillance and control that are transferable to many other potential infectious disease threats and can strengthen a broader programme of disease surveillance and response, for example for dengue fever, Rift Valley fever and MERS-CoV.

Annexes

Annex 1: Surveillance form in English

Ministry of Health
National Malaria Elimination Program

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Ministry of Health

Public Health Agency
General Directorate Control of Infectious Disease

Epidemiological Investigation Form for local or Imported Malaria Cases
((الإتقان في التقصي الوبائي من أساسيات المراحل المتقدمة في برنامج القضاء على الملاريا))

Region: -............ Hospital: -............ Date: / / Week No: ( )

General Information:

Where was the case discovered: Malaria Center ( ) Health Center ( ) Hospital ( ) Surveillance team ( )

Patient Name: .... Age: .... Nationality: ....

Sex: Male ( ) Female ( ) ID No :-............ Occupation............

Workplace: .... Name of sponsor and work phone numbers: ....

Full Address: (street/ District/ village/center/ Governorate)............

....

Phone No: .... Mobile: .... Other Phone No: .... Home No : ( )

History of current disease:

Source of information :- Patient ( ) Patient's relatives ( ) Patient's file ( )

Date of start of symptoms: / / Health Institution Revision Date: / / Date of start of treatment : / /

Description of symptoms : ....

Treatment prescribed : ....

Dose and Duration of Treatment :............

Has Patient been admitted to hospital: No ( ) Yes ( ) File No ( )

Physician Name :............ Signature:............ Date : / /

How the case was discovered : microscopic examination ( ) RTD examination ( ) clinically examination ( )

Result of microscopic examination :- Falciparum ( ) Vivax ( ) Malariae ( ) Ovale ( )

Other: .... Parasitaemia (%) Parasite Stage :-............

Has the microscopic examination results been double checked: Yes ( ) No ( )
Date of Blood Sample Examination: / /

Final result after confirmative diagnosis by the reference laboratory :-............

Examiner's name:............ Signature:............ Mobile:-............ Date : / /

1

Previous history of malaria:

Has the patient been diagnosed with malaria in the last 3 years: Yes ( ) when? .... No ( )

Where was the patient treated : House ( ) Hospital ( ) Name of the drug prescribed:............

Has patient completed the prescribed dose: Yes ( ) Dose? .... No ( )

Has anybody from patient's family diagnosed with malaria :Yes ( ) When?............ No ( )

Has anybody from patient's neighbors diagnosed with malaria :Yes ( ) When?............ No ( )

Information about influencing factors

Has the patient spent a night or part of night in any area outside his village more than10 days before symptoms appeared (during the last 12 months) Yes ( ) Where?............ No ( )

Where were those places that patient visited, whether inside or outside the Kingdom? And when?
....

Mention any of climatic or environmental factors that could be related such as rain fall at the infection site or around during the months prior to the discovery of the case or A mass exodus or migration of some workers from other countries or resettlement:
....
....

Has any blood been transferred to patient during the past three months? Yes ( ) When? ..... No ( )
Who was the Donor? Where does he/she live? (Medical history)?
....
....

Has the patient took any preventive treatment from malaria before the current infection? No ( ) Yes ( )
Describe the treatment , Doses, and length of use? ....
....
....

Number of children under five years ( ) Number of pregnant women ( )

Entomological investigation

Humidity: (%) Temperature: ( ) Coordinates GPS: (N) (E) Wind speed: ( )

Rainfall : No ( ) Yes ( )

Number of people in patient's house : ( ) Population in Village/District : ( )

1/ Entomological investigations activity:

Mosquito larval survey:

- Inspection of breeding sites : Number of units inspected ( ) number of positive units to anopheles ( ) Anopheles species :Malaria vector number ( ) Non malaria vector number ( )
- Place of larval collection: Inside house ( ) Around house ( ) diameter round house ( )
- Type of breeding sites: Wadi ( ) Drinking tanks ( ) Cement pool ( ) Rain ponds( ) Others ( )

2

Mosquito Adult survey:

Number of rooms inspected ( ) No. of positive rooms for anopheles ( ).

Anopheles species: Number of malaria vectors ( ) Number of non-malaria vectors ( )

Collection of light traps:

Number of light traps ( ) No. positive to anopheles ( ) Anopheles species : Number of malaria vectors ( ) Number of non-malaria vectors ( )

2/ Activities of vector control:

- Date of immediate intervention: / /
- Space spraying: Yes ( ) Date of action: / / No ( )
- Larviciding: Yes ( ) date of action / / No ( )
- Indoor Residual Spray [IRS]: Yes ( ) date of action / / No ( )
- Name of insecticides used: ……………………………………………………………………………
- Date of case notification / / Notification method: telephone ( ) fax ( ) by person ( )

Investigator's name ……………………………………………… Date of investigation / /

Signature: …………………………Mobile number ………………………………….

Parasitological Survey for Contacts

Microscopic examination of blood for largest available individuals of those who live in the village or in the infection site..(repeat the examination for four weeks following the infection considering the parasite incubation period)

Age group	less than one year	1- Less than 5 years	5 - Less than 10 years	10 - Less than 15 years	15 and over	Total
No. of subjects						
No. of positive						
No. subjects of *P. falciparum*						
No. subjects of *P. vivax*						
No. subjects of *P.malariae*						
No. subjects of *P.ovali*						
Others						

Laboratory technician's name: ……………………… Date of sampling: / / Mobile number: ………………….

- Note : If there are positive cases among patient's contacts, then new forms must be completed and links between them and original case should be established.

Remarks (if any):…………………………………………………………………………………………

3

Epidemiological classification of cases :

local

Local from the same region (Indigenous)

Introduced (Determine the case's original area of the infection)

……………………………………………………………………………………………………

Imported from outside the kingdom: (Determine the source of the case)

……………………………………………………………………………………………………

Induced: (e.g. infection during blood transfusion) recall the details of the source of infection

……………………………………………………………………………………………………

Recrudescence as a result of not taking the full treatment (in the case of falciparum malaria)

Describe the previous epidemiological category for the case (local or imported) serial No. if previously recorded: ……………………………………………………………………………

……………………

Recrudescence: As a result of possible parasite resistance to malaria drugs used for the treatment. Describe the previous epidemiological category for the case (local or imported) serial No. if previously recorded: ……………………………………………………

……………………………………………………………………………………………………

Relapse: describe the previous epidemiological category for the case (local or imported) …………

……………………………………………………………………………………………………

Classification of foci:

Previously recorded cases of the focus : 1year ( ) 2 years ( ) 3 years ( ) Cleared up ( )

Is the village / center considered malaria endemic areas during the last five years?
Yes ( ) when ? ……………………………………………… No ( )

Name of investigator	Occupation	Signature	Date

Notes:

- **A copy of this form by fax to head office of the National Malaria Elimination Program in the Ministry of Health as soon the investigation finishes (only the local cases) Fax: 0112917743 or 0114738275**
- **For imported cases from inside, the region source of infection should be notified immediately by fax and phone within 24 hours at latest and a copy of the investigation form should also be sent to the NMEP for the follow up and co-ordination. Also the region source of infection should send a copy of the complete**

4

investigation form to NMEP. (The imported cases from inside are reported by the region source of infection).

Vector control director:

Date :

Signature:

Responsible doctor:

Date :

Signature:

Annex 2: The people involved in the National Malaria Elimination Programme

1-Makkah Almukarammah

Dr Mustafa Jameel Baljoon
Dr Abdulhafiz Maroof Turkistani
Dr Turki Ghazi Bafaraj
Dr Abdelmoneim Rahmtallah Abdallah
Mr Sulaiman Khayrat Alansari
Mr Abotaleb Yahya Mahbob Naseeb

2- Al Baha

Dr Meshal Misfir Elsyali
Dr Mohammed Saad El Hurati
Dr Abdulaziz Abdurahman Alkanzi
Dr Adil Mohammed Ali Ibrahim
Mohammed Safar Lafi Algamdi
Mr Saed Abdullah Safar
Mr Maeed Ali Alzahrani

3- Aseer

Dr Abdullah Alwadaie
Dr Mohammad Ali Alhadban
Dr Mohammad Mohya
Dr Abdullah Mohammad Alshahrani
Dr Mohammad Algamdi
Dr Ali Mohammad Alshahrani
Mr Mohammad Soman
Mr Mohammad Salim
Mr Saad Alshahrani
Mr Yahya Theban
Mr Saeed Alwagdi
Mr Mohammad Moshied
Dr Abdullah Hemdatallah

4- Taif

Dr Mohammed Deif'alla Alzaidi
Dr Gaafar Hassan Ahmed
Mr Sami Misfer Aburkbah
Obaidallah Muneer Mater Alswat
Mr Salem AAli Ali Algurashi
Mr Ali Saad Salih Algarni
Mr Abdelmohsen Khedr Alharthi

5-Madinah

Dr Ayman Mustafaa Ynbeawy
Mr Saleem Fehaiman Althubyani
Dr Husam Sulayman Almawis
Dr Hasan Althobyane
Dr Khalid Dayfullah Alharbi
Dr Abdullah Musleh Aljohani
Mr Mousa Saad Aloufi

6- Qunfudah

Mr Shami Hussein Aluzaighi
Mr Adil Mohammed Algamdi
Dr Mustafa Bashir Mustafa
Mr Abdu Mohammed Hamza Aluzaighi
Mr Hassan Ahmad Alfageeh
Mr Abdelhadi Abdella Algharni

7-Tabuk

Mr Salman Suliman Abuhmoud
Mr Abdullah Salem Alatwi
Mr Fahad Awad Saiah Alharbi
Mr Abdulaziz Amear Skat Alanazi

8- Eastern Province

Dr Saleh Ali Alsalouk
Dr Kholood Mohammed Mugharbel
Dr Nawaf Abdulla Aooataibi
Dr Khalid Abdulrahman Alturki
Mr Mohammed Ali Algahtani
Mr Riyadh Ali Alherfi
Mr Abdulla Aqail Almotari

9- Alhassa

Mr Salah Mohammed Balghonaim
Mr Omar Fahad Buhalim
Mr Abdullatif Ibrahim Alragih
Mr Saleh Ibrahim Alfehaid
Mr Ahmed Yassin Almuhanna
Mr Emad Abdullah Mohammad Albather
Mr Radi Ali Alhababi

Mr Ali Nasser alhabarh

Mr Faisal Ibrahim Alragih

Mr Raed Eissa Busaleh

10 -Hayil

Mr Hesham Ibrahim Altamimi

Mr Abdullah Saud Alenazi

Mr Abdulrahman Abdullah Alsaleh

Mr Marzoq Salem Alshammary

Mr Salem Abdulaziz Alnazah

Mr Mousa Mnawar Alhayti

Mr Sami Fayz Aldammadi

11- Bisha

Mr Obaid Mohammad Mesrea Alshahrani

Mr Moshabab Abdullah Mohammad Alasmari

Mr Ali Mohammed Hussein Aseeri

Mr Muidh Fayz Muidh Almadshosh

12- Najran

Mr Hussain Fahaid Alsagoor

Mr Abdullah Ali Almehthel

Mr Mahdi Mohamed Alsagoor

Mr Saleh Manae Almutared

Mr Naji Mofarieh Alghoraish

Mr Ali Seran Alslim

Mr Ibrahim Salim Balharith

Mr Shanar Hadi Almarrie

13- Riyadh

Mr NAseer Faleh Aldosari

Mr Mamdooh Faleh Althaqeel

Mr Musaed Abdullah Alsuliman

Mr Osama Waheed Ibrahim

14- Jazan

Dr Mohsin Siddig Tubaigi

Dr Ahmed Ahmed Sahly

Dr Mohamed Khalid Alabd Alaali

Dr Abdulraheem Ageel

Mr Isa Ahmed Dahlan

Mr Abdo Ahmed Dahlan

Mr Mohamed Salim Alatass

Dr Mohamed Alhazmi

Mr Ahmed Mohamed Alsaadi

Dr Taj Eldin Bashir Aljamri

Dr Ibrahim Ahmed Faragalla

Dr Yousif Dafalla Abdalla

Dr Abubakr Hassan Abd Elgadir

Dr Elnuman Hamadelneel Alhadi

Dr Adil Hayder

Dr Abdalhameed Aldrdeeri

Mr Waheed Siddig

Mr Mohamed Mansour Zamim

Mr Atia Faragalla Abdalfattah

Annex 3: Suggested reading

Abdoon AMMO, Alshahrani AM (2003). Prevalence and distribution of Anopheline mosquitoes in malaria endemic areas of Aseer region, Saudi Arabia. Eastern Mediterranean Health Journal, 9: 240 – 247.

Al Farsi HM, Al Hashami ZS, Bin Dajem SM, Al Sheikh AA, Al Qahtani A, Beja-Pereira A, Idris MA, Babiker HA (2012). Source of drug resistant Plasmodium falciparum in a potential malaria elimination site in Saudi Arabia. Infection, Genetics and Evolution, 12: 1253–1259.

Al Harthi SA (2007). Detection of drug resistance markers for chloroquine and pyrimethamine-sulfadoxine in Jazan area, Saudi Arabia using PCR and restriction digestion. Journal of Egyptian Society of Parasitology, 37: 17–30.

Al Seghayer SM (1996). Malaria control in the Kingdom of Saudi Arabia. Saudi Epidemiological Bulletin, 3: 4.

Alshahrani AM, Abdelgader TM, Saeed I, Al-Akhshami A, Al-Ghamdi M, Al-Zahrani M, elHassan I, Kyalo D, Snow RW (2016). The changing malaria landscape in Aseer region, Kingdom of Saudi Arabia: 2000 - 2015. Malaria Journal, 15: 538

Al Zahrani MH (2010). Malaria Situation in Kingdom of Saudi Arabia. Presentation given at EMRO malaria regional meeting, Marrakech, Kingdom of Morocco, 22 – 24 September 2010.

Bakr RFA, Nassar MI, El-Barky NM, Kotb TF, Badrawy H, Abdeldayem MS (2014). Prevalence of mosquitoes in Jazan Province, Saudi Arabia. Egyptian Academic Journal of Biological Sciences, 7: 15 – 27.

Buxton PA (1944). Rough notes: Anopheles mosquitoes and malaria in Arabia. Transactions of the Royal Society of Tropical Medicine & Hygiene, 38: 205 – 214.

Coleman M, Al-Zahrani MH, Coleman M, Hemingway J, Omar A, Stanton MC, Thomsen EK, Alsheikh AA, Alhakeem RF, McCall PJ, Al Rabeeah AA, Memish ZA (2014). A country on the verge of malaria elimination--the Kingdom of Saudi Arabia. PLoS One, 9: e105980.

Daggy RH (1959). Malaria in oases of eastern Saudi Arabia. American Journal of Tropical Medicine & Hygiene, 8: 223 – 291.

El Hassan I, Sahly A, Al-Zahrani MH, Elhakeem R, Alhelal M, Alhogail A, Alsheikh A, Assirri AM, ElGamri TB, Al-Atas M, Akeel MA, Bani I, Aggeely HM, BiSaeed AA, Kyalo D, Noor AM, Snow RW (2015). Progress toward malaria elimination in Jazan Province, Kingdom of Saudi Arabia: 2000-2014. Malaria Journal, 14: 444.

El Hazmi MAF, Warsy AS, Al-Swailem AR, Al-Swailem AM, Bahakim HM (1996). Sickle cell gene in the population of Saudi Arabia. Haemoglobin, 20: 187– 198.

El Sebai MM & Makled MK (1987). Malaria in El-Taif, Saudi Arabia. Journal of Egyptian Society of Parasitology, 17: 373 – 375.

EMRO (2007). Strategic plan for malaria elimination in the WHO Eastern Mediterranean Region 2006 – 2010. Cairo: World Health Organization Regional Office for the Eastern Mediterranean.

EMRO (2008). Technical discussion on malaria elimination in the Eastern Mediterranean region: vision, requirements and strategic outline. Regional Committee for the Eastern Mediterranean, Fifty-fifth session, Agenda item 7 (b) (EM/RC55/Tech.Disc.2).

Farid MA (1951). Malaria reconnaissance trip – Saudi Arabia; 5–31, March 1951. World Health Organization (EM/MAL/4): 14.

Farid MA (1956). The pilgrimage and its implications in a regional malaria eradication programme. WHO/EMRO inter-regional conference on malaria for the Eastern Mediterranean and European regions, April

1956. World Health Organization report; WHO/MAL/168.
Farid MA (1956). Report on a visit to Saudi Arabia (19 February to 3 March 1956). World Health Organization (EM/ MAL/19): 11.
Farid MA (1996). An attempt to illustrate the malaria situation in Arabia at the time of the Prophet Muhammad. Eastern Mediterranean Health Journal, 3: 531− 537.
Gelpi AP (1967). Glucose-6-phosphate dehydrogenase deficiency, the sickling trait, and malaria in Saudi Arab children. Tropical Pediatrics, 71: 138 − 146.
Ghalib HW, Al-Ghamdi S, Akood M, Haridi AE, Ageel AA, Abdalla RE (2001). Therapeutic efficacy of chloroquine against uncomplicated, Plasmodium falciparum malaria in south-western Saudi Arabia. Annals of Tropical Medicine & Parasitology, 95: 773 − 779.
Jamjoom GA, Mahfouz AA, Badawi IA, Omar MS, al-Zoghaibi OS, Al-Amari OM, Ibrahim M, Siam I (1994). Acceptability and usage of permethrin-impregnated mosquito bed nets in rural south-western Saudi Arabia. Tropical Geographic Medicine, 46: 355–377.
Jupp PG, Kemp A, Grobbelaar A, Leman P, Burt FJ, Alahmed AM, Al Mujalli D, Al Khamees M, Swanepoel R (2002). The 2000 epidemic of Rift Valley fever in Saudi Arabia: mosquito vector studies. Medical & Veterinary Entomology, 16: 245 − 252.
Kinsara AJ, Abdelaal MA, Jeje OM, Osoba AO (1997). Chloroquine-resistant Plasmodium falciparum malaria: report of two locally acquired infections in Saudi Arabia. American Journal of Tropical Medicine & Hygiene, 56: 573–575.
Kondrachine AV (2003). Assignment report on strengthening the national malaria control programme in Saudi Arabia. World Health Organization Regional Office for the Eastern Mediterranean (EM/MAL/298/ E/R/12.03/20: 20).
Kondrachine AV (2004). Assignment report on national malaria programme in Saudi Arabia. World Health Organization Regional Office for the Eastern Mediterranean archives (EM/MAL/306/E/R/07.04/20).
Kondrachine AV (2004). Strategy for malaria elimination in the Kingdom of Saudi Arabia (2004 − 2007). In: Malaria elimination strategy in Saudi Arabia. Riyadh: National Malaria Control Programme, Ministry of Health: 63.
Kondrachine AV (2005). Assignment report on progress in malaria elimination strategy in Saudi Arabia. World Health Organization Regional Office for the Eastern Mediterranean (EM/MAL/315/E/R/08.05/20).
Kondrachine AV (2006). Assignment report on implementation of the strategy on malaria elimination in Saudi Arabia., World Health Organization, Regional office for the Eastern Mediterranean (EM/MAL/335/ E/R/11.06/20).
Magzoub M (1980). Plasmodium falciparum and Plasmodium vivax infections in Saudi Arabia, with a note on the distribution of anopheline vectors. Journal of Tropical Medicine & Hygiene, 83: 203− 206.
Malaria Control Service, Ministry of Health, Kingdom of Saudi Arabia (1963). Sketch map showing operational zones in 1962. Riyadh: Ministry of Health.
Malaria Control Service, Ministry of Health (1980). A brief report on the malaria control programme in the Kingdom of Saudi Arabia in 1979. Riyadh: Ministry of Health.
Malaria Control Service, Ministry of Health (1985). Malaria control programme in the Kingdom. 1404–1405 H. Riyadh: Ministry of Health.

Malaria Control Service, Ministry of Health (1986). Annual report on malaria control programme in the Kingdom of Saudi Arabia, 1985. Riyadh: Ministry of Health.

Mattingly PF, Knight KL (1956). The mosquitoes of Arabia, I. Bulletin of the British Museum (Natural History)
− Entomology, 4: 91− 141.

Nzila A, Al-Zahrani I (2013). Drugs for the treatment of malaria in the Kingdom of Saudi Arabia. Saudi Medical Journal, 34: 569–578.

Peffly RL (1959). Insecticide resistance in anophelines in Eastern Saudi Arabia. Bulletin of the World Health
Organization, 20: 757− 776.

Sebai ZA (1988). Malaria in Saudi Arabia. Tropical Doctor, 18: 183− 188.

Snow RW, Amratia P, Zamani G, Mundia CW, Noor AM, Memish ZA, Al Zahrani MH, Al Jasari A, Al-Zedjali MS, Fikri M, Atta H (2013). The malaria transition on the Arabian Peninsula: progress toward a malaria free
region 1960 - 2010. Advances in Parasitology, 82: 205 − 251.

Zahar AR, Dabbagh HS (1957). A malaria survey in the north western part of Saudi Arabia. World Health Organization Regional Office for the Eastern Mediterranean (EM/Mal.Erad,/27): 21.

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