Bioenvironmental and meteorological factors related to the persistence of malaria in Fayoum Governorate: a retrospective study

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العوامل البيئية والبيولوجية والمناخية المتعلّقة بديمومة الملاريا في محافظة الفيوم: دراسة استعادية

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خلاصة: أجريت هذه الدراسة لتحديد حجم مشكلة الملاريا في محافظة الفيوم وللتعرف على العوامل المحدِّدة لديمومتها فيها. تمت مراجعة سجلات الملاريا في محافظة الفيوم في الفترة 1971–1999. وقد أظهرت المعطيات عدم وجود حالات ناجمة عن المتصورة النشيطة طيلة الفترة 1997–1999، ولا تُتوقع ظهورها حتى عام 2004، كما لم تكتشف حالات ناجمة عن المتصورة المنجلية في عامي 1998 و1999 مع ميل واضح ولو أنه لا يُعتدّ به إحصائيا للانخفاض في توقع حدوثها. وتمت مناقشة العوامل المسؤولة عن ديمومة الملاريا في هذه المحافظة.

ABSTRACT The present study was conducted to determine the magnitude of the malaria problem in Fayoum Governorate and to ascertain the determinant factors behind its persistence in this area. Malaria records in Fayoum Governorate for the period 1971–1999 were reviewed retrospectively. The data show that no *Plasmodium vivax* cases were recorded during 1997–1999 and prediction up till 2004 indicated no positive cases expected. No *P. falciparum* cases were detected in 1998 and 1999. The prediction trend for this species showed an apparent but not statistically significant decrease in the incidence. The factors responsible for the persistence of malaria in this governorate are discussed.

Facteurs bio-environnementaux et météorologiques associés à la persistance du paludisme dans le Gouvernorat de Fayoum : étude rétrospective

RESUME La présente étude a été réalisée pour déterminer l'ampleur du problème posé par le paludisme dans le Gouvernorat de Fayoum et établir les facteurs déterminants qui expliquent la persistance du paludisme dans cette région. Les dossiers concernant les cas de paludisme dans le Gouvernorat de Fayoum durant la période 1971-1999 ont fait l'objet d'une étude rétrospective. Les données ont montré qu'aucun cas de *Plasmodium vivax* n'a été enregistré entre 1997 et 1999 et selon les prévisions jusqu'en 2004, aucun cas positif n'était attendu. Aucun cas de *P. falciparum* n'a été détecté en 1998 et 1999. La tendance des prévisions pour cette espèce a montré une diminution manifeste de l'incidence mais non statistiquement significative. Les facteurs responsables de la persistance du paludisme dans ce gouvernorat sont examinés.

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Introduction

In Egypt malaria belongs to the Palaearctic ecoepidemiological type. It is believed that the disease has been present in the Mediterranean area since antiquity or even pre-historic times. A great deal of material evidence suggestive of the presence of malaria in pre-dynastic Egypt as early as 3200 BC has been obtained. For example, *Plasmodium falciparum* antigen trophozoite-derived *P. falciparum* histidine rich protein-2 (PFHRP-2)] has been found in naturally desiccated mummies from Upper Egypt suggesting that they were suffering from untreated malaria at the time of their deaths more than 5000 years ago [*1*]. According to Madwar [*2*], records at Dandara Temple in Upper Egypt describe an intermittent fever following the Nile flood that was presumably due to malaria.

Historically, four malaria parasite species (*P. vivax*, *P. falciparum*, *P. malariae* [*3*] and *P. ovale* [*4*]) have been recorded in Egypt. Due to successful application of dichlorodiphenyl trichloroethane (DDT) since 1946, there was a dramatic decline in malaria incidence to the extent that in the 1990s all governorates of Egypt were free of malaria except for local transmission, which continued only in two out of five districts in Fayoum Governorate, namely Sinnuris and Fayoum where *P. falciparum* predominated [*5*].

Delfini (L. Delfini, unpublished report, 1989) commented that it seemed unclear how no falciparum malaria had occurred in other districts since all bioenvironmental and climatological factors of malaria transmission appeared to be the same. On the other hand, malaria occurred in focal outbreaks which seemed to die out without special measures being applied or substantial changes occurring in the factors influencing the dynamics of malaria transmission.

Egypt is well aware of the deteriorating global malaria situation and is keen to eradicate the disease from the country by following the principles and approaches of the World Health Organization's (WHO's) Roll Back Malaria (RBM) programme. RBM is committed to halving the world's malaria burden by 2010 by enabling communities to take effective, sustainable action against the disease. This target will be achieved through the six elements of the RBM strategy: evidence-based decisions, rapid diagnosis and treatment, multiple prevention, focused research, well-coordinated actions and a dynamic global movement (H.K. Bassiouny, unpublished report, 2000).

The objectives of the present study were:

- To make an estimate of the magnitude of the malaria problem in Fayoum Governorate during the period 1971–1999 with projection to the year 2004.
- To determine and ascertain the bioenvironmental and meteorological factors affecting the persistence of malaria in that governorate.
- To use the information as baseline data in the planning and evaluation of future malaria eradication programmes.

Methods

Study area

Fayoum Governorate is more or less a large agricultural oasis. It lies 90 km south-west of Cairo and has the following boundaries: in the north, Qaroun Lake; in the south, the Western Desert; in the west: the Western Desert; and in the east the River Nile. The governorate is located between latitude 29° 45′ and 30° 15′ and longitude 30° 30′ and

31°. It occupies an area of about 1778 km^2 with a total population around 1 989 900 according to the 1996 census. The governorate is composed of five districts, Fayoum, Sinnuris, Ebshway, Itsa and Tamiya (Figure 1). It is irrigated by Baher Youssef, a branch of the River Nile that breaks up into a number of streams before its water flows into Qaroun Lake. The lake lies in a depression about 45 m below sea level. It is a shallow lake with a depth of about 6–7 m, a length of 45 km, a width of 9 km and an approximate surface area of 214 km^2. The governorate has an open irrigation system with 39 000 km of waterways allowing the spread of many larval habitats. Two main anopheline vectors in the area are responsible for malaria transmission: *Anopheles sergenti* and *A. pharoensis*.

Study design, data collection and analysis

A retrospective study was conducted using the relevant data collected from the records of the Ministry of Health and Population (MOHP) on malaria cases in Fayoum Governorate during the period 1971–1999. The records included information about parasite species, patient's village and village altitude according to the topographical maps of the governorate.

The prediction of malaria cases was performed using an exponential model after addition of one to each actual value to eliminate the zero value. A logarithmic scale was used to present cases graphically in order to straighten the exponential curve and examine what happens when the incidence starts to approach a zero level.

Results

Table 1 and Figures 2 and 3 show the recorded and predicted indigenous malaria cases by parasite species in Fayoum Governorate during 1971–1999, with projection to the year 2004. The data reveal that no *P. vivax* cases were recorded during 1997–1999 and no positive cases are ex-

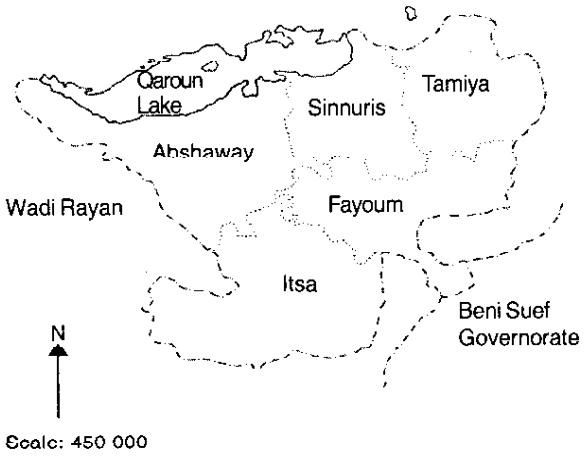

Figure 1 **Districts of Fayoum Governorate**

Table 1 **Recorded and predicted indigenous malaria cases in Fayoum Governorate (1971–1999) with projection to 2004**

Year	Number of malaria cases			
	P. falciparum		*P. vivax*	
	Actual	Predicted	Actual	Predicted
1971	208	82.11453	489	810.68222
1972	264	77.12518	888	634.47580
1973	8	72.43899	250	496.56886
1974	6	68.03753	129	388.63678
1975	175	63.90352	1102	304.16435
1976	205	60.02068	242	238.05249
1977	120	56.37376	271	186.31042
1978	131	52.94846	555	145.81479
1979	42	49.73126	271	114.12111
1980	9	46.70955	193	89.31623
1981	3	43.87144	109	69.90284
1982	103	41.20577	68	54.70906
1983	5	38.70208	28	42.81773
1984	52	36.35050	111	33.51105
1985	11	34.14182	4	26.22723
1986	41	32.06733	22	20.52659
1987	10	30.11889	10	16.06502
1988	218	28.28884	0	12.57320
1989	200	26.56999	0	9.84034
1990	69	24.95557	1	7.70149
1991	21	23.43925	4	6.02752
1992	9	22.01506	2	4.71741
1993	13	20.67741	3	3.69205
1994	473	19.42103	23	2.88956
1995	290	18.24099	16	2.26150
1996	69	17.13266	2	1.76995
1997	4	16.09166	0	1.38524
1998	0	15.11392	0	1.08415
1999	0	14.19558	0	0.84850
2000		13.33305		0.66408
2001		12.52292		0.51974
2002		11.76202		0.40677
2003		11.04735		0.31836
2004		10.37610		0.24916

pected in the year 2004 ($F = 95.64$, $P > 0.001$). No *P. falciparum* cases were recorded in 1998 and 1999. However the prediction trend of this type of parasite species shows apparent but non-statistical decreases ($F = 2.82$, $P < 0.05$).

Tables 2 and 3 illustrate the distribution of indigenous malaria cases during 1990–1999 according to parasite species, patient's village and village altitude (in metres) in relation to sea level in Sinnuris and Fayoum districts. There was a discrepancy in the distribution of the malaria foci in Sinnuris district. During 1990–1997, most of the malarious areas were located 11–20 m above sea level in Sinnuris district. However, some recorded foci were identified in areas located 15–24 m below sea level. The picture was not the same in Fayoum district, where all malaria foci were located 20–30 m above sea level.

Discussion

Egypt is one of the eight countries in the Eastern Mediterranean Region (EMR) of WHO with a national malaria control programme. Malaria transmission continues only in limited foci in Fayoum Governorate [5]. The dynamics of malaria transmission in Fayoum Governorate indicate a situation of a mainly hypoendemic, unstable, seasonal and focal distribution. The disease is only located in certain villages of Sinnuris and Fayoum districts inducing very low immunity in the resident population [6].

There were no recorded *P. vivax* cases during 1997–1999 and prediction indicates that no cases are expected to be recorded in the year 2004. At the same time the incidence of falciparum cases is showing an apparent decrease. This trend (where *P. vivax* is decreasing faster than *P. falciparum*) is to be expected when drugs are the main weapon used against malaria.

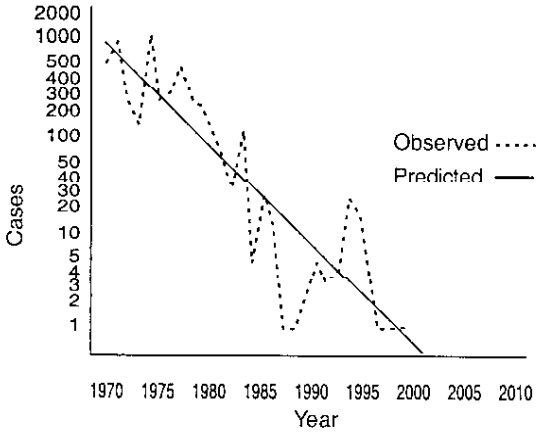

Figure 2 **Recorded *Plasmodium vivax* cases (1971–99) with projection to the year 2004**

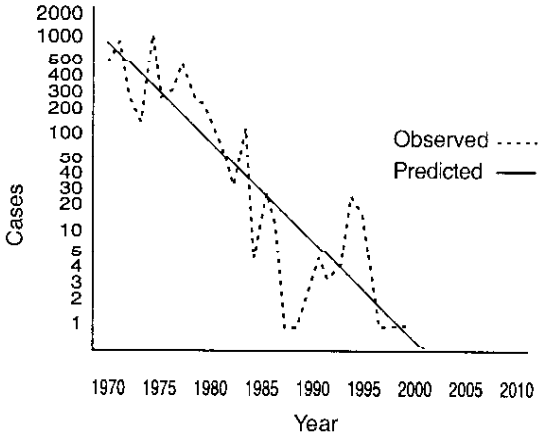

Figure 3 **Recorded *Plasmodium falciparum* cases (1971–99) with projection to the year 2004**

Even chloroquine-sensitive *P. falciparum* is less susceptible to chloroquine than *P. vivax*. Chloroquine remains very useful and is the drug of choice in Egypt.

Harb [7] reported that the main problem of malaria transmission in Fayoum Governorate is the high level of subsoil water because the governorate is on the whole

Table 2 **Distribution of indigenous malaria cases in Sinnuris district (1990–1999) according to parasite species, patient's village and village altitude**

Year	Patient's village	Altitude (m)[a]	Malaria cases			Total
			P. falciparum	*P. vivax*	*P. falciparum/ P. vivax*	
1990	Abdel-Hadi	–22	26	1	–	27
	El-Hanawi	+13	4	–	–	4
	Saudi	+18	25	–	–	25
	El-Manawia	+12	3	–	–	3
	Tantawi	+15	11		–	11
	Sub-total	–	69	1	–	70
1991	Abdel-Hadi	–22	2	–	–	2
	El-Hanawi	+13	3	–	–	3
	Saudi	+18	–	3	–	3
	Tantawi	+15	2	–	–	2
	Biahmou	+17	4	1	–	5
	Hana Bolus	+18	3	–	–	3
	Warda	+18	2	–	–	2
	Muhammad Abdel-Aziz	+18	4	–	–	4
	Mankrious	+18	1	–	–	1
	Sub-total	–	21	4	–	25
1992	Abdel-Hadi	–22	–	–	2	2
	Saudi	+18	–	1	–	1
	Biahmou	+17	1	–	–	1
	Hana Bolus	+18	1	–	1	2
	Warda	+18	3	1	–	4
	Tersa	–15	3	–	–	3
	Sub-total	–	8	2	3	13
1993	Biahmou	+17	3	–	–	3
	Hana Bolus	+18	–	2	–	2
	Warda	+18	4	–	–	4
	Muhammad Abdel-Aziz	+18	1	–	–	1
	Mankrious	+18	3	–	–	3
	Mansour	+20	–	1	–	1
	Ibrahim Abdel-Sayed	+13	1	–	–	1
	Sub-total	–	12	3	–	15

Table 2 **Distribution of indigenous malaria cases in Sinnuris district (1990–1999) according to parasite species, patient's village and village altitude** *(continued)*

Year	Patient's village	Altitude (m)[a]	Malaria cases			Total
			P. falciparum	*P. vivax*	*P. falciparum/ P. vivax*	
1994	Abdel-Hadi	–22	2	3	2	7
	Tantawi	+15	2	–	–	2
	Biahmou	+17	16	3	–	19
	Hana Bolus	+18	1	–	–	1
	Muhammad Abdel-Aziz	+18	1	2	–	3
	Mankrious	+18	1	–	–	1
	Tersa	–15	4	–	–	4
	Mansour	+20	12	1	–	13
	Ibrahim Abdel-Sayed	+13	2	2	–	4
	Kassem Zidan	–24	5	–	–	5
	Mabrouk	+11	2	–	–	2
	Nakalifa	+13	27	–	–	27
	Sub-total	–	75	11	2	88
1995	Abdel-Hadi	–22	9	1	–	10
	El-Hanawi	+13	1	–	–	1
	El-Manawia	+12	1	–	–	1
	Tantawi	+15	1	–	–	1
	Biahmou	+17	3	5		8
	Hana Bolus	+18	1	–	–	1
	Muhammad Abdol Aziz	+18	1	–	–	1
	Tersa	–15	43	2	–	45
	Mansour	+20	1	–	–	1
	Kafr Fazara	–15	6	–	–	6
	Nakalifa	+13	4	–	–	4
	Sub-total	–	71	8	–	79
1996	Kafr Fazara	–15	36	–	–	36
	El-Hanawi	+13	5	–	–	5
	Tawfikia	+18	2	–	–	2
	Biahmou	+17	1	–	–	1
	Sub-total	–	44	–	–	44
1997	Kafr Fazara	–15	4	–	–	4

Table 2 **Distribution of indigenous malaria cases in Sinnuris district (1990–1999) according to parasite species, patient's village and village altitude** *(concluded)*

Year	Patient's village	Altitude (m)[a]	Malaria cases *P. falciparum*	*P. vivax*	*P. falciparum*/ *P. vivax*	Total
1998	All areas		–	–	–	–
1999	All areas	–	–	–	–	–
Total	304	29	5	338		

[a]*Altitude in relation to sea level.*

located at 20 m below sea level. This leads to the formation of many swamps and pools of various sizes, creating suitable environmental conditions for anopheline vectors. Such an explanation is widely accepted; however, the problem of the persistence of malaria in Fayoum Governorate could be due to several interacting factors

Microgeographical configuration

It is well known that absolute altitude is not as important as the slope. For instance, anopheline vectors still transmit malaria at altitudes as high as 1000–1500 m in the highlands of Madagascar [*8*]. The data presented here show that the topographical features of Sinnuris district vary from south to north, resulting in different epidemiological settings.

Villages located in the southern part of the district such as Biahmou and the neighbouring villages such as Hana Bolus, Warda, Muhammad Abdel-Aziz, Mankrious, Ibrahim Abdel-Sayed, Mansour, Saudi, Tantawi and others, were malaria foci especially during 1990–1995. The altitude of Biahmou and neighbouring villages ranges between 11 m and 18 m above sea level. Biahmou, itself, is located 17 m above sea level and has a large swamp on its western side. Thus the problem here is not altitude but flatness and insufficient drainage of the land.

On the other hand, some villages such as Kafr Fazara, Tersa, Abdel-Hadi, Kassem Zidan, near the central part of Sinnuris district, are between 15 m and 24 m below sea level and were classified as malaria foci until 1997. Their problem is the high level of subsoil water concurrent with bad drainage leading to the formation of many swamps and pools. Trials to fill in these water collections failed because of the continuous rise in the subsoil water level or the bursting of subsoil water inside houses and formation of small springs as result of the phenomenon of communicating vessels. Similar situations are still observed in several houses in Sinnuris district.

In the northern part of Sinnuris, there is a steep slope to the edge of Qaroun Lake at 40–56 m below sea level where there is good drainage and the incidence of malaria during the past 30 years has been practically nil.

The topographical features of malaria foci in Fayoum district were more or less the same; all foci were located at an altitude of 20–30 m above sea level and insufficient drainage is the main problem.

Table 3 **Distribution of indigenous malaria cases in Fayoum district (1990–1999) according to parasite species, patient's village and village altitude**

Year	Patient's village	Altitude (m)[a]	Malaria cases			Total
			P. falciparum	*P. vivax*	*P. falciparum/ P. vivax*	
1990	–	–	–	–	–	–
1991	–	–	–	–	–	–
1992	Manshaa Abdulla	+20	1	–	–	1
1993	Manshaa Abdulla	+20	1	–	–	1
1994	Manshaa Abdulla	+20	182	9	–	191
	Harfoush	+30	34	1	–	35
	Fayoum City	+30	2	1	–	3
	Beni-Saleh	+30	108	–	–	108
	Zawia Kerdasah	+30	2	–	–	2
	El-Gawer	+30	23	–	–	23
	El-Daly	+30	3	–	–	3
	Sater	+30	2	–	–	2
	El-Hawari	+30	2	–	–	2
	Muhammad Farid	+30	1	–	–	1
	Sidnawi	+30	1	–	–	1
	Sub-total	–	360	11	–	371
1995	Manshaa Abdulla	+20	1	–	–	1
	Harfoush	+30	6	1		7
	Beni-Saleh	+30	160	7	–	167
	Zawia Kerdasah	+30	1	–	–	1
	El-Gawer	+30	43	5	–	48
	El-Daly	+30	1	–	–	1
	El-Santah	+30	4	–	–	4
	Geera	+20	2	–	–	2
	Abou Anan	+20	1			1
	El-Hadeer	+20	1	–	–	1
	Abdel-Kader	+20	1	–	–	1
	Sub-total	–	221	13	–	234

Table 3 **Distribution of indigenous malaria cases in Fayoum district (1990–1999) according to parasite species, patient's village and village altitude** *(concluded)*

Year	Patient's village	Altitude (m)[a]	Malaria cases			Total
			P. falciparum	*P. vivax*	*P. falciparum/ P. vivax*	
1996	Manshaa Abdulla	+20	–	–	–	–
	Beni-Saleh	+30	19	–	–	19
	El-Gawer	+30	1	–	–	1
	El-Daly	+30	3	–	–	3
	Geera	+20	2	–	–	2
	Sub-total	–	25	–	–	25
1997	All areas	–	–	–	–	–
1998	All areas	–	–	–	–	–
1999	Fayoum City	+30	1	–	–	1
Total	609	24	–	633		

[a]*Altitude in relation to sea level.*

Meteorological conditions

The favourable meteorological conditions, mainly optimum temperature and relative humidity, lead to the extension of the transmission season to 8 months a year from the end of March to the end of November [6]. Rainfall as a general trend is scarce and can be disregarded as a factor in the malariology of Egypt, except in the case of catastrophic rains leading to floods, as for example occurred in Nubia in 1919–1920 which led to a malaria epidemic with many deaths [9].

Brick factories

The role played by the brick factories cannot be ignored. Kafr Fazara, a small village in Sinnuris, has five working brick factories located throughout the village. One or more large water basins are attached to each factory for storing water used in the manufacturing of bricks. Over-flowing water from these tanks constantly creates stagnant water collection thus forming suitable breeding places for anopheline mosquitos. Bassiouny [6] found that most of the malaria cases detected in Kafr Fazara in 1996 were in close contact with these factories.

Housing conditions

Bassiouny [6] reported that the housing conditions and their location seemed to favour malaria transmission. The bricks, which are mostly used for construction of houses in Fayoum Governorate, seem to provide shelter for mosquitos. Also, the habit of keeping domestic animals and birds (pigeons and chickens) inside houses is associated with greater exposure to mosquitos. In 1996, most of the malaria cases detected in Kafr Fazara were located in the vicinity of the water streams. This may be due to the increased contact between hu

mans and anopheline vectors. In such conditions people are at risk of contracting malaria infection.

Excavation of agricultural land

The excavation of agricultural land for clay to be used in the brick industry has led to the formation of many borrow pits. Water drainage from the agricultural areas into shallow empty land, either naturally present or created by excavation, exacerbates the problem. Abou-Naoura area is a good example of the drawback of excavation. It is located in Sinnuris about 11 m below sea level. Extensive excavation was carried out in the 1980s, which caused a large swamp of about 1 *feddan* (about 1 acre) to form. Simultaneously, many malaria cases were recorded among people resident in the vicinity of the swamp. In 1995, drainage was carried out that made the land cultivable and consequently the incidence of malaria decreased dramatically almost to zero level. In 1990, laws were enacted that prohibited the excavation of agricultural land, which has led to a lowering of malaria incidence in the governorate.

Governmental policy

As a result of the policy of the Ministry of Agriculture and Land Reclamation to increase the areas cultivating rice, suitable breeding places for mosquitos were created, especially for *A. pharoensis*. Moreover, the Ministry changed its policy of spraying cotton fields with insecticides and now uses pheromones instead. This change in the pest control strategy removed the insecticide pressure on the mosquito population and allowed a rapid increase in the mosquito problem.

Conclusion

This study was conducted in order to determine the magnitude of the malaria problem in Egypt in a retrospective study during the period from 1971 to 1999 and to determine the bioenvironmental and meteorological factors causing its persistence. The assessment of the malaria situation in the country is a first step towards malaria eradication and prevention of reintroduction, in line with the WHO RBM principles and approach recently adopted by Egypt. Egypt adopted the RBM initiative through participation in the consensus-building meeting in Nairobi, 19–22 April 1999, in which the new RBM initiative was discussed, and in the Regional Consultation on RBM in Cairo, 14–16 September 1999 and finally participation in the Abuja Declaration on RBM, 25 April 2000, Abuja, Nigeria.

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Drug resistance in malaria

Malaria remains an important public health concern in countries where transmission occurs regularly, as well as in areas where transmission has been largely controlled or eliminated. It is a complex disease that varies widely in epidemiology and clinical manifestation in different parts of the world. Thus, malaria control and prevention efforts need to be designed for the specific environment in which they will be used and need to take into account the local epidemiology of malaria and the level of available resources and political will. Antimalarial drug resistance has emerged as one of the greatest challenges facing malaria control today. This review describes the state of knowledge on drug-resistant malaria and outlines current thinking regarding strategies to limit the advent, spread, and intensification of drug-resistant malaria. It covers disease incidence and trends, causes of resistance, detection of resistance, treatment and future trends. The document can be obtained from: Department of Communicable Disease Surveillance and Response, World Health Organization, Avenue Appia 20, CH-1211 Geneva 27, Switzerland. It is also available free on the Internet at: http://www.who.int/csr/resources/publications/drugresist/WHO_CDS_CSR_DRS_2001_4/en/