MALARIA EPIDEMICS:

FORECASTING, PREVENTION, EARLY DETECTION AND CONTROL

FROM POLICY TO PRACTICE

Report of an Informal Consultation
Leysin, Switzerland
8–10 December 2003

World Health Organization

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LIST OF ACRONYMS AND ABBREVIATIONS USED

ACT	artemisinin-based combination therapy
ADDS	Africa Data Dissemination Service
AIDS	acquired immunodeficiency syndrome
CIESIN	Center for International Earth Science Information Network
DDT	dichlorodiphenyltrichloroethane
EDS	early detection system
ENSO	El Niño Southern Oscillation
FEWS	famine early warning system
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
GIS	geographical information system
HIMAL	MARA Highlands Malaria Project
HIV	human immunodeficiency virus
IDA	International Dispensary Association
IM	intramuscular
INDEPTH	International Network of Field Sites with Continuous Demographic Evaluation of Populations and their Health in Developing Countries
IRS	indoor residual spraying
ITM	insecticide-treated materials
ITN	insecticide-treated mosquito nets
IV	intravenous
LRF	long-range forecasting
MARA	Mapping Malaria Risk in Africa Initiative
MEWS	malaria early warning system
MSF	Médecins Sans Frontières
NDVI	Normalized Difference Vegetation Index
NEPAD	New African Partnerships for Development Initiative
NGO	nongovernmental organization
PARSAC	Partnerships for Health and Climate
RBM	Roll Back Malaria
RDT	rapid diagnostic test
RFE	rainfall estimate
SAMC	Southern Africa Malaria Control Programme
S/P	sulfadoxine/pyrimethamine
SPR	slide-positivity rate
TSN	Technical Support Network
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
UV	ultra-low volume
WHO	World Health Organization
WHO/AFR	African Region of the World Health Organization
WMO	World Meteorological Organization

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SUMMARY

Malaria epidemics are serious public health emergencies. Typically, they occur with little or no warning in areas where the health system is unprepared to deal with the emerging problem. In most situations, however, epidemic conditions develop over several weeks, theoretically allowing time for preventive action. Even when an epidemic occurs, it may still take several weeks before it reaches its peak, so that some effective control may still be possible if implemented immediately.

A rapid response is possible solely if national authorities in epidemic-prone countries adopt an "epidemic preparedness plan of action" based on a strategic approach to epidemic prevention and control.

An epidemic preparedness plan of action should aim to:

- identify epidemic-prone areas and populations at risk, to allow prediction and detection, targeting of a rapid response, and planning of the logistics for such a response;
- prevent predicted malaria epidemics by vector control measures where feasible; and
- detect an epidemic in its early stages and bring it rapidly under control through individual case management, mass fever treatment and, where still possible, vector control.

Identification of epidemic-prone areas and populations at risk

There is a lack of reliable, validated maps with clearly demarcated epidemic-prone areas and methods for estimating populations at risk. Hard copy and sketch maps based on local expert opinion should be used for setting the boundaries of epidemic areas and plotting the distribution of cases, local population, availability of health services and any significant environmental modifications. Geographical information systems (GIS) are currently also being evaluated as tools for estimating populations at risk and decision-making in malaria epidemic-prone areas.

Long-range forecasting (LRF), early warning (MEWS) and early detection (EDS)

The LRF–MEWS–EDS continuum has the potential to provide complementary information with increasing accuracy and spatial resolution (continent–country–district–locality) but decreasing lead-times (10–14 months to 1–2 weeks).

However, many programmes simply do not have the resources to implement the entire continuum of long-range forecasting, early warning and early detection. The capacity of countries in malaria epidemiology and planning malaria epidemic prevention and control is generally weak. Few are able to collect and analyse relevant data and process them rapidly enough to allow effective prevention or control. The keys to success will be capacity building, realistic planning and community awareness.

It is more realistic to begin modestly and give priority to improving surveillance using a restricted number of validated indicators: the complexity of the system can be stepped up as staff capabilities improve, new information and techniques become available from research, and closer teamwork is established with other partners and information sources.

Long-range forecasting

Long-range forecasting is still a predominantly research-based technique. Current research is focused on how the El Niño Southern Oscillation (ENSO) affects the risk of malaria epidemics in

highland and desert-fringe areas. While more accurate prediction models and systems continue to be developed, rough and ready warning methods can already be used to advantage for prospective monitoring and validation; for example, the Southern Africa Malaria Control Programme (SAMC) is translating seasonal climate forecasts into seasonal malaria forecasts.

Early warning (MEWS)

The full practical potential of MEWS has yet to be realized. Over the past few years, attempts have been made in Africa to transform MEWS from a research project into a practical public health tool. The method is showing promise in southern Africa where some countries now routinely use rainfall, temperature and population vulnerability as early warning indicators of malaria epidemics, and others also regularly evaluate drought and food security status.

Early detection

The group recommended that a system of weekly reporting should be introduced wherever possible, while recognizing that this is currently beyond the reach of some countries. For some, monthly reporting and a concerted effort to improve the quality of data collection and reporting would be a better starting-point. In countries with poorly developed laboratory diagnostic facilities, it may be more cost-effective to designate selected health centres with laboratory facilities in epidemic-prone areas as sentinel surveillance sites. Data from these centres could then be relayed to the district and provincial authorities on a weekly basis. Malaria sentinel sites now exist in many African countries, such as Angola, Botswana, Kenya, Malawi, Mali, Mozambique, Namibia, Niger, Senegal, and Uganda.

Integration of malaria EDS into more general disease surveillance systems should be encouraged. It is likely to be beneficial in terms of both improving data quality and enhancing system efficiency provided that two conditions can be met: provision of appropriate training and feed-back at the peripheral level and surveillance approaches being consistent with malaria control needs.

Case management

The drugs used to treat **uncomplicated malaria** in epidemics should be highly efficacious (at or above 95%) and safe and should offer good compliance. To date, artemisinin-based combination therapy, ACT, is the only appropriate treatment for uncomplicated malaria in falciparum epidemics and in mixed falciparum/vivax epidemics. The only exceptions are central America and Hispaniola where *P. falciparum* remains sensitive to chloroquine and sulfadoxine/pyrimethamine. In vivax-only epidemics chloroquine remains the drug of choice. Anti-relapse therapy with primaquine should be considered only once the epidemic subsides.

Intramuscular injectable artemether is the drug of choice for management of **severe disease** during epidemics because quinine use is impractical in most epidemic situations. If injectable artemether is not available, artesunate suppositories are recommended for emergency use in outlying areas when severely ill patients are unable to swallow oral medication. Where referral is impossible, treatment with rectal artesunate should be continued until oral drugs can be taken.

Once malaria has been established as the cause of the epidemic, **mass treatment of fever cases** (MFT) with ACT is appropriate as a strategy to reduce mortality. There is no evidence to support mass drug administration (MDA), i.e. indiscriminate distribution of treatment to the entire population at risk.

Vector control

While the first priority in an epidemic is the prompt and effective diagnosis and treatment of malaria, vector control can significantly contribute to reducing the risk of infection and saving lives provided that it is well planned, targeted and timely.

Anti-vector measures for epidemic prevention and control can be implemented effectively only if they are buttressed by an infrastructure of well trained personnel, adequate supplies and equipment, preparedness planning, and supervision and evaluation. Epidemic-prone countries without an infrastructure of this kind should develop one.

Implementation of vector control is most cost-effective when used for prevention, and for control at the very start of an epidemic, and when high (>85%) coverage levels can be achieved. It can be used preventively for long-term suppression of transmission in the following situations: to hinder the resurgence of malaria in a previously controlled area, to prevent a gradual transmission build-up over years and/or seasonal transmission surge, and to target communities in which an epidemic is expected soon.

Indoor residual spraying

Indoor residual spraying is especially well adapted to epidemic prevention and response. DDT, where effective, meets the criteria for situations in which resources are limited and a residual action beyond 6 months is required, provided WHOPES specifications are met and ; the requisite safety precautions for its use and disposal are taken. Synthetic pyrethroids are an effective alternative to DDT: they have a residual action of 2–6 months, are safer to apply than most other insecticides and still enjoy limited resistance.

There is limited documented evidence on the impact of **insecticide-treated mosquito nets** (ITNs) in epidemic prevention and control. Community use of ITNs in most epidemic-prone areas is limited and, given the overriding importance of implementing epidemic control measures, distributing ITNs would be impractical. The effectiveness of ITNs is dependent on behavioural change. This requirement limits their suitability in most epidemic situations where ITNs are seldom used in the long non-transmission periods.

In some circumstances, however, it may be quicker to implement ITNs for prevention and control than indoor residual spraying (IRS). This is likely to be the case where (i) ITNs are readily available and there are staff experienced in implementing ITN programmes, (ii) a high coverage with untreated nets has already been achieved and a functioning infrastructure can ensure timely treatment with insecticide (ideally at no cost to the end-user), (iii) in refugee camps along with other personal protection measures; and (iv) in emergencies involving scattered or displaced populations where implementation of IRS is both impractical and exorbitantly expensive.

Larval control

Larval control is unsuitable for epidemic control but may be useful for prevention in exceptional circumstances where breeding sites are few, permanent, identifiable and accessible. There is no evidence to support the use of **ULV space spraying** (fogging) as a means of epidemic prevention and control.

1. INTRODUCTION

Malaria epidemics are some of the most serious public health emergencies with which health officials are confronted. Typically, they occur with little or no warning and in areas where the health system is generally unprepared to deal with the problem. They affect highly vulnerable populations with only limited immunity to malaria. This situation is exacerbated by public outcry and intense political pressure for a rapid and decisive intervention.

In most situations epidemic conditions build up over several weeks, theoretically allowing time for preventive action. Even when an epidemic occurs, several weeks will elapse before it peaks: some effective control is therefore possible in the early stages of its development.

The most important factor in reducing the impact of an epidemic is a timely response in which effective control measures are undertaken as soon as the episode has been detected.

The longer an epidemic goes undetected without effective control measures, the higher the cost in terms of morbidity and mortality (Delacollette, 1999). Control measures are inherently costly. If preventive measures are implemented around the epidemic peak, there is little or no benefit in terms of deaths averted. Implementing control measures just after initial detection of the epidemic may, however, be able to prevent deaths, with a maximum effect when measures are undertaken in the very early stages. This requires the development of a cost-effective monitoring system based on forecasting, early warning and detection. Such a system enables either very early recognition of epidemics and the immediate implementation of control measures, or implementation of preventive measures before the epidemic starts. There is a strong correlation between the latter option and the accuracy of the monitoring systems used to predict epidemics.

It is therefore essential that national authorities in epidemic-prone countries develop a strategic plan for epidemic prevention and control that can be used as a template for regional/provincial preparedness plans of action.

In order to assist epidemic-prone countries and their partners to be prepared and to be able to respond rapidly, Roll Back Malaria established a Technical Support Network (TSN) for the prevention and control of malaria epidemics in 1998. Its priority activities were to develop:

- a malaria early warning system (MEWS) based on validated indicators identified through case studies of past epidemics and field research;
- early detection systems (EDS) linked to integrated disease surveillance and response;
- standard epidemic reporting forms as part of rapid assessment guidelines;
- rapid assessment guidelines, including “post mortem” assessment;
- guidelines for epidemic prevention and control;
- epidemic training modules for use at international and national levels for capacity building;
- international and national partnerships to help attain these goals; and
- country support for epidemic prevention and control.

Previous meetings of the TSN addressed:

- priority activities for TSN support (December 1998) (WHO, 1998);
- concepts and indicators required for the development of a MEWS (June, 2000) (WHO, 2001a); and
- progress made from 1998 to 2001 and activities planned for 2002–2003 (December, 2001) (WHO, 2002).

2. THIS MEETING

This was the fourth meeting of the TSN. Dr Fatoumata Nafo-Traoré, Director Roll Back Malaria (RBM) and Acting Executive Secretary of the RBM Partnership Secretariat, opened the meeting, pointing out that:

- the prevention and control of malaria epidemics continue to be major priorities for RBM;
- the meeting should provide clear and practical guidelines to assist malaria epidemic-prone countries across the world to develop realistic strategies and preparedness plans of action for the prompt prevention and control of malaria epidemics;
- to be effective, the implementation of national strategies and preparedness plans of action requires advocacy and community participation; malaria programmes should therefore study what has been learned from other programmes, e.g. vaccine-preventable diseases, that have great experience in obtaining community support; and
- it is often difficult to obtain funds for developing and implementing preventive action against epidemics – since donors tend to be wary of providing funds for events that are uncertain to occur. However, the Global Fund to fight AIDS, Tuberculosis and Malaria (GFATM) is a potential source of revenue for funding innovative approaches.[1]

3. PURPOSE OF MEETING

The overall objectives of the meeting were to:

- review progress made since the inception in 1998 of the RBM Technical Support Network on malaria epidemics; and
- develop practical policies for the prevention and control of malaria in epidemic-prone areas and in complex emergencies.

The specific aims of the meeting were to provide WHO and Member States with evidence-based technical guidelines (what to do? how to do it?) on the following aspects of *P. vivax* and *P. falciparum* epidemics:

- estimating the population at risk of malaria epidemics;
- forecasting and early warning systems for epidemic prediction;
- early detection systems for detection, verification and notification of malaria epidemics within two weeks of onset;
- options for epidemic prevention and control:
  - diagnostic methods, particularly the role of light microscopy and rapid diagnostic tests (RDTs);
  - case management of uncomplicated and severe malaria; and
  - vector control options for prevention and control.

[1] Eleven African countries (Angola, Eritrea, Ethiopia, Kenya, Madagascar, Mali, Mauritania, Niger, Rwanda, Senegal and Sudan) have earmarked malaria epidemic prevention and control as a priority in their submissions for GFATM funding, and a regional GFATM proposal has been developed for Sahelian countries in 2003.

4. STRATEGIC APPROACH TO EPIDEMIC PREVENTION AND CONTROL

The main goal of an epidemic preparedness plan of action is to minimize the malaria burden in an epidemic situation. Its objectives are threefold and complementary:

- identification of epidemic-prone areas and populations;
- forecasting and prevention of epidemics; and
- early detection and control of epidemics.

The national strategic plan should address all practical aspects of individual activities, especially the issues "how", "where" and "by whom". Realistic budgets and deadlines should be assigned to each task. Capacity building is a key factor for a successful outcome; it should be part of the planned activities, targeting all partners that have a role to play in epidemic prevention and control.

The national strategic plan should underline the responsibility of the central national malaria control programme in providing epidemic-prone districts with technical advice and support and mediating partnerships with implementing agencies such as bilateral agencies and NGOs, at the district level and within the community at large.

Other government departments (agriculture, meteorology, water, etc.), local authorities, media, civil society and private companies may all have a role to play in the prevention and control of malaria epidemics. They should be involved in both the planning and the implementation of specific actions.

5. IDENTIFICATION OF EPIDEMIC-PRONE AREAS AND POPULATIONS

There is a lack of reliable validated maps, showing the boundaries of epidemic-prone areas, and of methods for estimating the number of people at risk. This hampers the development of effective systems for prediction and early detection of malaria epidemics, as well as forward planning of logistics and response targeting.

Geographical information systems (GIS) are increasingly used in health sector decision-making and are currently under evaluation as tools for the determination of malaria risk, particularly in epidemic-prone areas, by the WHO HealthMapper project, the Mapping Malaria Risk in Africa (MARA) project, and TSN/Columbia University in collaboration with the U.S. Geological Survey Africa Data Dissemination Service (ADDS) web site.[2]

RBM and WHO HealthMapper have evaluated three methods for stratifying the risk of malaria epidemics and estimating the total population at risk in epidemic-prone countries of Africa:

- **WHO/AFR** estimates made in the 1990s as part of the programme for accelerating the implementation of the Regional Malaria Control Strategy in Africa. The proportion of the population at risk of malaria epidemics was determined by expert national opinion based on historical malaria incidence data and knowledge of risk factors. The population at risk of epidemics was calculated for each country by multiplying its total population by the proportion thought to be at risk.

[2] http://edcintl.cr.usgs.gov/adds

- **MARA** maps and estimates in which malaria risk is extrapolated from analysis of long-term monthly rainfall and temperature readings for 21 different sites, representing areas that are traditionally considered malaria-free, or in which malaria transmission has traditionally been regarded as perennial, seasonal, or epidemic. Epidemic-prone zones are poorly defined by this method since it makes no provision for climate-dependent annual variations.
- **TSN/Columbia** maps in which epidemic-prone areas are identified on the basis of climate changes correlated with increased malaria transmission and interannual climate variability.

Comparative data for the three methods are displayed in Annexes 2 and 3. They indicate that current overall estimates of the population at risk of climate-dependent malaria epidemics in Africa south of the Sahara vary by a factor of two or more depending on the method used (ranging from 52 to 145 million); disparities for individual countries are even greater. It should be noted that United Nations population data for 2001 were used for the WHO/AFR estimate, 1990 United Nations World Population Prospects population data adjusted for population growth rate for 2002 were used for the MARA estimate, and CIESIN[3] 1994 data for the TSN/Columbia maps.

Plans have been made to test and validate approaches used for measuring the population at risk of malaria epidemics. The TSN/Columbia project intends to refine techniques used to map epidemic risk at the district/provincial level and to develop guidelines likely to provide a more exact estimate of these populations. These products will be integrated into the WHO HealthMapper.

Maps have to be updated regularly at local and national levels, using district-level MEWS information for the spatial and temporal mapping of malaria risk. Stratification of risk is based on locally validated risk factors such as rainfall (e.g. Sahelian belt), temperature (e.g. Ethiopia, Madagascar, parts of South-East Asia and south America) or other environmental, social and occupational factors and seasonal patterns. When demarcating epidemic risk areas, adult-to-child ratios of malaria morbidity and mortality should be monitored. Criteria for mapping should be defined and regularly updated, especially at district levels.

GIS is resource-intensive. Any country intending to make use of it should give careful thought to the following questions: how is GIS to be used? by whom? what level of GIS development is required to meet the immediate requirements of the control programme? Where computer-based systems are not available, sketch maps with broad classification of risk areas into highland and desert-fringe areas, seasonal transmission areas, normally malaria-free areas, and complex emergency situations are still informative and should be used.

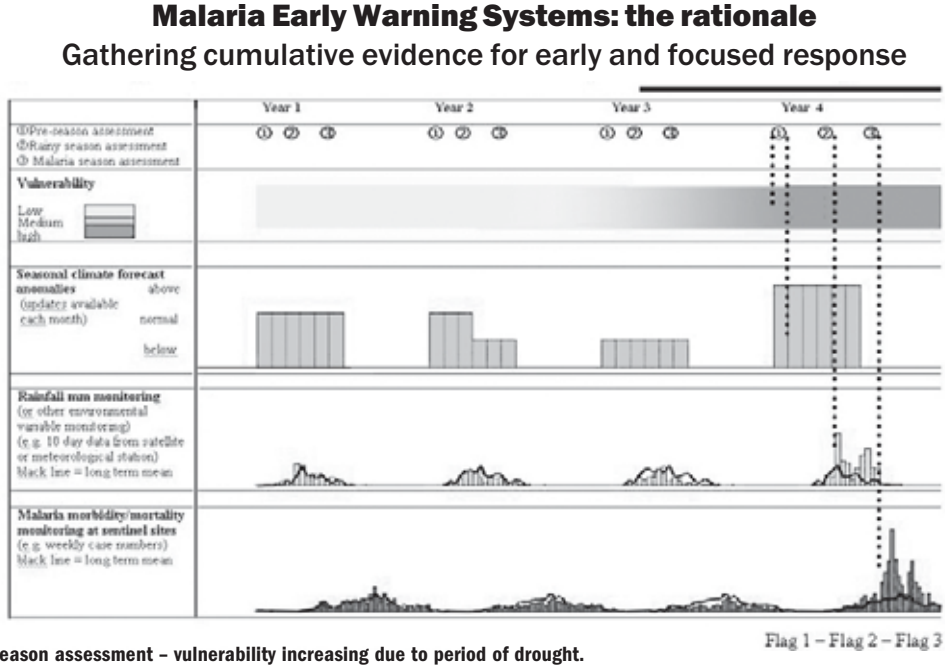
6. LONG-RANGE FORECASTING, EARLY WARNING AND EARLY DETECTION

Long-range forecasting, early warning and early detection monitor escalation towards a possible epidemic with decreasing lead-times but increasing accuracy and spatial resolution of prediction (Kovats et al., 2003). Data provided by these three surveillance mechanisms are sequential and complementary, allowing health services to prepare and mobilize appropriate prevention and control activities in a timely manner.

[3] Center for International Earth Science Information Network, http://www.ciesin.org

6.1 Rationale

Systems for early warning and long-range forecasting (if proven to be sufficiently accurate) have an important role to play in reducing the adverse outcomes of epidemics through preparedness and prevention. The rationale for early detection, early warning and long-range forecasting of malaria epidemics is shown in Figure 1.



Year 3 Pre-season assessment – vulnerability increasing due to period of drought.
Year 4 Pre-season assessment – vulnerability still increasing due to period of drought and seasonal forecast above normal – Flag 1.
Year 4 Rainy season assessment – vulnerability remains high, weather monitoring indicates higher than normal rainfall – Flag 2.
Year 4 Malaria season assessment – vulnerability remains high, rainfall higher than normal through much of season, malaria cases pass epidemic threshold – Flag 3.

Figure 1: The use of early warning indicators in the malaria control planning cycle (WHO, 2001a)

Vulnerability indicators predict the potential severity but not the timing of epidemics. Some, especially climatic, indicators may be relatively stable over time. Others, such as civil unrest, population displacement and insecurity of food supply, may change abruptly and require routine monitoring.

Long-range forecasting is based on ENSO[4] indices and climate forecasting (WHO, 2001a). For areas in which future climates can be predicted, such measurements can very broadly forecast malaria epidemic risk months in advance, thus giving countries time to plan for the availability of resources should an epidemic occur in the coming season.

Early warning is based on monitoring of climatic indicators, population vulnerability factors and operational and environmental factors in order to detect whether epidemic-conducive conditions already exist at a given time and place (Nájera, 1999). It can potentially predict epidemics weeks to months in advance, allowing enhanced surveillance and targeting of preventive and control measures in specific areas.

[4] ENSO or the El Niño Southern Oscillation is a seesaw of atmospheric pressure between the eastern equatorial and Indo-Australian areas of the Pacific Ocean which can produce serious weather disturbances in wide areas throughout the world (Bouma & van der Kaay, 1994, 1996). El Niño events occur roughly every 2–7 years and are associated with severe floods in some areas and drought in others. The risk of a natural disaster is highest in the years during and after the appearance of El Niño or La Niña and lowest in the years when ENSO is weak. The 1991–1992 El Niño, for example, brought the worst droughts in southern Africa in the 20th century: nearly 100 million people were affected. La Niña is characterized by unusually cold ocean temperatures in the equatorial Pacific.

Early detection attempts to detect the beginning stages of an epidemic by measuring changes in the incidence of malaria cases. This method offers very little lead-time (days to weeks) for preparation of control measures – generally not enough time to prepare and implement effective malaria prevention. However, if the epidemic is detected early in its development and the response is rapid and effective, peak morbidity and mortality can be averted.

6.2 Vulnerability assessment

The first step in a vulnerability assessment is the identification of areas at risk of epidemics based on climatic factors and the incidence of previous malaria epidemics. However, vulnerability may change over time because of other factors, including:

- prolonged drought;
- migration of non-immune populations into malaria risk areas, either in search of work or because of civil unrest;
- poor nutritional status of the population;
- high incidence of other diseases that may compromise health status, e.g. HIV;
- breakdown of control activities;
- drug resistance of the parasite; and
- environmental changes that increase the risk of transmission, such as the construction of dams, agricultural projects, and flooding or drying out along river margins.

It is not difficult to monitor these factors and monitoring should be carried out regularly. Much of this information can be obtained by peripheral and district health services with an intimate knowledge of the local situation and able to match these factors to epidemic risk. Nevertheless, data of this kind are still not systematically collected by or reported to the malaria control programmes.

6.3 Climatic indicators

Climatic indicators can be used to predict the timing of an impending malaria epidemic. Excessive rainfall is usually associated with epidemics in arid and semi-arid areas where the limiting factor for malaria transmission is the absence of breeding sites. The risk of such epidemics is increased in areas of Africa where members of the *Anopheles gambiae* complex are the principal vectors: these efficient vectors of falciparum malaria breed mainly in temporary rain pools close to human dwellings.

The combination of increased rainfall and higher temperatures is particularly conducive to malaria epidemics in highland and cool desert-fringe areas where both are normally limiting factors for transmission. These variables should be monitored locally and validated in all such epidemic-prone areas.

6.4 Long-range forecasting

The ability to predict ENSO and associated climate anomalies is dependent on the time of year. Climate variability is also more predictable in some areas than in others.

ENSO and climate are most predictable from about June when forecasts can be provided for up to 10 months ahead, and least predictable around March when predictions may be accurate for only three months at most. In areas such as the Sahel, where most rain falls in the months immediately after June, forecasts may therefore be available only shortly before the rainy season starts, whereas

in southern Africa, where the peak rainfall occurs between December and January, it may be possible to obtain long lead-times.

In many countries, increases in malaria transmission occur cyclically over periods of 2–7 years. In Colombia, India, Madagascar, Sri Lanka and Venezuela these changes have been linked to altered weather conditions during the ENSO cycle (Bouma & van der Kaay, 1994, 1996; Bouma et al., 1997). It has therefore been suggested that, where they are freely and routinely available, climate forecasts could be used to predict future malaria epidemics, allowing countries time to ensure availability of resources (staff training, drugs, ITNs, insecticides) and raise community awareness in the event of an epidemic in the coming season. There is an extensive literature on ENSO and climate prediction (see Goddard et al., 2001).

Practical challenges to the use of long-range climate forecasting for prediction of malaria epidemics are (i) the need to identify local climate factors that favour epidemics and subsequently to circumscribe geographical regions where long-range forecasting is feasible, and (ii) the interplay of climatic factors with other factors such as population immunity. Advance prediction of El Niño events is still problematic although seasonal climate forecasts are generally more reliable during an El Niño event because of its marked effect on climate (Kovats et al., 2003). It is difficult to generalize about the association between malaria transmission, El Niño events and medium-term weather forecasting since local transmission depends on the ecology of the local vector species, which can differ in their response to the period and amount of rainfall.

International long-range forecasts are regularly updated as more specific indicators of an impending event become available, thus enhancing accuracy. They can be converted into practical and simple public health tools by linking forecasts (with clear estimates of their accuracy) to specific programme decisions at each point in time for each health care level: what courses of action are available to take in which situations.

Current research is focused on the impact of ENSO on the risk of malaria epidemics in highland and desert-fringe areas. While more accurate prediction models and systems are still being developed, simple and crude warning methods can already be used to advantage, allowing prospective monitoring and validation; for example, SAMC in southern Africa is translating seasonal climate forecasts into seasonal malaria forecasts.

6.5 Early warning

MEWS provide incremental early warnings based on known meteorological (rainfall, temperature), environmental, social or occupational (e.g. migration, agricultural developments) risk factors and other potential indicators, in order to enhance malaria epidemic preparedness and prevention. The aim is to gather cumulative evidence for an early and targeted response to an epidemic threat. Information can be used to assign resources to specific areas and to implement preventive measures.

Prediction is possible only if (i) sufficient information about past events is available, (ii) information can be quantified as numerical data, and (iii) aspects of the past pattern are highly likely to continue into the future. Early warning indicators such as temperature and rainfall can predict the time and place of an epidemic; population vulnerability indicators will predict the severity of disease outcome in the event of an epidemic.

Prediction is useful only if there is a lapse between awareness of an impending event and its occurrence: the lead-time should be used for planning, and forecasting should be integrated within decision-making. Forecasts should be linked to decision-support options (courses of action that may be taken in a given situation) and include an estimation of predictive uncertainty that can be

taken into account when making decisions. The most useful format for communicating early warnings should be developed in conjunction with end-users.

Unusual rainfall increases may predict the timing of an increase in transmission up to 2–4 months before a malaria epidemic occurs. In some situations, a higher-than-average seasonal rainfall may be predicted from seasonal climate forecasts 2–6 months in advance.

In many countries, health services may obtain meteorological data through the national weather centres, which measure and record rainfall, temperature and sometimes humidity. Since June 2002, rainfall anomaly maps for Africa covering 10–day periods have been available from ADDS.

6.5.1 Current constraints

The full practical potential of MEWS has not yet been realized. Detailed mapping and stratification of areas according to risk are not yet available for many epidemic-prone districts. The relationship between early warning indicators and malaria is complex, variable and regionally specific. As a result, operational action thresholds must be derived separately for each district concerned. At the same time, many countries lack the skilled human resources to issue, interpret, utilize or respond to forecasts at national and district levels.

One of the obstacles to the practical development of local MEWS is a lack of reliable morbidity data and representative data on weather and other risk factors. Methods to validate available prediction systems have not yet been standardized, and validation is often based on retrospective data with too little prospective data to allow in-depth examination of correlations. Representative sentinel sites may be selected to gather high-quality prospective data, as in the HIMAL[5] experience. It ought to be possible to improve teamwork between health and other sectors (e.g. meteorological services) at national and local levels.

Once up and running, MEWS should stimulate a prompt and effective response from health services and community: it is thus essential that health services and other relevant sectors, as well as the community at risk, are in regular routine communication. Use should be made of the information and communication technologies most relevant to the local situation, e.g. rural radio and satellite communication. Wherever appropriate, MEWS should involve partnerships with information and communication technology (ICT) organizations.

6.5.2 Status of implementation

Over the past few years, MEWS in Africa has gone from the research stage to a practical public health tool. It is showing good promise in southern Africa: the Southern Africa Development Cooperation's Drought Monitoring Centre in Botswana now provides the national malaria control programme with regular assessments of drought and food security status. Botswana, Swaziland and to a lesser extent Madagascar, Namibia and the United Republic of Tanzania routinely use rainfall, temperature and population vulnerability as indicators for the early warning of malaria epidemics. These indicators are also monitored by sentinel sites in the HIMAL project to develop systems for the prediction and detection of malaria epidemics in the East African Highlands of Kenya and Uganda, and in Madagascar. In another project, weather and malaria data from Ethiopia, Kenya and Sudan are analysed in order to obtain MEWS indicators and thresholds.

[5] HIMAL – the Highlands Malaria Project is a joint project between the Ministries of Health in Kenya and Uganda, the London School of Hygiene and Tropical Medicine and the University of Oxford, England. It has been a component of the Mapping Malaria Risk in Africa (MARA) project since 1998.

In south America, the Brazilian malaria control programme is working with the Ministry of Agriculture in the planning and implementation of new agricultural projects in order to prevent the epidemics that used to afflict the Amazon region. In addition, the World Meteorological Organization (WMO) has established a centre in Guayaquil, Ecuador, to develop early warning systems for health and development, including malaria prevention and control.

Other MEWS activities are beneficial in terms of raising awareness, helping countries to identify epidemic-prone regions and consider what risk indicators should be monitored and how to use various control options in the time available. Remote sensing data (e.g. Normalized Difference Vegetation Index, rainfall estimate, population density) are increasingly used to forecast and map malaria transmission risks.

Nine countries have included MEWS with climate and vulnerability monitoring in their application to the Global Fund (GFATM) as part of their action plans for the prevention and control of malaria epidemics in 2004: Eritrea, Ethiopia, Kenya, Mali, Niger, Pakistan, Senegal, Uganda and Zambia.

6.5.3 Improving multisectoral collaboration

MEWS information used by health services is usually collected by other government sectors (e.g. rainfall data by the meteorological services and population movement data by the national statistics department). The success of MEWS thus depends on successful intersectoral collaboration.

Health services must identify where they can obtain critical MEWS information and build working partnerships with these services in order to develop appropriate and sustainable early warning systems. On a practical level this may imply that donor proposals for development of local MEWS may need logistic support to improve these other services.

Examples of international networks that can provide essential MEWS information are FEWS[6] (Famine Early Warning System) and the World Weather Watch.[7] WMO[8] has also adopted several resolutions to promote data exchange and provide meteorological data at no cost for education, research and early warning systems such as MEWS.

Other potential partners in MEWS are the research and scientific institutions that process meteorological and environmental data and make climate predictions. Health services should encourage local institutions to become involved in weather data analysis and assessing how climate variability affects the development of strategies against major health problems such as malaria. Implementing such strategies would be a major step forwards in improving health and reducing poverty, and thus contribute to the achievement of the United Nations Millennium Development Goals.

It might also be possible to find resources for developing MEWS through joint work with initiatives such as NEPAD[9] (New Partnership for Africa's Development) and the various climate-development partnerships such as PARSAC-Africa. This would bring together health, climate and environmental communities, all of which have a role to play in malaria epidemic control and prevention.

To support local MEWS, WHO/Healthmapper should develop and maintain appropriate databases to facilitate the exchange of GIS, demographic surveillance (e.g. INDEPTH[10]) and other relevant climate and environmental data at national and regional levels. Capitalizing on relevant experience from other sectors, WHO should develop an "information tool box" for epidemic early warning systems and response strategies at the district level.

[6] http://www.fews.org
[7] http://www.wmo.int/web/www
[8] http://www.wmo.int
[9] http://www.nepad.org
[10] http://www.indepth-network.org

6.5.4 Research issues

There is need to:

- conduct cost-analysis for MEWS and determine the economic impact of early versus late implementation of responses to contain malaria epidemics;
- develop standardized criteria for evaluating MEWS; and
- document and evaluate experiences (including constraints) on how MEWS is currently used in order to determine the scope for wider application.

6.6 Early detection of epidemics

An early detection system (EDS) is based on surveillance data of clinical malaria cases, laboratory-diagnosed malaria cases, and malaria mortality. These data can be used for the early detection of a potential malaria epidemic only if:

- data collection and notification are punctual;
- data collection is representative;
- data analysis is prompt; and
- data interpretation provides an accurate indication of an unfolding epidemic.

In most countries, health information systems routinely collect and report health data, including data on the incidence of malaria, monthly and sometimes even quarterly. The time taken to report these data to a higher level (e.g. from health care facilities to the district management team) is at least 10 days and usually significantly longer. Experience shows that malaria epidemics develop relatively quickly and tend to last 3–4 months on average. It is clear, therefore, that a monthly reporting system is unable to detect at an early stage the increase in suspected malaria cases that would indicate an emerging epidemic. This situation is compounded by the fact that peripheral health workers are not trained to analyse the data they generate and, consequently, usually do not react to their implications. As a result, the health services are unable to mobilize the resources needed to control the epidemic in a timely manner.

In 2000, this led African heads of state and ministers of health in Abuja, Nigeria, to agree on several key malaria targets, one of which was **"to detect and control epidemics within 2 weeks of onset"** (WHO, 2000a).

In some countries, e.g. Botswana and Swaziland, malaria incidence is reported from all health facilities on a weekly basis – which is more likely to ensure a rapid response. Increasingly, countries outside southern Africa, e.g. Mali and Niger, are using sentinel sites to report malaria cases on a weekly basis.

6.6.1 Reporting and data analysis

The group recommended that a weekly reporting system should be introduced wherever possible, but recognized that not all countries are currently able to do this. In many cases, monthly reporting and a concerted effort to improve the quality of data collection and reporting would be a better starting-point. This would involve:

- improving diagnostic capacities in peripheral areas;
- making staff more aware of the reasons for data collection and the use to which data will be put;
- encouraging peripheral health workers to record data in the form of graphs, thus making abnormalities easier to detect;

- enabling peripheral health workers to make appropriate (and simple) interpretations based on recommendations supplied by district staff;
- wherever possible, building upon existing surveillance approaches, and regular dialogue between peripheral and district health staff.

Peripheral units should be encouraged to record and interpret data on a weekly basis even when they are not able to report them on a weekly basis.

6.6.2 Parasitological confirmation of fever cases

It was agreed that the principal role of parasitological confirmation was to establish whether malaria was the primary cause of any unusual rise in febrile illness.

There is added value in being able to undertake confirmatory testing at the peripheral level. Local malaria epidemiology determines whether such testing would be conducted routinely, seasonally or to provide an on-the-spot assessment of aberrations in patterns of febrile illness.

It was recognized that rapid diagnostic tests (RDTs) have a role to play in parasitological confirmation; however, they are not foolproof, and appropriate training, supervision and guidelines are required (see also section 7).

6.6.3 Use of other data for EDS

Collation of health data other than those that are currently included on standard outpatient attendance records should be encouraged – inpatient data, slide-positivity rate (SPR), drug usage, blood transfusions, etc.

6.6.4 Use of sentinel sites for surveillance

In epidemic-prone areas of countries where laboratory diagnostic facilities are poorly developed, it may be cost-effective to designate certain health centres with laboratory facilities for malaria diagnosis as sentinel sites. Data from these centres could then be relayed to the district and provincial authorities on a weekly basis. Malaria sentinel sites now exist in many Africa countries, including Angola, Botswana, Kenya, Malawi, Mozambique, Namibia, South Africa, Swaziland, Uganda, the United Republic of Tanzania, Zambia and Zimbabwe. A weekly notification system based on sentinel site monitoring is becoming routine in certain of these countries, such as Botswana and Zimbabwe, and offers the possibility of detecting malaria epidemics early in their development.

The choice of the sentinel sites is crucial. Their suitability should be determined by the following factors:

- vulnerability assessment, including an epidemiological assessment and whether previous malaria epidemics have occurred in the area;
- whether health delivery, diagnostic facilities and data recording are of high quality;
- size and “representativeness” of the population served by the site; and
- population movements in the area.

EDS should not rely solely on sentinel site monitoring, because epidemics may well occur outside the catchment areas of these health services. In areas with nomadic populations, mobile sentinel sites may be considered (see also section 8.6).

6.6.5 Epidemic thresholds

Attempts have been made to identify epidemic thresholds that can provide an unambiguous definition of normal variations and abnormalities in malaria incidence as compared with earlier experiences of the disease in a particular area.

Determining such thresholds is relatively easy in areas where (i) there are functioning health information systems; (ii) there is a good health care coverage; (iii) historical epidemiological data are available for a period of several years; (iv) there is a history of epidemics; and (v) the population has remained stable.

Several epidemic threshold methods have been developed (WHO, 2004a):

- constant case count thresholds;
- normal channel of mean monthly/weekly number of malaria cases ±2 standard deviations;
- upper third quartile method; and
- cumulative sum method, with or without 1.96 standard deviations.

Most of these methods aim to identify those points in a disease-incidence time series that fall outside the 95% confidence intervals of a normal distribution curve determined from the history of cases at any given location. Normally, historical malaria incidence data for at least 5 years are required, and these may be partially or completely lacking in many areas. In such situations, alternative strategies need to be developed, based, for example, on SPR or on some form of situational analysis.

Given the uncertainty about whether these thresholds are appropriate, the group recommended that:

- training for peripheral staff with regard to epidemic thresholds should not be prescriptive but aimed at enabling them to interpret relative changes in case numbers and assess the implications of these variations from the point of view of disease control; and
- threshold development and evaluation should be a future priority topic for an RBM review.

6.6.6 Integration of malaria EDS

Integration of malaria EDS into more general disease surveillance systems should be encouraged as it is likely to be beneficial in terms of improving data quality and system efficiency. This is contingent on the provision of appropriate training and feedback at peripheral levels and on the degree of correspondence between surveillance approaches and malaria control needs.

The group discussed the proposal that malaria in epidemic-prone areas should become a WHO “notifiable” disease but failed to reach consensus. It was noted that such an approach would be feasible only if routine parasitological confirmation of all suspected malaria fever cases were introduced in all epidemic-prone areas.

6.7 Capacity building

The capacity of countries for malaria epidemiology and planning malaria epidemic prevention and control is generally limited. Few countries are able to collect and analyse the relevant data and report promptly enough to implement effective control or prevention. The key to success will be capacity building, realistic planning and community awareness.

6.7.1 Training

Priority should be given to training at:

- peripheral levels – in simple surveillance techniques;
- district levels – in surveillance, data analysis and planning an effective epidemic response; and
- central level – in strategic planning for malaria epidemic control and prevention.

To support this training, the following guidelines and training materials have been produced by the TSN:

- standard malaria epidemic reporting forms as part of rapid assessment guidelines that include "post mortem" assessments, which are currently being field-tested;
- draft guidelines for the prevention and control of malaria epidemics, which were to be finalized following this meeting;
- a draft epidemic training module for use in international and national training courses, which was evaluated in courses held in Benin and Ethiopia in 2003; and
- a protocol for assessment of the economic impact of malaria epidemics, which is currently being evaluated in Ethiopia.

6.7.2 Realistic planning

Comprehensive details on the planning of early warning and early detection systems have been previously developed by the TSN (WHO, 2001a). However, many programmes will not have the resources to implement all stages in the continuum of early detection, early warning and forecasting of epidemics.

It is more realistic to begin modestly and give priority to improving surveillance using a restricted number of validated indicators: the complexity of the system can be stepped up as staff capabilities improve, new information and techniques become available from research, and collaboration is established with other partners and information sources

7. MALARIA DIAGNOSIS

7.1 General principles

Early diagnosis and treatment are the keys to reducing malaria morbidity and mortality. However, in epidemic and complex emergency situations, facilities for laboratory diagnosis may be either unavailable or so overwhelmed with the caseload that parasite-based diagnosis is impossible. In such circumstances, it is impractical and unnecessary to demonstrate parasites before treatment in all cases of fever. Once malaria has been confirmed, and if case numbers are high, treatment based solely on the clinical history is appropriate in most cases, using a full treatment course.

However, parasite-based diagnosis is essential to:

- diagnose the cause of an epidemic of febrile illness;
- confirm the end of an epidemic; and
- follow progress in high-risk cases, e.g. severe malaria.

It would also be useful to diagnose a proportion of cases parasitologically during the epidemic, to monitor the SPR. As the epidemic wanes, the proportion of fever cases investigated for parasites

can be increased. It is important to monitor the clinical response to treatment wherever possible, bearing in mind that other causes of fever may be involved.

In mixed falciparum/vivax epidemics, parasitaemia should be monitored in order to determine a species-specific treatment. When case numbers are high, schizontocidal treatment based on clinical diagnosis and targeted at the more resistant parasite is appropriate. In these circumstances, treatment should be completely effective against both species. Sulfadoxine/pyrimethamine should never be used alone as it is not fully effective against *P. vivax* infections. One advantage of parasitological diagnosis is that it allows vivax cases to be traced for anti-relapse therapy, once the acute phase of the epidemic has waned.

7.2 Rapid diagnostic tests

7.2.1 Principles

When parasite-based diagnosis is essential, rapid diagnostic tests (RDTs) may be an alternative to light microscopy in situations where normal laboratory services are non-existent or overworked. RDTs are immuno-chromatographic tests that detect parasite-specific antigens in a finger-prick blood sample. Some tests detect only one species (*Plasmodium falciparum*), others detect one or more of the other three species of human malaria parasites (*P. vivax*, *P. malariae* and *P. ovale*) (WHO, 2000b, 2003a). RDTs are commercially available in different formats, as dipsticks, cassettes or cards. Cassettes and cards are easier to use in difficult conditions outside health facilities.

7.2.2 Current experience

The potential advantages of RDTs include:

- producing rapid results;
- needing a lower level of training/skilled personnel;
- requiring lower capital costs than light microscopy (although RDTs can be more costly when case numbers are high);
- reinforcing patient confidence in the diagnosis; and
- permitting rational use of expensive drugs, thus reducing costs in areas where artemisinin-based combination therapy (ACT) is required for *P. falciparum* but microscopic diagnosis is not available; this may not apply if parasite prevalence is very high, when the additional costs of improved diagnosis may provide little benefit in terms of savings on drug costs.

RDTs also have some disadvantages:

- where prevalence (and host immunity) is high, positive RDT test results may mislead the diagnosis in patients with incidental parasitaemia in the presence of another illness;
- they detect antigens and not parasites – results may therefore reflect recent and not current parasitaemia; however, antigen detection may be a better reflection of parasite load than light microscopy;
- sensitivity in the field may be unpredictable: published sensitivities for *P. falciparum* range from comparable to good field microscopy (> 90% at 100–500 parasite/µl) to very poor (40–50%) for some widely used products, and are generally lower for non-falciparum species.

Reasons for poor sensitivity are not clear. They may include:

- poor manufacture;
- damage due to temperature or humidity exposure;
- incorrect handling by end-users;

- possible geographical variation in the test antigen; and
- poor comparative microscopy.

7.2.3 Quality assurance and storage

Variable field performance and sensitivity to damage through heat exposure underline the importance of quality-control testing and careful monitoring of RDTs. It should also be noted that:

- there is currently no standardized way of testing RDT sensitivity;
- no RDT has been approved by the United States Food and Drug Administration; and
- many endemic countries have no national regulations covering the quality and use of diagnostics.

The recommended storage temperature for most products is below 30 ºC. This is impossible to achieve in remote places in many endemic areas. Exposure to higher temperature shortens the shelf-life (currently 1–2 years). Short-term exposure to high temperatures (e.g. in parked vehicles exposed to the sun) can rapidly denature some products. Temperature sensitivity appears to vary widely between products.

Stability at prolonged high temperatures may be of less importance when RDTs are to be used in malaria epidemics and some complex emergency situations, since they can be stored centrally under controlled conditions and used in the field only when required. However, storage facilities at a complex emergency site are likely to be poorer and end-user training may be less predictable.

Some form of quality assurance of RDT test results should be undertaken, for example by taking blood films in a proportion of RDT-tested patients and cross-checking results by reliable and good-quality light microscopy. It is also appropriate to test new “lots” or batches for sensitivity after purchase and before field use.

7.2.4 Use in epidemic situations

RDTs offer the advantage of simplicity and speed in epidemic situations, but heat stability may be a problem and false-negative results may be seen. A negative result should not automatically preclude treatment, especially in severe clinical disease.

Current experience with RDTs indicates that:

- they are useful for confirming the cause and end-point of malaria epidemics;
- they should not be relied on as the sole basis for treatment;
- they should be backed up with adequate quality assurance, including temperature stability testing; and
- negative test results should not preclude treatment.

If RDTs are used, transport and storage should be based on the following principles:

- Avoid heat exposure, e.g. at airports and in vehicles.
- Ensure that stockpiles are stored in central locations that are kept as cool as possible (e.g. air-conditioned areas) in readiness for an outbreak, with quality testing every few months to ensure that RDTs remain in good condition. Proper storage extends the shelf-life.
- Seek to maximize the length of time for which RDTs are kept under such conditions before rapidly deploying them to the field for short-term use.
- Consider simple methods to reduce the temperature at outlying sites (e.g. evaporative cooling, thatched roofs).

8. MALARIA DISEASE MANAGEMENT

8.1 Managing uncomplicated malaria

8.1.1 Guiding principles

Malaria epidemics are emergencies in which populations at risk in epidemic-prone areas are mainly non-immune or only partially immune. The blood schizontocidal drug to be used in epidemics (and complex emergencies) must therefore:

- be highly efficacious (> 95% cure);
- be safe; and
- offer good patient compliance.

Complete treatment doses should always be given in all circumstances.

8.1.2 Choice of blood schizontocidal drugs

Global malaria control is being threatened on an unprecedented scale by the rapidly growing resistance of *P. falciparum* to conventional monotherapies such as chloroquine, sulfadoxine/pyrimethamine (S/P) and amodiaquine. Multiresistant falciparum malaria is widely prevalent in South-East Asia and south America, and drug resistance is now also seriously affecting Africa.

As a response to this situation, WHO recommends that treatment policies for falciparum malaria in all countries experiencing resistance to monotherapies should be based on the use of combination therapies, preferably those based on artemisinin derivatives (WHO, 2004b).

The advantages of artemisinin and its derivatives for combination therapy are:

- rapid reduction of parasite densities;
- rapid resolution of clinical symptoms;
- effective action against multidrug-resistant *P. falciparum*;
- no documented resistance as yet;
- few adverse clinical reactions; and
- reduction of gametocyte carrier rate with possible reduction in transmission.

These features of artemisinin-based combination therapies (ACTs) make them ideally suited for the management of uncomplicated malaria in epidemic situations, in line with the guiding principles established above.

Recommendations for the management of uncomplicated malaria in epidemic situations are as follows:

P. falciparum epidemic-prone areas

ACTs are recommended for all areas with the exception of central America and Hispaniola, where chloroquine and S/P still have a very high efficacy against falciparum malaria. Elsewhere, ACTs are preferable as resistance to chloroquine and S/P is common.

In situations where ACTs are not immediately available, the most effective alternative should be used while delivery of ACTs is awaited.

Mixed *P. falciparum* and *P. vivax* epidemic-prone areas *(see also section 8.3)*

Resistance of *P. vivax* to chloroquine has been reported from South-East Asia and Oceania but is probably limited. There is insufficient knowledge at present to allow specific recommendations to be made for treatment of *P. vivax* in areas of suspected resistance, since pure vivax epidemics are rare in these areas. ACT should be used for treatment.

P. vivax epidemic-prone areas

In areas with pure vivax epidemics, drug resistance has not been reported. Chloroquine is therefore the most appropriate drug once the cause of the epidemic has been established.

The following ACT combinations are recommended by WHO (WHO 2001b, 2003b, 2004b):

- Artemether/lumefantrine. This combination is a 3-day regimen registered under the brand-name Coartem®[11] for developing countries. It is currently the only available fixed combination, and is also the only ACT included in the WHO Model List of Essential Medicines (WHO, 2003c). Parasite resistance to either component has yet to be reported, which makes this combination the treatment of choice where information on the drug sensitivity pattern of local parasites is lacking. WHO has reached agreement with the manufacturer for differential pricing of Coartem® for public sector use in malaria-endemic countries. The current cost to developing countries is US$ 2.40 per adult treatment dose (WHO, 2003b).
- Artesunate plus amodiaquine. The combination of 3-day artesunate with standard 3-day amodiaquine (WHO, 2001b) has been shown to reduce treatment failure, recrudescence and gametocyte carriage substantially when compared with standard amodiaquine therapy in clinical trials in Gabon, Kenya and Senegal (Adjuik et al., 2002; International Artemisinin Study Group, 2004). The average cost of this combination was estimated in 2002 to be US$ 2.40 per adult treatment dose, although the price is expected to drop considerably with time (WHO, 2003b). This combination may be considered where recent data indicate that resistance to amodiaquine is low.
- Artesunate plus S/P. This combination of 3-day artesunate plus a standard single dose of S/P has been shown to reduce treatment failure, recrudescence and gametocyte carriage substantially when compared with standard S/P therapy in trials conducted in Gambia, Kenya, Malawi, Peru and Uganda (von Seidlein et al., 2000; Dorsey et al., 2002; International Artemisinin Study Group, 2002, 2004). It was estimated in 2001 that the cost of an adult treatment dose of this combination was US$ 2.24 (WHO, 2001b). The use of this combination may be considered where recent data indicate that resistance to S/P is low.
- Artesunate plus mefloquine. This combination has been shown to improve treatment efficacy and also to contain multidrug resistance in South-East Asia (White & Olliaro, 1996; White, 1999; International Artemisinin Study Group, 2004). There is no documented experience of the use of this combination in Africa. Use in epidemic situations is hampered by the cost (estimated to be US$ 5.38 per adult treatment dose) and the long half-life of mefloquine and its potential to produce adverse reactions in certain circumstances (WHO, 2001b).

Artesunate–amodiaquine and artesunate–S/P are available as multiple-dose therapy or blister-packed combinations.

At present, artemisinin compounds cannot be recommended for treatment of uncomplicated malaria in the first trimester of **pregnancy**. However, they should not be withheld if treatment is considered to be lifesaving for the mother and other antimalarials are considered unsuitable. Because safety data are limited, artemisinin compounds should be used in the second and third trimesters only

[11] Coartem® is not currently licensed for use in children under 10 kg, but is likely to receive this indication very soon

when other treatments are not suitable. Alternatives are quinine or S/P where these drugs are still effective; S/P should not be used in the first trimester.

8.2 Use of gametocytocidal drugs to reduce transmission

When ACT is not used, a single dose of 45 mg primaquine combined with a fully active blood schizontocide can be used to reduce transmission provided that it is possible to achieve high coverage (> 85%) of the population infected with malaria (WHO, 1994, 2001b). This strategy has been effective in South-East Asia and south America where the single primaquine dose was well tolerated and prior testing for glucose-6-phosphate dehydrogenase (G6PD) deficiency was not required. There is no experience with its use in Africa, where there is the highest prevalence of G6PD deficiency in the world.

The use of single-dose primaquine is contraindicated in **pregnancy** since the foetus is G6PD-deficient (WHO, 2001b).

8.3 Anti-relapse therapy – vivax epidemics

Anti-relapse therapy for vivax malaria is impractical in most epidemic situations because of the duration of treatment and poor compliance. If adequate records are kept, it can be given in the post-epidemic period to patients who have been treated with blood schizontocides.

The WHO-recommended course of 15 mg primaquine base/kg for 14 days is appropriate (WHO, 2001b), but not a course of 15 mg primaquine base/kg for 5 days (Rowland et al., 1999). Compliance with anti-relapse therapy is often poor and the drug should ideally be given under supervision, which is very difficult in many epidemic situations. Compliance problems can be overcome with appropriate health education even when the majority of individuals are illiterate and have no formal education (Leslie et al., 2004).

The radical curative action of primaquine appears to be correlated with the total dose and not with the duration of treatment. More research is needed to evaluate the efficacy of other regimens that may increase compliance without decreasing efficacy.

Primaquine may cause haemolysis in G6PD-deficient patients: whenever possible, therefore, G6PD deficiency should be excluded before treatment. However, G6PD deficiency alone should not necessarily preclude treatment as haemolysis in most cases is mild and self-limiting. Although screening tests for G6PD deficiency exist, there is a need to develop simpler tests for use in the field.

Primaquine is contraindicated in **pregnancy** since the foetus is G6PD-deficient (WHO, 2001b). Anti-relapse therapy can be started after delivery.

8.4 Managing severe malaria

Management of severe malaria in epidemic situations will often take place in temporary clinics or situations in which staff shortages and high workloads make intensive care monitoring difficult. Drug treatment should therefore be as safe as possible, with simple dosing schedules and a minimum need for monitoring.

Data indicate that the efficacy of intravenous (IV) quinine and intramuscular (IM) artemether are similar under hospital conditions (WHO, 2000c). However, the more complicated dosing regimen of IV quinine and the accompanying need to monitor both cardiac function and glucose levels make IM artemether the drug of choice for severe malaria in most epidemic situations.

Intramuscular artemether is included in the WHO complementary Model List of Essential Medicines as a reserve antimalarial (WHO, 2003c).

Artesunate suppositories are now being produced under conditions of Good Manufacturing Practice, and one formulation, Plasmotrim®, has been registered in several African countries. However, experience with these products is limited. Their use may be appropriate in severely ill patients who are unable to swallow oral medication when IM artemether (or IV quinine) is unavailable (Bhatt, 1996; WHO, 2000c; Krishna et al., 2001; UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases, 2003). If artesunate suppositories are used, patients should be moved as soon as possible to a facility where IM or IV therapy can be started. When the patient cannot be moved, continued treatment with rectal artesunate is appropriate until he or she can take oral drugs. There is very little evidence on the efficacy of suppository formulations during operational use, and these formulations should be considered only when alternatives are unavailable.

Where conditions allow intensive care monitoring, quinine may be used safely for the treatment of severe malaria in all stages of pregnancy. Intramuscular artemether is the drug of choice in the second and third trimesters.[12]

8.5 Mass drug administration

Mass drug administration (MDA – mass treatment of all, or a large section, of the population whether symptoms are present or not) has been carried out in the past, usually in conjunction with insecticide residual spraying, as a way of controlling epidemics. There is little evidence that it is efficacious. Recently, von Seidlein and Greenwood (2003) analysed the results of 19 MDA projects during the period 1932–1999, but it proved very difficult to draw definitive conclusions from the analysis because study designs were so variable. Many projects were unsuccessful, although a reduction in parasite prevalence and some transient reduction in mortality and morbidity occurred in some cases. Reduced transmission was seen only in one study, in Vanuatu, where MDA was provided to a relatively small, well-defined and controlled population. It remained unclear how much MDA contributed to the overall situation and whether mass treatment has advantages over treatment of symptomatic patients.

The group was unanimous in agreeing that there is no convincing evidence for the efficacy of MDA. Mass treatment of symptomatic febrile patients is considered appropriate in epidemic and complex emergency situations. Whenever this strategy is adopted, a full treatment dose should be given: the criteria for drug selection are the same as those for the treatment of uncomplicated malaria (see section 8.1.2. above). It is recommended that an active search be made for febrile patients to ensure that as many cases as possible are treated, rather than relying on patients to come to a static clinic.

8.6 The role of mobile clinics

Mobile heath teams and temporary health stations can fulfil a vital role during epidemics. Both have the potential to:

- provide health care to populations removed from permanent health facilities;
- ease the pressure on existing permanent facilities; and
- undertake rapid surveys to confirm epidemics and identify areas in need of reinforced disease management and anti-vector measures.

They should be capable of:

- carrying out parasitological diagnosis;

[12] IMPAC document *Managing complications in pregnancy and childbirth* (WHO/RHR/00.7)

- managing both uncomplicated and severe malaria: and
- providing communication and health education activities likely to encourage local people to seek appropriate treatment and comply with treatment regimens.

Maintaining mobile teams is an expensive way of providing health care, and careful thought must be given to allocating staff in such a way that other programmes are not depleted. Mobile teams should be considered only as a temporary, time-limited measure. Once the epidemic has been brought under control, resources should be reallocated as soon as possible in order to reinforce local health systems, thereby helping them to avert or cope with future epidemics.

8.7 Interagency new emergency health kit[13]

The kit was developed for emergency situation use by a partnership including WHO, United Nations Children's Fund (UNICEF), International Committee of the Red Cross (ICRC), Médecins Sans Frontières (MSF) and other agencies. It is designed to provide medicines and medical supplies for 10 000 people for approximately 3 months. Kits are provided by UNICEF, the International Dispensary Association, Action Pharma and MSF. It is recommended that the antimalarials and guidelines for malarial disease management supplied with the kit be updated in accordance with the conclusions of this meeting.

8.8 Preparedness

8.8.1 Monitoring drug resistance

In epidemics and complex emergencies there is no opportunity to monitor drug efficacy and scant prospect of patient follow-up. Drug resistance monitoring must be an integral part of preparedness plans of action and be conducted before an epidemic occurs.

8.8.2 National antimalarial drug policies

- *Drug registration*

All countries prone to falciparum epidemics will need to register ACT for the management of uncomplicated malaria, and injectable artemether and artesunate suppositories for severe malaria.

- *Drug policy for epidemic-prone areas*

The above recommendations for the management of uncomplicated and severe malaria make it clear that, in some countries, treatment guidelines may advocate the use of different drugs in epidemic and complex emergency situations.

This difference may lead to confusion among partners involved in malaria control. It is therefore crucial that clear recommendations be made for disease management in routine malaria control and epidemic control. In order to avoid confusion and ensure that drugs are promptly procured and effective case management initiated, these recommendations should be integrated within both national drug policies and epidemic preparedness plans of action and should be provided to all partners in malaria control.

- *Cost of drugs to the patient*

During epidemics and complex emergencies, it is recommended that antimalarial drugs should be provided at no cost to all patients.

[13] http://www.who.int/medicines/library/par/new-emergency-health-kit/nehken.shtml

8.8.3 Central stocks of supplies and equipment

It is essential that national authorities ensure the availability of adequate supplies of diagnostics and antimalarial drugs by establishing and maintaining stocks to deal with the eventuality of an epidemic. Centralized stocks of this type exist in several southern and eastern African countries but they should be an integral part of all national malaria epidemic preparedness plans. Whether stockpiles are set up at provincial or national level depends on country-specific circumstances.

These stocks will need to be continuously rotated to ensure that commodity shelf-lives do not expire. Replenishment assumes prompt release, transport and customs clearance of commodities (if required).

Difficulties have previously been encountered with rapid procurement of artemether/lumefantrine (Coartem®) but drug manufacturers have now agreed to maintain an emergency stockpile. WHO and RBM are currently developing conditions and criteria for rapid release and dispatch of the drug combination in discussion with the manufacturer. The group recommends that discussions be extended to other manufacturers and interested parties so that stockpiles of the other antimalarial drugs recommended for epidemic control can be developed.

8.9 Prevention of malaria in pregnancy during epidemics

Use of chemoprophylaxis cannot be recommended during falciparum epidemics because of chloroquine resistance, problems with drug regimen compliance, and the limited choice of suitable drugs. Use of antimalarials for malaria prevention during epidemics – either as chemoprophylaxis or as intermittent preventive treatment – is an area that requires urgent study. During epidemics, pregnant women should be protected by ITNs and other personal protection measures.

9. VECTOR CONTROL

While the first priority in the acute stage of a malaria epidemic is the prompt and effective diagnosis and treatment of malaria, well-planned and timely vector control can significantly contribute to reducing the risk of infection and saving lives.

Vector control must be implemented at an early stage of epidemic development. Timing depends on effective early warning and early detection. Economic modelling studies show that selective vector control options need to be implemented when the mosquito population is small; they also need to exert a residual effect throughout the transmission period to be cost-effective in terms of the lives saved (Worrall, 2001).

Moreover, once an increase in malaria cases is detected, implementing vector control is worthwhile only if the epidemic is expected (on the basis of local experience) to persist for more than 2–3 months after interventions are initiated. This has implications for the choice of insecticide. It must also be borne in mind that, once the decision to implement vector control measures has been made, delivering them takes more than 4 weeks.

Unfortunately, vector control during epidemics is often ineffective because it is:

- implemented too late;

- determined by political and not technical considerations; and
- undertaken without adequate preparation and planning.

The main indications for vector control in epidemic-prone areas are:

- control of epidemics detected in the very early stages of development; and
- epidemic prevention following identifiable alarm signals from the early warning system.

9.1 Vector control options

The major vector control options are:

- indoor residual spraying (IRS) with insecticides; and
- insecticide-treated materials (ITMs), e.g. mosquito-nets.

The role of these options in epidemic control and prevention is discussed below.

Larval control and space spraying are not recommended except in very specific and strictly defined circumstances (see section 9.1.4).

9.1.1 Indoor residual spraying (IRS)

IRS is the most powerful method of vector control and is especially well adapted to the prevention and control of malaria epidemics, provided that it is targeted and timely. Preconditions for successful IRS are that:

- local populations live in huts or houses – IRS is less effective against vectors that rest outdoors, as in parts of South-East Asia and in high-transmission areas of Africa;
- local mosquito species enter and rest inside houses long enough to absorb the insecticide;
- mosquito species are susceptible to the insecticide used;
- the insecticide is applied safely;
- spraying is targeted on the basis of local environmental factors, including topography and seasons; and
- the proportion of houses and rooms sprayed is high enough (> 85%) to ensure that most mosquitoes are exposed to the insecticide, thus producing the phenomenon known as "mass effect" whereby the small proportion of the targeted community not covered by the intervention benefits because of the overall reduction in the transmission risk.

The choice of the insecticide should be based on the following criteria:

- surface to be sprayed;
- adequate residual effect persisting over the entire transmission season;
- high vector susceptibility to the selected insecticide: in the absence of data on insecticide resistance, an insecticide should be chosen from among the 12 recommended by WHO for IRS (Nájera & Zaim, 2001, 2002), avoiding those currently or recently in use locally for agricultural purposes;
- good storage stability, easy formulation and application;
- acceptable cost;
- safety for humans and domestic animals (this is an absolute requirement);
- good acceptability by the local population (e.g. little or no odour and non-staining for household surfaces); and
- effectivess against other household pests, such as bed-bugs, fleas and cockroaches – a major advantage since it leads to greater acceptance by the local population.

DDT meets most of these criteria. It is the only organochlorine insecticide still recommended for indoor residual spraying. It is highly persistent and has a long residual effect of over 6 months on most household surfaces. It is relatively cheap compared with other pyrethroid alternatives but leaves a white residue on sprayed surfaces, which has led to high refusal rates in the past.

DDT has been banned for agricultural use in many countries on the grounds of environmental pollution and potential human toxicity. However, WHO still recommends its use (WHO, 2000c; 2004c, 2004d; Nájera & Zaim, 2001, 2002,) provided that:

- it is used only for indoor spraying;
- it is of proven effectiveness;
- WHOPES product specifications are met; and
- appropriate safety precautions for use and disposal are respected.

No consensus was reached about the ideal alternative to DDT for IRS in epidemic situations. Any of the insecticides recommended for IRS by WHOPES may be selected, provided that it is affordable and of proven efficacy against the mosquito vector. The choice will depend on the local situation and should be based, along with its procurement and use, on WHOPES guidelines and specifications (Nájera & Zaim, 2001, 2002).

Synthetic pyrethroids are an effective alternative to DDT: they have a residual action of 2–6 months, are safer to apply than most other insecticides, enjoy limited resistance at present, and are less bulky to store and transport.

9.1.2 Insecticide-treated mosquito nets (ITNs)

The use of ITNs impregnated with synthetic pyrethroids such as deltamethrin, permethrin and lamda-cyhalothrin is gaining momentum in many malaria-endemic parts of the world, including Africa. However, coverage in many epidemic-prone areas is still low. Like indoor residual spraying, ITN uptake and net re-treatment rates need to be high for these measures to be fully effective. This is not yet the case in most endemic areas and even less in epidemic-prone regions where insects are not seen as a nuisance by residents.

ITNs are effective in many situations but documented evidence of their impact on epidemic prevention and control is scanty. Distributing ITNs at the onset of an epidemic is not a practical option given the urgency of the need to implement epidemic control measures. Only a behavioural change will guarantee their effective use. ITNs are thus of limited suitability for most epidemic-prone areas where, even though they may be available in the community, they often go unused in the long non-transmission periods. While ITNs would be inappropriate in epidemic and emergency situations if a behavioural change in the population is required to ensure their use, they may be considered in some circumstances, such as the following:

- where they are readily available and there are staff experienced in implementing ITN programmes;
- where there are both an existing high level of coverage with untreated nets and the infrastructure for prompt re-treatment of ITNs (which, for epidemic prevention, should ideally be provided free of charge);
- in refugee camps, along with other personal protection measures; and
- in emergencies with scattered displaced populations.

9.1.3 Other insecticide-impregnated materials

Pyrethroid-impregnated blankets (Graham et al., 2002a, 2002b), canvas tents (Hewitt et al., 1995; Bouma et al., 1996;) and plastic tents (Graham et al., 2002b) appear to have been shown to have

potential for mosquito control in epidemic and emergency situations but have not yet been widely evaluated (Rowland & Nosten, 2002).

9.1.4 Larval control and space spraying

Larval control is unsuitable for the control of epidemics but may be useful in exceptional circumstances where breeding sites are few, permanent, identifiable and accessible. Such conditions may prevail in desert refugee camps, urban areas of the Indian subcontinent where *An. stephensi* is the vector, and close to irrigation projects.

Insect growth regulators such as methoprene, pyriproxyfen and diflurobenzeron and the biological control agents *Bacillus thurigiensis israelensis* (serotype H-14) and *Bacillus sphaericus* are the larvicides of choice since they are safe to use and present little or no environmental risk. Organophosphates (chlorpyriphos, fenthion, pirimiphos-methyl and temephos) and fuel oil may also be used. Organochlorines such as DDT and insecticides with high mammalian toxicity should not be used as larvicides. Pyrethroids are also not recommended for use as larvicides because they have a broad spectrum of activity against non-target arthropods and their high potency may readily potentiate selection of pyrethroid resistance in larvae (Nájera & Zaim, 2002).

Ultra-low volume space spraying (fogging) is not cost-effective as a means of epidemic prevention and control because:

- there is no solid evidence of its efficacy;
- operational costs are high;
- residual effects are low;
- other more cost-effective methods are available; and
- its use is very often purely cosmetic and not followed up by proper technical evaluation of its appropriateness or impact.

However, fogging may be considered in very exceptional circumstances, such as emergency situations in refugee camps. In this event, if the target mosquito species is exophilic, treatment should be applied outdoors on mosquito resting points. If the vector is endophilic, treatment should be applied both indoors and outdoors. Suitable insecticides can be used as cold aerosol sprays or as thermal fogs. Wherever possible, applications should coincide with local vector flying times.

9.2 Planning vector control

9.2.1 Infrastructure

Good infrastructure and preparedness planning are essential for rapid response and flexibility in targeting vector control measures to epidemic-prone areas in need. Many epidemic-prone countries either do not have adequate infrastructure or are no longer able to meet the challenge of rapid response. Unfortunately, some donors consider ITNs to be a more “modern” and cost-effective approach to vector control and fail to see the specific advantages of indoor residual spraying for epidemics and the commensurate need for a supporting infrastructure.

It is not possible to create such an infrastructure during an epidemic; if it does not already exist, time and money are better spent on case detection and treatment.

9.2.2 Preparedness for vector control

A preparedness plan of action is essential to delivering and implementing effective vector control. The following aspects need to be taken into account:

- areas to be sprayed need to be defined and application times and frequency determined;
- knowledge of local geography and community structures and habits is essential to ensure high coverage with vector control measures; it cannot be achieved without community participation and agreement (see section 10);
- well-trained and motivated staff are needed to plan, implement and evaluate control activities, and this may require the organization of refresher or training courses;
- adequate stocks of insecticides, spraying equipment and ITNs (where applicable) should be available at central or regional levels to allow their rapid deployment to areas of need – existing EPI (Expanded Programme on Immunization) systems may be considered for social mobilization and rapid delivery of ITNs and insecticides for re-treatment of nets; and
- sensitivity of local vectors to insecticides needs to be determined in advance so that a rational choice of insecticide can be made – this is not feasible during an epidemic.

9.3 Epidemic prevention

The use of targeted vector control using IRS and/or ITNs for epidemic prevention is difficult because early warning systems are not yet sufficiently reliable in predicting, well in advance, the areas where epidemics will occur.

IRS or ITNs can be used preventively for long-term suppression of transmission in some situations, such as:

- to hinder malaria resurgence in previously controlled areas;
- to prevent gradual build-up of transmission over years and/or seasonal transmission surges;
- to target communities where an epidemic is imminent.

In such cases, use of IRS will produce a more rapid response than ITNs.

10. COMMUNITY COOPERATION AND PARTICIPATION

Constant contact between health authorities and the population at risk is essential for successful prevention and control of malaria epidemics. Community cooperation and participation can be encouraged by providing health education and through information channels such as newspapers, radio and television.

Communities need to be informed about:

- the risk of malaria epidemics and how to avoid them;
- what to do if family members become ill;
- what, where and why control measures are carried out; and
- how to help health authorities to combat the outbreak.

11. RECOMMENDATIONS AND MAJOR ACTION POINTS FOR STRATEGY IMPLEMENTATION

Target: clear, practical, technical, evidence-based guidelines (what to do? how to do it?) in order to develop realistic strategies and preparedness plans of action for the prompt prevention and control of malaria epidemics. Aimed at malaria epidemic-prone countries worldwide, covering *P. vivax* and *P. falciparum* epidemics.

11.1 Estimating the population at risk of malaria epidemics

Countries wishing to undertake realistic contingency planning should:

- start by plotting recent epidemics on administrative boundary maps;
- stratify epidemic risk based on local experience, making provision for climate, population vulnerability, environmental and epidemiological factors and other local determinants of epidemic risk; and
- use existing tools such as WHO HealthMapper to develop risk maps and calculate populations at risk based on (sub-)district population data.

In order to assist these countries, WHO and RBM partners should develop a standard protocol for estimating populations at risk of malaria epidemics based on HealthMap.

11.2 Long-range forecasting (LRF) and early warning systems (MEWS) in epidemic prediction

The LRF–MEWS–EDS continuum provides complementary information with increasing accuracy and spatial resolution (continental/national to district/local) but decreasing lead-time (10–14 months to 1–2 weeks) before an epidemic strikes. Using LRF and MEWS warnings for forward planning and targeting of early detection activities, countries should:

- start to make use of freely available remote sensing information, e.g. rainfall and temperature estimates, for mapping and monitoring changes in epidemic risk;
- access relevant real-time data from non-health sectors that are likely to have a bearing on the risk of local epidemics, e.g. demographic and environmental services; and
- train and encourage district health workers to monitor population vulnerability and environmental indicators of epidemic risk.

In order to assist countries, WHO should facilitate collaboration between health programmes, meteorological services and other early warning initiatives, e.g. drought monitoring systems, famine early warning systems and livestock disease surveillance and information systems, to identify relevant indicators and key informants, and ensure routine information transfer for malaria epidemic forecasting and early warning.

11.3 Early detection systems

To detect, verify and notify malaria epidemics within 2 weeks of onset, countries should:

- train and encourage peripheral health workers to record and interpret disease data on a weekly basis, especially during the epidemic season;

- select representative sentinel sites to collate better-quality prospective data for use in both early warning and early detection activities;
- encourage weekly reporting and analysis as part of integrated surveillance activities;
- maintain a human overview of data processing and interpretation (epidemiological "common sense");
- use parasitological confirmation (microscopy and/or RDTs) to determine whether malaria is the primary cause of fever outbreaks; and
- periodically monitor and evaluate EDS for accuracy and effectiveness within the epidemic preparedness plan of action.

Capacity development:

- reinforce the capacity of district and national teams to provide the appropriate technical support to outlying areas;
- review the system regularly and step up coordination between partners by providing feedback on the accuracy and utility of LRF, MEWS and EDS warnings, improving definitions of indicators and thresholds, and making explicit recommendations on the action to be taken in response to warnings.

In order to assist countries, WHO and RBM partners should:

- develop a simple public health tool, translating LRF, MEWS and EDS warnings into action points, with evaluation of accrued experience;
- encourage and review accrued experience with EDS epidemic thresholds and warnings.

11.4 Case management and drug use

11.4.1 Malaria diagnosis

- Parasite diagnosis by either light microscopy or RDT is essential to establish malaria as the cause of epidemic fever and to confirm that the epidemic has ended.
- Once malaria has been confirmed as the cause of an epidemic, treatment based solely on symptoms is appropriate in epidemic and emergency areas where laboratory facilities are non-existent or not functioning.
- Light microscopy should be available, at least, at referral facilities in order to track the progress of high-risk cases of severe malaria. Back-up should be supplied in the form of quality assurance, adequate supplies and trained personnel.
- Rapid diagnostic tests:
  - should not be relied on as the sole basis for treatment;
  - negative test results should not preclude treatment; and
  - testing should (i) be backed up by adequate quality assurance including temperature monitoring during storage and transport, and (ii) be ordered from a list of pre-qualified products that meet requirements for malaria control.

11.4.2 Choice of antimalarial drugs

- Drugs used to treat uncomplicated malaria in epidemics should be highly efficacious (> 95%) and safe and should offer good compliance.
- To date, ACT is the only appropriate treatment for uncomplicated malaria in *P. falciparum* epidemics and in mixed *P. falciparum/P. vivax* epidemics (with the limited exception of central America and Hispaniola where *P. falciparum* remains sensitive to chloroquine and S/P).

- Chloroquine remains the drug of choice in vivax-only epidemics. Anti-relapse therapy with primaquine should be considered only later, once the epidemic subsides.
- Intramuscular injectable artemether is the drug of choice for the management of severe disease since quinine use is impractical in most epidemic situations.
- If injectable artemether is unavailable, the use of artesunate suppositories is recommended for emergency use in outlying areas when severely ill patients are unable to swallow oral medication. In conditions where referral is not possible, continued treatment with rectal artesunate is recommended until the intake of oral drugs is possible.
- Mass treatment of fever cases with ACT as a mortality-reduction strategy is appropriate once malaria has been established as the cause of the epidemic.
- There is no evidence to support the use of mass drug administration, i.e. the indiscriminate distribution of treatment to the entire population at risk.

11.4.3 Preparedness

- All epidemic-prone countries should register artemisinin combinations for the treatment of uncomplicated *P. falciparum* malaria and intramuscular injectable artemether for severe malaria.
- Continuously updated stockpiles of these drugs and of RDTs should be established regionally and nationally to allow rapid deployment, and internationally by the manufacturers to allow rapid procurement.
- Parasite diagnosis, either by light microscopy or using RDTs, needs the support of adequately trained staff, quality assurance and continuing availability of supplies and equipment.

11.5 Vector control

11.5.1 Preparedness

- Anti-vector measures for epidemic prevention and control can be effectively implemented only where there is a functioning infrastructure with adequate provision for well-trained personnel, supplies and equipment, preparedness planning, and supervision and evaluation.
- Epidemic-prone countries without this infrastructure should develop this capacity as part of their preparedness plans of action. These plans should also include:
  - entomological input – this is of primary importance to provide baseline data before the intervention and assess its impact; it should also include data on the sensitivity of local vectors to insecticides;
  - understanding of local geography and community structures and habits, in order to ensure high coverage of vector control measures;
  - setting up and maintaining central stockpiles of insecticides and spraying equipment for rapid deployment to epidemic-prone areas.
- Community and local authority cooperation and participation must be forthcoming if all vector control measures are to be properly implemented: this requires planning for health education, including use of information channels such as newspapers, radio and television.

11.5.2 Implementation

- Implementation of vector control is most cost-effective when used for (i) prevention, and (ii) control at the very beginning of an epidemic, and if high (> 85%) coverage can be obtained.

- Vector control can be used preventively for long-term suppression of transmission:
  - to hinder malaria resurgence in previously controlled areas;
  - to prevent a gradual build-up of transmission over years and/or a seasonal transmission surge;
  - to target communities where an epidemic is imminent.

11.5.3 Indoor residual spraying

- IRS remains a powerful method of malaria vector control and is especially well-adapted to epidemic prevention and response.
- Provided that WHOPES specifications are met and that it is still effective, DDT meets the criteria for situations in which resources are limited and a residual action beyond 6 months is required; the requisite safety precautions for DDT use and disposal must also be respected.
- Synthetic pyrethroids are an effective alternative to DDT: they have a residual action of 2–6 months, are safer to apply than most other insecticides and still enjoy limited resistance.

11.5.4 Insecticide-treated mosquito nets

- There is little documented evidence regarding the use of ITNs for epidemic prevention and control.
- Community use of ITNs in most epidemic-prone areas is low and distributing ITNs is impractical in view of the urgent need to implement epidemic control measures.
- The effectiveness of ITNs is dependent on behavioural change, which limits their suitability for most epidemic-prone areas where, even though ITNs may be available in the community, they often go unused in the long non-transmission periods.
- In some circumstances, however, the use of ITNs for prevention and control may be quicker to implement than IRS:
  - where ITNs are readily available, along with staff experienced in implementing ITN programmes;
  - where there are both an existing high level of coverage with untreated nets and an infrastructure for their prompt re-impregnation (ideally free of charge);
  - in refugee camps along with other personal protection measures; and
  - in emergencies with scattered displaced populations where IRS implementation is exorbitantly expensive and logistically impractical.

11.5.5 Larval control and space spraying

- Larval control is generally unsuitable for epidemic control but it may be a useful preventive method in exceptional circumstances, where breeding sites are few, permanent, identifiable and accessible.
- There is no evidence to support the use of ULV space spraying (fogging) as a means of epidemic prevention and control.

11.6 Monitoring and improving preparedness plans

Documented evidence on malaria prevention and control is still scanty. Post-epidemic evaluation is a crucial step in the action plan for epidemic preparedness and response: it is required to identify whether the various activities undertaken to detect and control the malaria epidemic have been

successful or not, and determine whether the detecting systems and control options have had an effect on the malaria burden. Countries should:

- assess MEWS and EDS functioning;
- evaluate the impact of the response on the burden of disease;
- perform a cost-effectiveness/cost analysis for each component of the response;
- examine the functioning of the overall partnerships; and
- assess logistics and budgetary matters.

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CDS	Communicable Disease Cluster
CPE	Communicable Disease Prevention, Control and Eradication
CSR	Communicable Disease Surveillance and Response
HTM	HIV, TB and Malaria Cluster
MCO	Operational Support and Capacity Development
MPO	Policy and Strategy Team
OEH	Occupational and Environmental Health
PHE	Protection of the Human Environment
PS	Roll Back Malaria Partnership Secretariat
RBM	Roll Back Malaria
RMD	Risk Containment, Mapping and Drug Resistance
SDE	Sustainable Development and Healthy Environments Cluster

ANNEX 2.
ESTIMATED POPULATION AT RISK OF MALARIA EPIDEMICS IN AFRICAN COUNTRIES

Country	WHO 2001	TSN CIESIN (1994)	MARA 2002
Angola	4 734 450	6 512 280	1 102 624
Botswana	621 200	1 419 308	No data
Burkina Faso	No estimate	505 435	0
Burundi	3 250 500	3 584 264	1 194 606
Cameroon	No estimate	1 932 359	620 842
Cape Verde	218 000	0	No data
Chad	1 220 100	1 754 975	313 678
Côte d'Ivoire	No estimate	8 052	0
Democratic Republic of the Congo	5 252 100	9 369 350	1 674 526
Djibouti	No estimate	8 617	653 277
Equatorial Guinea	No estimate	14 300	4 790
Eritrea	2 289 000	2 703 124	278 062
Ethiopia	32 229 000	21 131 811	15 893 523
Guinea	No estimate	18 167	0
Kenya	7 823 000	9 406 870	7 664 295
Liberia	No estimate	1 873	0
Madagascar	8 218 000	0	1 291 449
Malawi	No estimate	5 429 717	328 575
Mali	2 335 200	1 546 766	122 421
Mauritania	1 098 400	699 623	972 896
Mauritius	468 000	0	0
Mozambique	3 728 800	1 114 067	0
Namibia	714 800	683 054	No data
Niger	2 245 200	5 548 067	342 433
Nigeria	No estimate	2 225 295	0
Rwanda	3 974 000	5 060 158	1 021 308
Senegal	966 100	1 841 773	0
Sierra Leone	No estimate	5 356	0
Somalia	4 578 000	8 598 221	9 160 789
South Africa	2 189 550	7 710 551	No data
Sudan	15 904 500	16 515 771	7 628 766
Swaziland	374 800	666 041	No data
Uganda	2 402 200	8 084 173	693 370
United Republic of Tanzania	8 991 000	6 073 027	1 060 444
Zambia	5 324 000	5 857 212	292 058
Zimbabwe	3 598 280	8 696 507	0
Total	**124 894 319**	**144 726 164**	**52 314 731**

ANNEX 3.
ESTIMATED PROPORTION OF POPULATION AT RISK

(EXPRESSED AS % OF TOTAL POPULATION) OF MALARIA EPIDEMICS IN AFRICAN COUNTRIES

Country	WHO	TSN -CIESIN	MARA
Angola	35	56.5	8
Botswana	40	98.1	No data
Burkina Faso	No estimate	5.0	0
Burundi	50	59.6	17
Cameroon	No estimate	14.6	4
Cape Verde	50	0	No data
Chad	15	Pop. data NA	4
Côte d'Ivoire	No estimate	0.06	0
Democratic Republic of the Congo	10	Pop. data NA	3
Djibouti	No estimate	Pop. data NA	98
Equatorial Guinea	No estimate	3.7	1
Eritrea	60	73.8	7
Ethiopia	50	39.8	24
Guinea	No estimate	0.03	0
Kenya	25	36.4	24
Liberia	No estimate	0.06	0
Madagascar	50	0	7
Malawi	No estimate	50.9	3
Mali	20	0	1
Mauritania	40	31.7	35
Mauritius	40	0	0
Mozambique	20	6.7	0
Namibia	40	44.0	No data
Niger	20	63.1	3
Nigeria	No estimate	2.3	0
Rwanda	50	63.8	14
Senegal	10	22.7	0
Sierra Leone	No estimate	0.1	0
Somalia	50	Pop. data NA	79
South Africa	5	19.0	No data
Sudan	50	Pop. data NA	25
Swaziland	40	79	No data
Uganda	10	Pop data NA	3
United Republic of Tanzania	25	21.4	3
Zambia	50	66.7	3
Zimbabwe	28	78.3	0

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