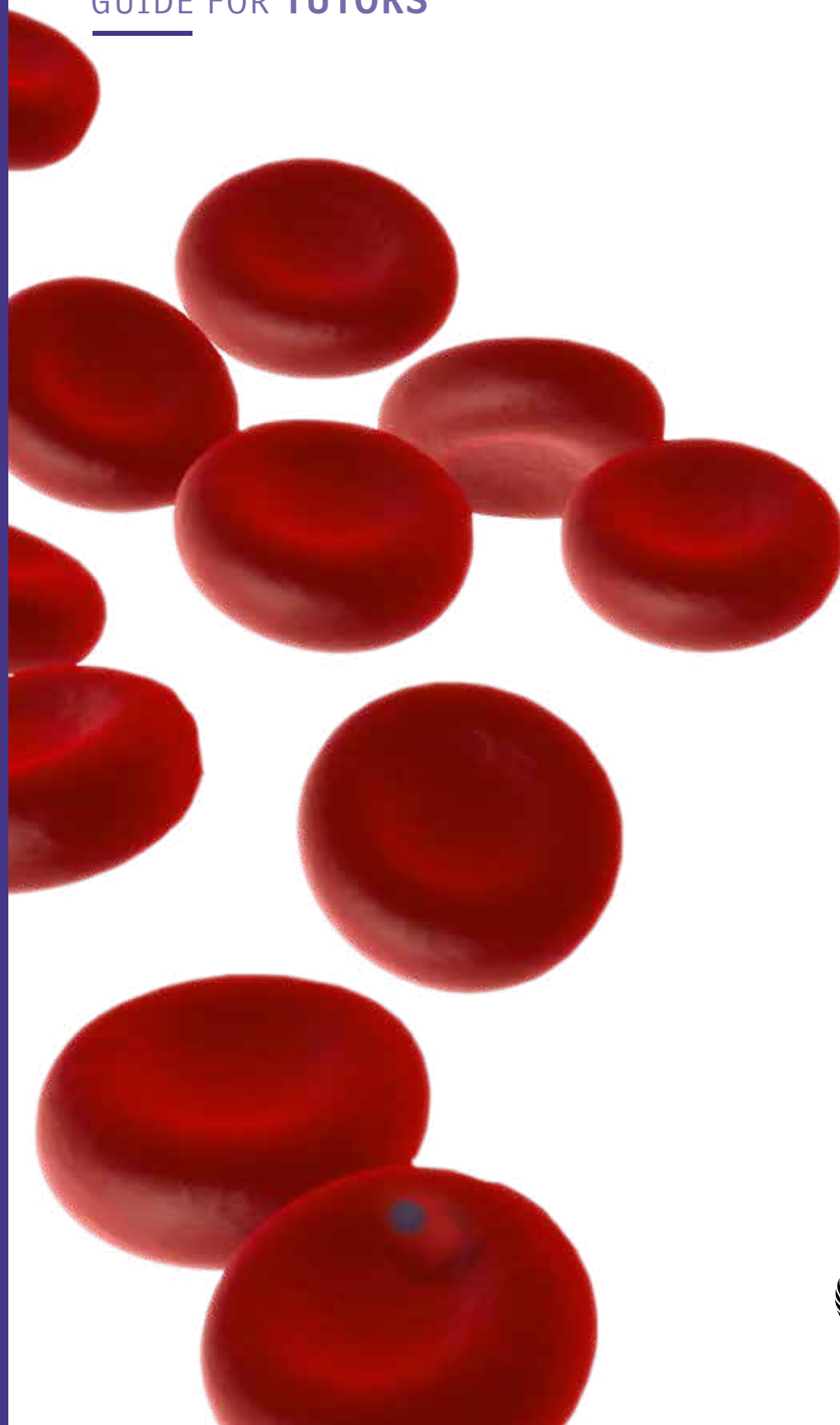


# *Malaria elimination*



GUIDE FOR TUTORS





# Malaria elimination



GUIDE FOR **TUTORS**

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# Abbreviations

ACT	artemisinin-based combination therapy
bw	bodyweight
ESP	elimination scenario planning
G6PD	glucose-6-phosphate dehydrogenase
GIS	geographical information system
GMP	Global Malaria Programme
IRS	indoor residual spraying
ITN	insecticide-treated net
LLIN	long-lasting insecticide-treated net
PCR	polymerase chain reaction
pLDH	parasite lactic dehydrogenase
RDT	rapid diagnostic test
WHOPES	WHO Pesticide Evaluation Scheme

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# Development of the module

The content of the module is based on current WHO guidelines and other evidence-based technical documents. The following manuals and technical documents served as the main references and resources: *Malaria elimination: a field manual for low and moderate endemic countries*, 2007; *Global malaria control and elimination—report of a technical review*, 2008; *Guidelines for the treatment of malaria*, 3<sup>rd</sup> edition; *Malaria microscopy quality assurance manual*, version 1, 2009; *Disease surveillance for malaria elimination: an operational manual*, 2012 and *World malaria report 2014*.

The training module was prepared by WHO/GMP in collaboration with the WHO regional offices for the Eastern Mediterranean and Europe. Several technical experts from malaria training and academic institutions, malaria researchers, country programme managers and WHO contributed to the content of the module. The process comprised the following steps:

- ▶ Three WHO consultations of technical experts (7–9 April 2008, 14–16 October 2008 and 15–17 April 2009) were held to review existing WHO technical documents on malaria elimination and to identify relevant materials for development of a training package for malaria elimination. The content of the training module was then prepared and agreed upon.
- ▶ Technical experts were commissioned to write the content of specific sections of the training module on the basis of the agreed outline.
- ▶ The revised module was then reviewed for content and completeness by WHO technical staff and additional external experts.
- ▶ The updated module was field-tested in four international training courses, held in Egypt in 2012, the Philippines in 2014, Zimbabwe in 2014 and Tunisia in 2014.
- ▶ Feedback from participants and facilitators in these training courses and input from technical experts and WHO/GMP secretariat were used to finalize the text for publication.



# Introduction

This *Guide for tutors* is designed to help trainers to train the health personnel responsible for planning, implementing, monitoring and evaluating malaria elimination programmes. The guidance supplements the introduction in the *Guide for participants*.

This module can be used in various ways and can be adapted to the starting level of the participants, which should be ascertained during a preliminary assessment. After the formal course, the trainees can use the *Guide for participants* as a reference. All trainees who are or will be in a managerial or supervisory position are likely to be involved in teaching others; therefore, the participants in this course should also receive the *Guide for tutors* at the end of the course. As it contains answers for many of the exercises, it should not be provided before the end.

## Potential users of the training module

The module is designed for health professionals who, in their professional practice, are responsible for planning, managing and evaluating antimalaria programmes. They include medical officers, medical assistants, public health officers, environmental health officers, parasitologists and entomologists involved in malaria control and working either with a national programme or with a partner organization. Participants should be recruited only if they have a level of education corresponding to at least Bachelor level, practical public health experience, knowledge of basic malariology and can use a spreadsheet.

## Length and structure of the course

The complete module is designed to be accomplished in 8–10 working days. The timetable proposed in the *Guide for participants* is based on the assumption of 8 working days with 1 rest day in the middle; 9–10 working days would be preferable, based on a 7-h working day: 4 h in the morning and 3 h in the afternoon. In addition, participants are expected to spend 1 or 2 h reading and doing exercises in the evenings.

## Design and content of the training module

The module is designed to stimulate active learning by using data that participants have brought from their place of work. Participants may consider that they have too little time and insufficient data; however, part of the educational process is to learn to manage time, use it effectively and plan with the data available that can be collected.

The learning objectives are stated at the beginning of each learning unit. The tutor and facilitators should ensure that each participant has achieved the stated objectives of each unit before proceeding to the next.

## Responsibilities for running the course

The tutor is responsible for organizing and conducting this training activity, assisted by two to five facilitators, depending on the number of participants. The class will be divided into three to five groups of five to six participants, with one facilitator allocated to each group.

There must be a clear division of responsibilities between the tutor and the course organizer or coordinator. The coordinator will usually invite the participants and take care of all practical aspects.

The tutor decides the extent to which teaching tasks will be delegated to the facilitators. Both the tutor and the facilitators must be thoroughly acquainted with the complete *Guide for participants* and *Guide for tutors*, supplementary exercises, additional reading materials and hand-outs.

### The syllabus

The contents of the guides represent the syllabus, i.e. the list of subjects covered by the course. The tutor should consider each learning unit, calculate the time required and decide the type of training activity that is best adapted to the topic. Time will always be a constraint. Good organization of group work and clear instructions about the exercises will ensure the best use of the time available.

Some tutors may be in a position to introduce new exercises or to replace some of the existing exercises with others that are more relevant for the participants in a particular course. That is encouraged. Tutors might take inspiration from the teaching materials of the 1970s at <http://apps.who.int/iris/handle/10665/69663> (accessed 14 September 2015).

### Preparation by participants before and during the course

At the end of each learning unit, the tutor should remind the participants to study the next unit before the session in which it is taught. The *Guide for participants* should be e-mailed to participants 7–10 days before the start of the course or placed on a SharePoint accessible to them. They should be advised by e-mail to read the following before the start of the training:

- ▶ *Malaria elimination. A field manual for low and moderate endemic countries.* Geneva: World Health Organization; 2007 (<http://www.who.int/malaria/publications/atoz/9789241596084/en/index.html>, accessed 14 September 2015).
- ▶ *Disease surveillance for malaria elimination. An operational manual.* Geneva: World Health Organization; 2012 ([http://whqlibdoc.who.int/publications/2012/9789241503334\\_eng.pdf](http://whqlibdoc.who.int/publications/2012/9789241503334_eng.pdf), accessed 14 September 2015).
- ▶ In the *Guide for participants*, all the introductory sections; unit 1, Introduction to malaria elimination, and unit 2, Basic malaria epidemiology, including transmission dynamics. They should browse through the rest of the *Guide*.

Below is a sample e-mail to be sent by the tutor or course organizer to the participants 10–14 days before the start of the course.

Dear participants in the [organizing unit] training course on malaria elimination in [place], [dates]

This message is being sent to you to convey essential information **for your preparation** for the course.

The timetable of the course is attached. You will note that it is intense, with [n] full days of work, so please arrive in good shape! The facilitators will make sure that the timetable is respected, so that sessions end every day at 17:00; however, participants are expected to spend a couple of hours every evening reading the required materials for the following day's learning unit(s).

To keep the course on track from the first day, [organizing unit] has set up a Sharepoint, where participants can download reading material and essential information for the course. To access it, [directives]

From the folders there, you can download all the important documents for the course. If you have any difficulty, please contact [appropriate person, email address].

The course folder has three sub-folders: Core materials, References and Other course documents. The core materials include:

- ▶ *Guide for participants* for this course and some associated exercises
- ▶ *Malaria elimination. A field manual for low and moderate endemic countries*. Geneva: World Health Organization; 2007
- ▶ *Disease surveillance for malaria elimination. An operational manual*. Geneva: World Health Organization; 2012

*Before the course, please read the main text of the two WHO manuals and annexes 2 and 3 in each. Please browse the Guide for participants and read carefully the introductory sections and learning units 1 and 2. These three documents will be given to you in hard copies at the start of the course, so you do not have to print them.*

The references include three sub-folders:

- ▶ *WHO documents*, with selected publications and documents, parts of which should be read for certain learning units, as indicated in the *Guide for participants*;
- ▶ *Case studies* on elimination in individual countries prepared by WHO and the Malaria Elimination Group. Some of these should be read in preparation for particular learning units.
- ▶ *Publications*, with selected references relevant to malaria elimination. Generally, these need not be read for this course, but they will be useful for people who wish to know more, do research or train others.

The materials in the References folder will not be made available as hard copies; if you already have some of them, you may wish to bring them with you.

*Please bring with you to the course:*

- ▶ Your laptop computer
- ▶ As the most important part of the course will be the assessment of feasibility in each country and a planning exercise for each country, all participants should bring the following information on their own country (preferably in electronic format):
  - ▶ health and socio-economic profile;
  - ▶ current malaria situation and data for at least 10 past years;
  - ▶ detailed data on the epidemiological and entomological situation;
  - ▶ information on the malaria programme (capacity, coverage, gaps, challenges, etc);
  - ▶ maps for stratification;
  - ▶ financial resources available or anticipated;
  - ▶ current operational manuals, national guidelines and standard operating procedures, in particular for malaria surveillance. Guidelines and standard operating procedures of other programmes should also be brought if they are relevant for malaria surveillance in the country.
  - ▶ policy or strategy background, current national malaria strategic plan and other relevant information (e.g. national development plan, integrated vector management plan).

Much of this will be available in strategic plans or programme review reports, if they have been updated recently.

If you have any questions about the contents of the course, please do not hesitate to contact the undersigned by e-mail.

With kind regards

[name and title of tutor or course coordinator, e-mail address]

## **Training facilities**

A number of basic facilities and equipment must be organized before training can begin. In some countries, these are readily available, but in others the tutor may have to improve or modify existing resources. One large room should be available for presentations and plenary discussions. Depending on the number of participants, smaller rooms may be required for small group work.

The number of working groups should be decided ahead of time. This will depend on the number of participants and the number of facilitators available. Groups of four to six participants are best. If possible, the room should be arranged so that participants sit in groups in a semi-circle, everyone having a clear view of the blackboard and projector screen.

## Training equipment

For tutored sessions and group discussions, the following items should be available, if possible:

- ▶ two data projectors
- ▶ flipcharts: one for each small group; supplies of cheap, readily available “butcher’s paper” or “newsprint paper”
- ▶ large blackboard or white board
- ▶ chalk for blackboard or marker pens for white board, in a selection of colours
- ▶ ready access to a photocopier
- ▶ about 1000 sheets of photocopy paper
- ▶ sufficient toner for the photocopier
- ▶ access to computers with Microsoft Word, Excel, PowerPoint, and EpiInfo (participants should bring their own laptops)
- ▶ Internet connection, which should preferably be interrupted during class sections unless it is required for teaching purposes
- ▶ compact discs or memory sticks

## Participants’ supplies

The equipment listed below should be provided to each participant. When supplies have to be ordered, this should be done well in advance of the course, as many items may be difficult to obtain at short notice:

- ▶ copies of the *Guide for participants* (soft copy e-mailed before the start of the course and hard copy given at the opening) and the *Guide for tutors* (to be given at the end)
- ▶ a notebook
- ▶ sheets of paper for the exercises in the working groups and for individual plans
- ▶ ball-point pen
- ▶ compact discs or memory sticks (one will be given to each participant at the end of the course containing the main documents and presentations).

*The multiple-choice questions for pre- and post-tests must not be given to the participants under any circumstances.*

## Opening session

The tutor should lead the opening session to present a broad overview of the course. The team of facilitators should be presented, and then each participant should introduce him- or herself. The tutor may ask each participant to express her or his expectations of the course. This can serve to “break the ice” and also suggest to the tutor and facilitators how to present the material.

## Guidance in preparation for each learning unit

The day before each learning unit, the tutor or facilitator should tell the participants how to prepare themselves, i.e. what material to read and which portions to prioritize. If there are time constraints, the participants should be asked to prepare certain exercises but not all.

## Presentations

The presentations should be as brief as possible and focus on the parts that are most difficult to learn. They should always be interactive: the tutor or facilitator should ask questions and elicit the experience of the participants.

## Small group discussions

Once participants become accustomed to group discussions, the two-way exchange of information between them and the facilitators makes this an effective learning activity. They share their knowledge and experience and stimulate each other's thoughts on the subject; however, the objectives must be clear, and the tutor must ensure that the allotted time is not exceeded. For many exercises, the tutors should prepare empty tables in PowerPoint format, as shown in the learning units, and distribute them on memory sticks when the group work starts.

## Main group work: country exercise

Experience from the first malaria elimination courses showed that participants tend to find it difficult to use spreadsheets and revise plans prepared for submission for international funding. Therefore, a good way of helping participants to apply what they are learning to the situation in their country, especially if time is a constraint, is to ask them to prepare a plan for a surveillance system for malaria elimination. At the outset of the course, the tutor and facilitators should therefore decide whether the main group work in the course should be the comprehensive exercise or the more focused one. In the latter case, the tutor or facilitator should select only some of exercises 5.1–5.6. Participants should be told that exercise 5.7 will be the main one in the course, which they will initiate as they learn unit 5 and will work on every day until the end of the course, incorporating lessons from each unit. It may therefore be necessary to reduce the number of exercises proposed in units 6–9.

## Using the *Guide for tutors*

The *Guide for tutors* does not contain extra technical information that is not in the *Guide for participants*. The *Guide for tutors* is designed primarily to help the tutor plan, implement and assess the course.

## Evaluation

The progress and achievements of the participants will be evaluated by the tutor, the facilitators and the participants themselves. The evaluation will comprise a general assessment during group activities and a number of questionnaires and tests. Its intention is to provide an opportunity for participants to measure their progress and to contribute to the learning process. For details of the evaluation method, see the *Guide for participants*.

At the end of the course, the tutor, assisted by the facilitators, should prepare a report, which should include:

- ▶ an evaluation of the course modules by the participants,
- ▶ the tutor's evaluation of the participants,
- ▶ the tutor's evaluation of whether the course fulfilled its purpose,
- ▶ the results of the pre- and post-tests,
- ▶ a summary of the answers to the questionnaires,
- ▶ a summary of the open discussion held at the end of the course,
- ▶ an assessment of the administrative and practical arrangements and
- ▶ any other matters.

### **Certificates**

The attendance and performance of each participant should be noted during the course and the record retained for future reference. Participants should receive a certificate of successful completion of the course.

Suggested timetable								
Time	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
08:00–09:00		<b>Unit 2.</b> Basic malaria epidemiology: small groups	<b>Unit 3.</b> Road map to elimination: class discussion	<b>Unit 5.</b> Surveillance: small groups	<b>Unit 6.</b> Prevention of reintroduction: presentation	<b>Unit 8.</b> Feasibility: presentation		<b>Unit 9.</b> Certification: presentation
09:00–10:00	Registration Opening	<b>Unit 2.</b> Basic malaria epidemiology: class discussion	<b>Unit 4.</b> Approaches and interventions: presentation	<b>Unit 5.</b> Surveillance: class discussion	<b>Unit 6.</b> Prevention of reintroduction: small groups	<b>Unit 8.</b> Feasibility: small groups	Free	<b>Unit 9.</b> Certification: class discussion
10:00–10:30	Break							
10:30–11:30	Pre-test Introduction to the course	<b>Unit 2.</b> Basic malaria epidemiology: presentation	<b>Unit 4.</b> Approaches and interventions: small groups	<b>Unit 5.</b> Surveillance: presentation	<b>Unit 6.</b> Prevention of reintroduction: class discussion	<b>Unit 8.</b> Feasibility: small groups		Post-test
11:30–12:30	<b>Unit 1.</b> Introduction to malaria elimination: presentation	<b>Unit 2.</b> Basic malaria epidemiology: small groups	<b>Unit 4.</b> Approaches and interventions: small groups	<b>Unit 5.</b> Surveillance: small groups	<b>Unit 7.</b> Health systems: presentation	<b>Unit 8.</b> Feasibility: class discussion	Free	Evaluation by participants
12:30–13:30	Break							
13:30–14:30	<b>Unit 1.</b> Introduction to malaria elimination: small groups	<b>Unit 2.</b> Basic malaria epidemiology: class discussion	<b>Unit 4.</b> Approaches and interventions: class discussion	<b>Unit 5.</b> Surveillance: small groups	<b>Unit 7.</b> Health systems: small groups	<b>Unit 8.</b> Feasibility: presentation		
14:30–15:30	<b>Unit 1.</b> Introduction to malaria elimination: class discussion	<b>Unit 3.</b> Road map to elimination: presentation	<b>Unit 5.</b> Surveillance: presentation	<b>Unit 5.</b> Surveillance: class discussion	<b>Unit 7.</b> Health systems: small groups	<b>Unit 8.</b> Feasibility: small groups	Free	Closure
15:30–16:00	Break							
16:00–17:00	<b>Unit 2.</b> Basic malaria epidemiology: presentation	<b>Unit 3.</b> Road map to elimination: small groups	<b>Unit 5.</b> Surveillance: small groups	<b>Unit 5.</b> Surveillance: class discussion	<b>Unit 7.</b> Health systems: class discussion	<b>Unit 8.</b> Feasibility: class discussion	Free	



# LEARNING UNIT 1

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## Introduction to malaria elimination

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### Learning objectives

By the end of this unit, participants should be able to:

- Define malaria control, elimination and eradication
- Explain the concept of malaria elimination and the control–elimination continuum
- Specify key differences between malaria control and elimination approaches
- Explain the concepts, achievements and shortcomings of the 1955–1969 Global Malaria Eradication Programme, including lessons learnt
- Place the “elimination debate” in the context of historical and recent developments and the current situation of malaria in the world

## 1.1 The tutor should prepare:

A PowerPoint presentation covering the essential points in the module, including the learning objectives and Box 1.1 and Table 1.1 from the *Guide for participants*.

## 1.2 Suggested time-frame

Allot 3 h to this learning unit: 1 h for presentation, 1 h for small group work and 1 h for class discussion.

If time is limited, you may shorten the first session to about 30 min for the presentation and 90 min for group work and feedback.

## 1.3 Presentation

Review the learning objectives with the participants and make sure they understood them.

Present the material in the participants' manuals, but avoid in-depth discussion at this stage.

Ask questions to assess the participants' knowledge and experience in malaria control and elimination. Weaknesses and strengths will be examined in the small group discussions.

## 1.4 Small group exercise

The participants are expected to do two or three of the exercises in 1 h, working in small groups. Distribute the exercises to the groups. The responses to the exercises will be presented in plenary by one member of each small group, e.g. group 1 will presents 1 and 2, group 2 will present 3 and 4, etc., while the other groups will comment on the presentations.

## 1.5 Answers to exercises

### Exercise 1.1

The answers to this exercise are in the latest *World malaria report*, although countries that were certified malaria-free before 1980 may not be listed there. In these cases, refer to *World malaria report 2014* (you may ask participants to access this on-line at <http://www.who.int/malaria/en/>).

### Exercise 1.2

The distinction is clear from the definition of elimination; continued measures are necessary. Lack of understanding at the outset of the Global Malaria Eradication Programme led to confusion and unnecessary discussions for years (see for example, Cohen et al.<sup>1</sup>). In countries in which the risk for importation of malaria is high, malaria-free status may resemble control more than eradication because of the continued efforts.

### Exercise 1.3

Nearly all countries were affected by the Global Malaria Eradication Programme, one way or another. Many African countries had a "pre-eradication project", which led to capacity-building

<sup>1</sup> Cohen JM, Moonen B, Snow RW, Smith DL. How absolute is zero? An evaluation of historical and current definitions of malaria elimination. *Malar J* 2010;9:213.

in some cases but not in others. Whatever the result, it is useful to study and analyse the events. Many programmes were technically sound, but they were unsuccessful mainly because resources were insufficient or because they were stopped prematurely in the early 1970s.

### Exercise 1.4

Suggested responses:

1. Only countries for which a feasibility analysis is positive should launch an elimination programme; country-specific targets will be determined by analysis of the situation in each country. At the outset of the Global Malaria Eradication Programme, WHO told almost all countries except those in tropical Africa to undertake eradication; “control had become a dirty word”.
2. Much more is known about what vector control operations work where. There are more insecticides and a broader array of delivery modes, especially nets. However, progress has not been as great as is sometimes portrayed. There is now extensive resistance to DDT, which is now the only accepted insecticide for IRS as it has a long residual effect. Resistance to pyrethroids is becoming more and more common.
3. The importance of integrating research and control is better appreciated than it was at the time of the first eradication programme.
4. It is now understood that control strategies must be adapted as they progress and as the epidemiology of malaria changes due to an effective intervention. In particular, the loss of immunity may partly offset reductions in vectorial capacity.
5. There are many more well-trained scientists in malaria-endemic countries than in 1955, especially in tropical Africa.
6. New diagnostic techniques are available.
7. Health systems are better developed, although they are still not strong enough in most endemic areas.
8. Computers are available to transfer and quickly process surveillance data and to develop models based on local data.
9. Developments such as village databases, global positioning systems, geographical information systems, web-based mapping and cell phones provide much better basic tools for epidemiology and surveillance. On the Internet, information on ecology, migration, agriculture and employment can now be obtained much more easily than before, and this may be the most important advance since the 1950s.

### Exercise 1.5

Outline a table and perhaps help the learners by suggesting items for comparison. At this stage, the learners might not be able to identify all the differences and similarities, but the exercise should help them to appreciate that elimination is not just “more of the same”.

Example of Table 1.1 filled in:

Item	Control programme	Elimination programme
Objective	Reduction of the malaria burden, usually by a certain percentage over a certain time; should be re-set regularly	Total and maintained end of local malaria transmission by a certain date
Area of operations	May depend on endemicity, accessibility and social, political or economic importance	All malaria transmission foci
Minimum acceptable standard of operations	Good: reduction of transmission to a level at which it ceases to be a major public health problem, or, malaria has been reduced to a level that is locally acceptable	Perfect: transmission has been interrupted in the entire area; should new locally acquired infections occur, the cause must be determined and removed.
Duration of operations	Without limit, or until malaria disappears spontaneously	A country can be considered malaria-free when there has been no transmission for 3 years over the entire territory; however, surveillance must continue until (global) eradication has been achieved.
Economic aspects	Expenditure for malaria interventions continues, although gradual reductions are expected, especially for treatment.	Some expenditure will be required after elimination, when the focus will shift to preventing re-establishment of malaria transmission.
Integration with other health programmes	Often convenient and feasible as an integrated public health programme	Less feasible largely because elimination has a highly specific, usually time-limited objective. Yet, malaria surveillance should increasingly become a function of the general health system; after elimination, in the phase of preventing re-establishment of transmission, vigilance should be fully integrated into the general surveillance system.
Case-finding	Subordinate to case management, mainly by passive case detection (people seeking care)	Of primary importance is also finding asymptomatic cases, including by active case detection
Imported cases	Of minor importance, with the exception of importation of <i>P. falciparum</i> in areas where this does not usually occur	Very important
Epidemiological investigation of individual cases	Of little value, except for <i>P. falciparum</i> cases in areas where they do not usually occur	Of increasing importance and finally essential as elimination is approached
Epidemiological evaluation and analysis	Reduction of parasite prevalence; trends in reported malaria incidence and mortality	Proven disappearance of locally transmitted malaria cases; analysis addresses whether transmission has resumed and how it is transmitted. In the final stages, analysis involves less mathematics and statistics.
Unit of intervention	Population, patients, with particular attention to vulnerable groups	Focus (locality), patients

## 1.6 Conclusion

Draw a conclusion at the end of the discussion and then go through the learning objectives to make sure that the participants agree that the objectives have been met.

# LEARNING UNIT 2

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## Basic malaria epidemiology, including transmission dynamics

---

### Learning objectives

By the end of this unit, the participants should be able to:

- Specify the biological and epidemiological features of *P. falciparum* and *P. vivax* that favour or hinder elimination
- Specify the factors related to vectors that influence malaria elimination
- Specify the factors related to human hosts that influence malaria elimination
- Specify eco-geographical factors that influence malaria elimination
- Define the major parameters of transmission intensity used in malaria epidemiology
- Identify the relations between vectorial capacity, basic reproduction rate, entomological inoculation rate and the incidence and prevalence of malaria infection

## 2.1 The tutor should prepare:

A PowerPoint presentation of the learning objectives and the figures and tables from the participants' and tutor's guides and a PowerPoint presentation or printed hand-outs of the exercises.

## 2.2 Suggested time-frame

Allot 5 h to this learning unit: 1 h for presentation, 2 h for the group to do the exercises and 2 h for group presentations and discussion.

The material is important, but most of it, up to 2.4, is suitable for self-study.

## 2.3 Presentation

Review the learning objectives with the participants, and ensure that they understand them.

Start the unit with a review of the biology of malaria parasites and general malaria epidemiology, with emphasis on geographical distribution and ecology. Then, address vectorial capacity, the basic reproduction ratio, the intensity of transmission and malaria stability. Some participants may find it difficult to follow the mathematical derivation of the formulae, and you should adjust the time spent on these parts to ensure that the class is following the presentation.

The participants should understand that the purpose of the models and of graphs in this unit is not to obtain exact values but rather to explain the roles of different factors in malaria transmission. Some participants may not be familiar with exponential functions. You may explain or recall that exponential functions are widely used in biology to describe biological decay and growth, where the rate (speed) of change is proportional to the size of the population at any given time, and in pharmacokinetics, where the clearance is often proportional to the concentration at any given time.

You should gradually introduce the participants to vectorial capacity and basic reproduction rate,  $R_0$ . Not all the participants will grasp the derivation of vectorial capacity; however, what is important is the concept and the relation between duration of infection,  $C$ , and  $R_0$ .

In most texts, students will find the term "basic reproduction rate". This is, however, a dimensionless ratio. This is easily understood by envisioning an area that is malaria-free until one case is imported. The number of introduced cases (first-generation secondary cases) divided by the number (1) of imported cases is then the basic reproduction rate. The word "rate" refers to fractions in which time is in the denominator, such as incidence rate and growth rate. Terms like "parasite rate" and "slide positivity rate", which are proportions, have, however, become so well established that they cannot be abolished.

For participants who want to know more

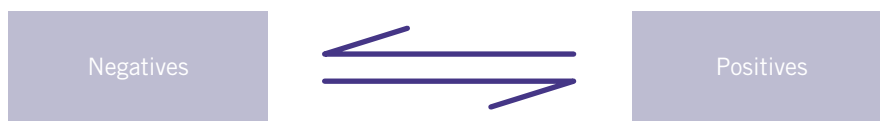
Obtaining data for the variables included in vectorial capacity

Factors that determine the vectorial capacity of a mosquito population and the basic reproduction rate<sup>2</sup>

Definition of index	Common name of index	Method of obtaining the index	Expressions used in text
Bites per human per night by vector population	Human-biting rate	Night-biting captures on human baits, e.g. 10 bites per human	<i>ma</i>
[Bites per mosquito per night ] x [Proportion of bites on humans (“human blood index”) ] =	Human-biting habit	Composed of: (i) feeding frequency, based on the observed gonotrophic cycle in nature, e.g. 0.4 when the female oviposits and feeds an average of once in 2.5 days; and (ii) the human blood index, assessed by the precipitin test on daytime resting samples, e.g. 0.5. Hence, $a = 0.4 \times 0.5 = 0.2$	<i>a</i>
Probability of vector’s survival throughout sporogonic period of parasite		<i>g</i> can be estimated by age-grading mosquitoes or by determining the parous proportion and the duration of the gonotrophic cycle.  <i>n</i> for a given parasite at a given ambient temperature can be found in the literature.	$e^{-gn}$
Proportion of female vectors infected by malaria parasites after ingestion of gametes	Human-to-mosquito transmission probability	Can be assessed only from infections of captive samples on malaria cases, e.g. 0.8	<i>c</i>
Proportion of humans who are infected from a bite of an infectious mosquito	Mosquito-to-human transmission probability	Can be assessed only from forced infections, for example, 0.8	<i>b</i>
Reciprocal of recovery rate, corresponding to the duration of infectivity in humans	Longitudinal observations of local cases of malaria in the absence of transmission, e.g. 200 days		$\frac{1}{r}$

Quantitative relation between prevalence and vectorial capacity

To determine the relation between vector capacity and prevalence of disease, Ronald Ross<sup>3</sup> divided communities into two groups: the ill group and the healthy group. In his model, a number of the healthy individuals acquire malaria and a number of ill individuals are cured and return to the healthy group each day. Note that drug treatment has no place in this model: the ill individuals are assumed to recover once the disease has run its course (reciprocal of the recovery rate, *r*), on the assumption that humans who are infected are infectious to mosquitoes. Reciprocally, the healthy people become ill at a rate that is the product of the prevalence, *y*, multiplied by vectorial capacity, *C*. His model can be represented as follows:



<sup>2</sup> Black RH. Manual of epidemiology and epidemiological services in malaria programmes. Geneva, World Health Organization; 1968.

<sup>3</sup> Dietz K. Mathematical models for transmission and control of malaria. In: Wernsdorfer WH, McGregor I, Eds, *Malaria—principles and practice of malariaology*. Edinburgh: Churchill Livingstone; 1988: Ch. 37 pp. 10911133.

On this basis, Ross gave the following mathematical model of malaria:

$$y(t+1) = y(t) + y(t) C [1-y(t)] - ry(t) \quad (1)$$

where  $y$  is the proportion of positives in the human population,  $1-y$  is the proportion of negatives in the human population,  $C$  is vectorial capacity (per unit of time),  $r$  is the recovery rate (per unit of time),  $t$  is at time  $t$  and  $t+1$  is at time  $t+1$  time unit.

The logic behind formula 1 is that the prevalence at time  $t+1$  is equal to the prevalence at time  $t$  **plus** the new cases that occur in the interval and **minus** the cases recovering in the interval.

Prevalence is represented by  $y$  in the formula;  $y(t)$  represents the prevalence of disease at time of  $t$ , and  $y(t+1)$  represents the prevalence of disease at a time later than  $t$  (e.g. 1 day after). In this formula,  $r$  is recovery rate and  $C$  is vectorial capacity. The prevalence of disease at the time  $y(t+1)$  is a function of:

- ▶ the prevalence of the disease at present, i.e.  $y(t)$ ,
- ▶ the number of cases added to this group, which is obtained by multiplying vectorial capacity by the prevalence of the fraction of the community that is ill, and
- ▶ the number of cases that recover and reduce prevalence, which is the third element of the formula and is obtained by multiplying the recovery rate by the prevalence of disease at time  $t$ .

At equilibrium,  $y(t+1)$  must equal  $y(t)$ ; the added and subtracted terms should be equal:

$$y(t) C [1 - y(t)] = r y(t).$$

Hence:

$$y = 1 - \frac{r}{C}$$

and, when  $r=C$ , then  $y=0$ .

## 2.4 Group exercises

Working in groups, the participants are expected to do at least four of the six exercises in about 2 h. The facilitator should assign exercises to each group.

### Exercise 2.1

Compare the natural history and epidemiology of two species of malaria.

The following traits are important:

- ▶ temperature dependence and geographical distribution;
- ▶ total duration of infection;
- ▶ incubation period, duration of sporogony;
- ▶ time of appearance of gametocytes;
- ▶ susceptibility to different antimalarial agents, emergence of resistance; and
- ▶ clinical manifestations (many recent studies report a risk for complications after vivax malaria; yet, the few rigorous comparative studies indicate that it can be nearly as dangerous as falciparum malaria).



Trait	<i>P. falciparum</i>	<i>P. vivax</i>	Considerations
Presence of hypnozoites	Always absent	Usually present	Long latency in <i>P. vivax</i> , with long incubation and true (exo-erythrocytic) relapses (Add epidemiological features that result from the long latency.)
Temperature dependence: lower threshold for development in the vector	19 °C	16 °C	Explains the difference in geographical distribution of the two species. As a result of the difference from <i>P. falciparum</i> , <i>P. vivax</i> extends to temperate areas.
Incubation period	9–14 days	12–17 days	The small difference has little epidemiological significance. In fact, vivax epidemics often take off more rapidly, probably because of the shorter duration of sporogony and the earlier appearance of infective gametocytes.
Duration of sporogony	Varies with temperature	Varies with temperature	Duration of sporogony decreases with increasing temperature. A shorter duration of sporogony increases the chances that the mosquito will transmit the infection within its lifespan.
Time of appearance of gametocytes	8–15 days	0	A specific anti-gametocyte drug is required to clear the falciparum gametocytes as they appear after treatment of the infection.  Vivax gametocytes are treated at the same time as the asexual stage, and they are susceptible to all the antimalarial drugs.
Susceptibility to antimalarial drugs	Emergence of resistance widespread, multidrug resistance	Emergence of resistance limited to chloroquine and in some areas	The efficacy of the recommended antimalarial drugs must be monitored for effective treatment, particularly falciparum malaria.
Clinical manifestation	Main species that causes severe disease	Can also cause severe disease	Falciparum malaria should be treated promptly, as it causes severe illness and can be rapidly fatal.  The danger of severe vivax malaria should not be underestimated, as recent reports indicate that it can also cause severe illness, mainly severe anaemia.

### Which species is easier to eliminate in your area?

In most areas, *P. vivax* is more difficult to eliminate, mainly because of the reservoir of hypnozoites, which are difficult to detect and treat. In the 1980s and 1990s, falciparum malaria often appeared to be more difficult to tackle in many countries because of its widespread resistance to drugs and the relatively ineffective treatment regimens used. More recently, a number of countries that are on track for elimination have found that they can eliminate *P. vivax* from a given area only a few years after *P. falciparum*.

## Exercise 2.2

### *Factors that determine transmission of malaria*

*Identify the factors in your area that are the most important for the local epidemiology of malaria. Prepare a short presentation to be discussed in plenary.*

The answer could be formulated in response to the following questions:

- ▶ What is the zoogeographical region?
- ▶ What are the important local vectors?
- ▶ How does the natural ecology determine the local bionomics of these vectors, and what kind of transmission pattern results?
- ▶ How does human ecology influence transmission?
- ▶ Are there special risk groups and why?
- ▶ Are there other risks related to, for example, weather or disasters?

## Exercise 2.3

### *Geography of malaria*

*Examine the map (Fig. 2.3). Compare the red line, representing the limits of the area distribution of malaria during the time of its maximum extent, with its present distribution (blue shading).*

It should be easy to provide answers to the questions from the text. You should note that there are secular trends, which are not fully understood, for example, why malaria in Europe peaked in the late nineteenth century and then decreased rapidly. At the moment, malaria appears to be decreasing in Africa, even in the absence of interventions; it is not fully understood why. Unfortunately, malaria might not disappear from Africa the way it did in Europe.

## Exercise 2.4

### *Vectorial capacity and basic reproduction ratio*

The Excel sheet is easy to use. Participants should put in values corresponding to what they consider to be a realistic baseline scenario that they know and then to implement some control measures, preferably trying some that affect density or longevity. The relevant parts of the Excel sheet can be copied onto a PowerPoint presentation, as shown below.

<b>Baseline example</b>			
Parameters	Minimum	Maximum	Your value
$m$ = mosquito density per person	0	500	50
$a$ = human-biting habit	0	0.5	0.5
$g$ = daily mortality rate of the vector	0.05	0.95	0.25
$n$ = number of days for full maturation of sporozoites	12	30	15
$b$ = human susceptibility to infection	0	1	1
$D$ = mean duration of infection in humans	1	220	50
$r$ = daily recovery rate from infection in humans	0.005	1	0.02
Results:			
Intermediate			
$ma^2$			12.5
etc.			
$C$ = vectorial capacity			0.580652
$R_0$ = basic reproduction rate or ratio			29.03262

<b>Density reduced by 80%</b>			
Parameters	Minimum	Maximum	Your value
$m$ = mosquito density per person	0	500	10
$a$ = human-biting habit	0	0.5	0.5
$p$ = daily mortality rate of the vector	0.05	0.95	0.25
$n$ = number of days for full maturation of sporozoites	12	30	15
$b$ = human susceptibility to infection	0	1	1
$D$ = mean duration of infection in humans	1	220	50
$r$ = daily recovery rate from infection in humans	0.005	1	0.02
Results:			
Intermediate			
$ma^2$			2.5
etc.			
Final			
$C$ = vectorial capacity			0.11613
$R_0$ = basic reproduction ratio			5.806523

<b>Transmission reduced</b>				
Density reduced by 50%, longevity by 20%				
Parameters	Minimum	Maximum	Your value	
$m$ = mosquito density per person	0	500	25	OK
$a$ = human-biting habit	0	0.5	0.5	OK
$p$ = daily mortality rate of the vector	0.05	0.95	0.4	OK
$n$ = number of days for full maturation of sporozoites	12	30	15	OK
$b$ = human susceptibility to infection	0	1	1	OK
$D$ = mean duration of infection in humans	1	220	50	OK
$r$ = daily recovery rate from infection in humans	0.005	1	0.02	
Results:				
Intermediate			2.5	
$ma^2$			6.25	
etc.				
Final			0.005753	
$C$ = vectorial capacity			0.287638	
$R_0$ = basic reproduction ratio			0.287638	

# LEARNING UNIT 3

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## Road map to elimination: from advanced control to the prevention of reintroduction

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### Learning objectives

By the end of this Unit, participants should be able to:

- Describe the continuum of malaria control to elimination
- Explain the objectives of each programme phase
- Describe the major programme reorientations and approaches, from malaria control to elimination to prevention of reintroduction
- Identify major programme transition milestones, interpret them, and discuss their limitations

### 3.1 Reading for participants

Before starting this learning unit, the participants should read carefully the evening before (i) Chapter 2, Principles and practice of malaria elimination and (ii) Annexes 2 and 3 in: *Malaria elimination. A malaria elimination field manual for low and moderate endemic countries*. Geneva: World Health Organization; 2007 (<http://www.who.int/malaria/publications/atoz/9789241596084/en/>, accessed 14 September 2015).

### 3.2 The tutor should prepare:

A PowerPoint presentation of:

- ▶ the learning objectives,
- ▶ the figures from the participants' manual,
- ▶ the two figures from the field manual shown below and
- ▶ the learning exercise questions.

Give the figures below to the participants as hand-outs at the beginning of the lesson.

Figure 3.1. Classification of malaria cases by origin of infection

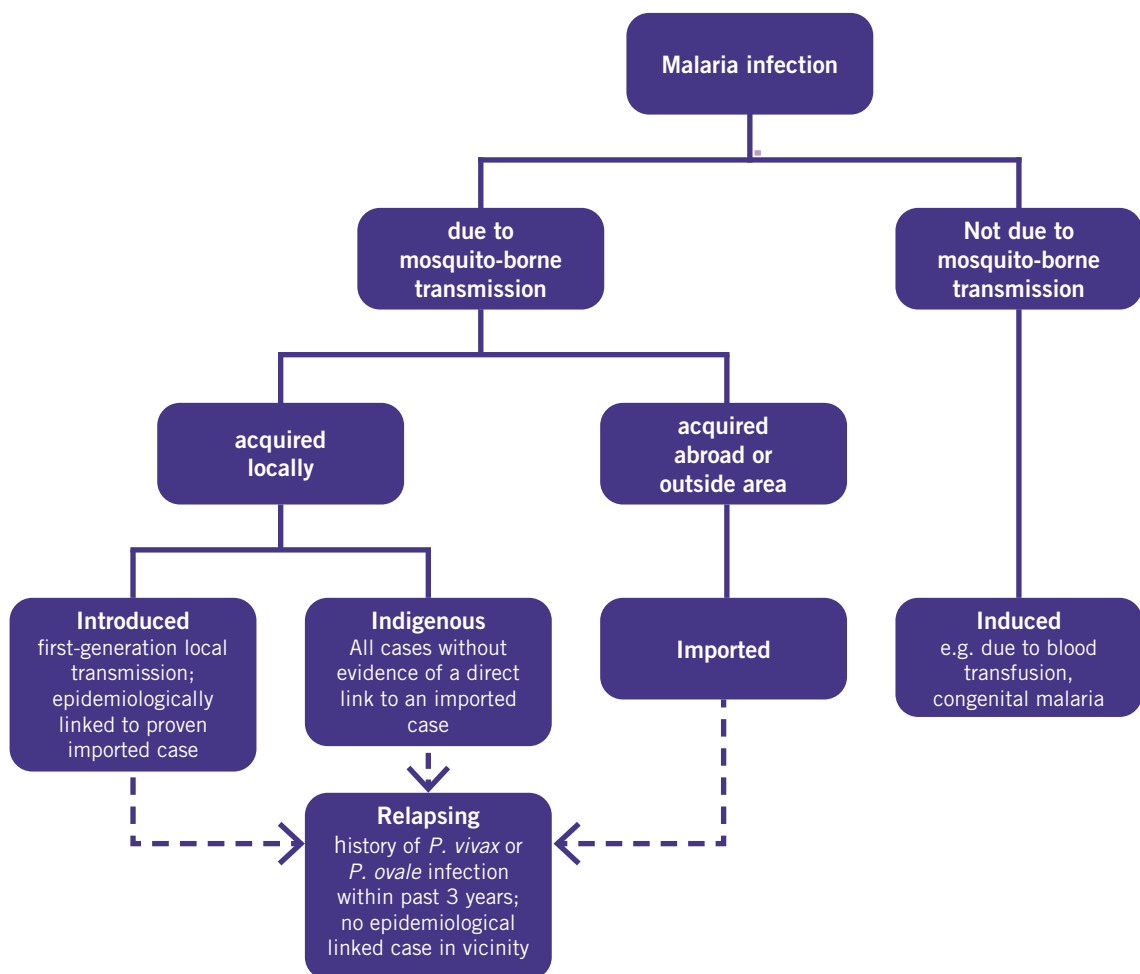
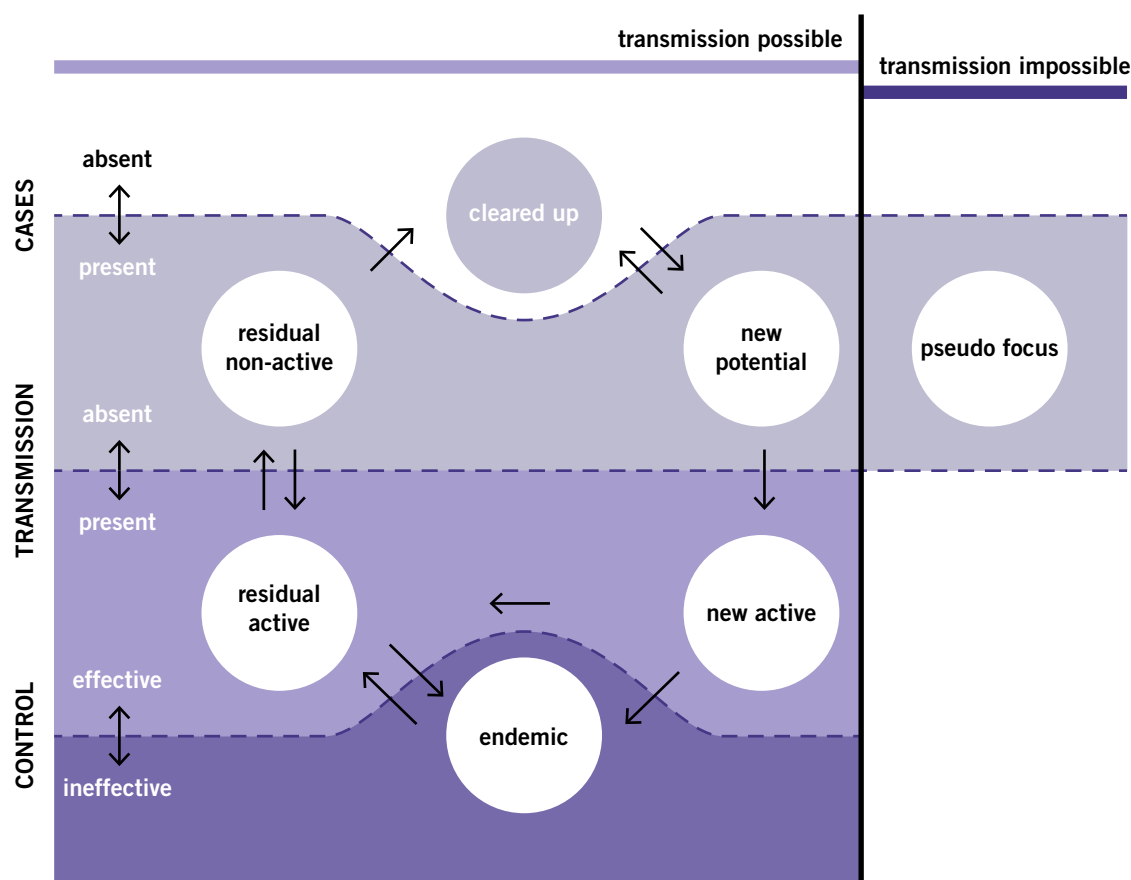


Figure 3.2. Transition of functional status of a malaria focus depending on the situation



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### 3.3 Suggested timetable

Allot 3 h to this learning unit: 1 h for presentation, 1 h for small groups to do the exercises and 1 h for small group presentations and discussion.

### 3.4 Introduction

Review the learning objectives with the participants and ask if they understand them. Ask questions to assess the participants' knowledge and experience of the phases of malaria elimination.

### 3.5 Presentation

Present the material in the participants' guide and the field manual, and discuss the main points with the participants. Emphasize the principal differences between the phases, but note also that the process is a continuum.

Go through the three figures carefully, referring to annexes 2 and 3 in the field manual.

Three points should be emphasized to make sure that all the participants understand them.

- ▶ The epidemiological benchmarks for programme transitions are only indicative. Assessments of operational and programmatic maturity are more important.

- ▶ The pre-elimination phase is that in which the “apparatus” is put in place. The complete requirements are listed in the field manual (Table 2B and pp. 19–20). The apparatus depends on people, and additional recruitment and additional training may be required. Importantly, there must also be well-trained, dedicated staff for the different tasks at province or district level, as national staff can not investigate every case and focus.
- ▶ Stratification should be simplified and streamlined, as indicated in the learning unit (but not in the field manual). There is a paradox here: On the one hand, to assess feasibility, the situation in relatively small areas must be assessed, as, if one district has a very difficult malaria situation, the elimination ambition of a whole nation may be thwarted. On the other hand, once a programme has been set towards elimination, it is meaningless to micro-stratify areas into pre-elimination or elimination phase: this could be continued *ad absurdum*, if for example a given village or household has an annual parasitic index above for example 20 per 1000 per year.

### 3.6 Answers to the exercises

#### Exercise 3.1 (this corresponds to Table 2A in the malaria elimination field manual)

**Table 3.1. Comparison of the different programme phases**

Item	Advanced control programme	Pre-elimination programme	Elimination programme	Prevention of reintroduction programme
Main programme goal	Reduce morbidity and mortality.	Halt local transmission nationwide.	Halt local transmission nationwide.	Prevent re-establishment of local transmission.
Epidemiological objective	Reduce the burden of malaria.	Reduce the number of active foci to 0. Reduce the number of locally acquired cases to 0.	Reduce the number of active foci to 0. Reduce the number of locally acquired cases to 0.	Prevent introduced cases and indigenous cases secondary to introduced cases.
Transmission objective	Reduce transmission intensity.	Reduce onward transmission from existing cases.	Reduce onward transmission from existing cases.	Reduce onward transmission from imported cases.
Unit of intervention	Country- or area-wide	Foci	Foci, individual cases (locally acquired and imported)	Individual cases (imported cases only)
Milestone for transition to next programme step	Slide positivity rate < 5% in suspected malaria cases	< 1 case per 1000 population at risk per year	0 locally acquired cases	–
Data source for measuring progress towards reaching milestones	Proxy data: health facility data Confirmatory data: population-based surveys	Proxy data: health facility data notification reports Confirmatory data: population-based surveys	Notification reports, individual case investigations, genotyping	–



**Table 3.2. Critical health systems and programme issues in different programme phases**  
(this corresponds to Table 3.2 in the participants' manual)

Issue	Control programme	Pre-elimination programme	Elimination programme	Prevention of reintroduction programme
Health system	<p>Access to treatment</p> <p>Access to diagnostics</p> <p>Health system strengthening (coverage, private and public sectors, quality assurance)</p>	<p>Engaging the private sector</p> <p>Control of over-the-counter sales of antimalarial medicines</p> <p>Availability of qualified staff</p>	<p>Full cooperation of the private sector</p> <p>No over-the-counter sale of antimalarial medicines</p> <p>Free diagnosis and treatment for all malaria cases</p>	<p>Integration of malaria programme staff into other health and vector control programmes</p>
Programme	<p>Procurement, supply management</p> <p>Resource mobilization</p> <p>Regional initiative</p> <p>Pharmacovigilance</p> <p>Adherence to the "three ones" principles</p> <p>Integration with other health programmes for delivery of interventions, e.g. ITNs or LLINs, intermittent prophylactic treatment in pregnancy</p> <p>Domestic or external funding</p>	<p>Elimination programme development</p> <p>Legislation</p> <p>Regional initiative</p> <p>Mobilization of domestic funding</p> <p>Establishment of malaria elimination committee</p> <p>Reorientation of health facility staff</p>	<p>Implementation of elimination programme</p> <p>Implementation of updated drug policy, vector control, active case detection</p> <p>Malaria elimination committee: <ul style="list-style-type: none"> <li>manages malaria elimination database</li> <li>repository of information</li> <li>periodic review</li> <li>oversight</li> </ul> </p> <p>Reorientation of health facility staff</p>	<p>WHO certification process</p>

### Exercise 3.2

By the end of the pre-elimination phase, the requirements for elimination should have been met. Therefore, for practical planning, go through the following points, emphasizing those that have been highlighted, and examine the human resource requirements at central level and at decentralized levels, e.g. province and district.

Pre-elimination phase	Elimination phase
Engage private sector Control of over-the-counter sale of antimalarial medicines Availability of qualified staff	Full cooperation of private sector No over-the-counter sale of antimalarial medicines Free diagnosis and treatment for all malaria cases
Elimination programme development Legislation Regional initiative Mobilization of domestic funding Establishment of malaria elimination committee Reorientation of health facility staff	Implementation of elimination programme Implementation of updated drug policy, vector control, active case detection; all cases confirmed by quality-assured microscopy Investigation, classification and recording of all cases and foci Malaria elimination committee: <ul style="list-style-type: none"> <li>• monitor malaria elimination database of cases and foci</li> <li>• repository of information</li> <li>• periodic review</li> <li>• oversight</li> </ul> Health facility staff reoriented

# LEARNING UNIT 4

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## Approaches and interventions in pre-elimination, elimination and prevention of reintroduction

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### Learning objectives

At the end of this unit, the participants should be able to:

- List the objectives of malaria treatment in elimination programmes
- Describe antimalarial treatment strategies for *P. falciparum* and *P. vivax* malaria in elimination programmes
- Describe the indications and objectives of mass drug administration
- List the different vector control methods and their roles in malaria elimination
- Describe the technical and operational issues related to vector control measures
- Review the interventions that can be applied, from the pre-elimination to the prevention of reintroduction stage
- Describe the four approaches (strategic elements) that define a malaria elimination programme

## 4.1 Reading for participants

Before starting this learning unit, the participants should carefully read Chapter 4, Tools and approaches in Malaria elimination. A malaria elimination field manual for low and moderate endemic countries. Geneva: World Health Organization; 2007 (<http://www.who.int/malaria/publications/atoz/9789241596084/en/>, accessed 14 September 2015).

## 4.2 The tutor should prepare:

A PowerPoint presentation of the learning objectives and the figures and tables from the participants' manual and a PowerPoint presentation or printed hand-out of the learning exercise questions. A matrix may be prepared for exercise 4.5.

## 4.3 Suggested timing

Allot 3 h to this learning unit: 1 h for presentation, 1 h for small groups to do the exercises and 1 h for small group presentations and discussion.

## 4.4 Introduction

Review the learning objectives with the participants and make sure that they understand them. Ask questions to assess the participants' knowledge and experience on the approaches to malaria elimination. Identifying weaknesses and strengths will help to highlight issues that might require more detailed explanation and discussion.

*Suggested questions include:*

- ▶ What are the main approaches to malaria elimination?
- ▶ List the tools needed for:
  - ▶ detection of all cases,
  - ▶ prevention of onward transmission from cases,
  - ▶ management of malaria foci and
  - ▶ management of importation of malaria parasites.
- ▶ What is the role of diagnostic laboratories in malaria elimination?
- ▶ What modifications or measures are required so that the laboratory services can fulfil this role?
- ▶ What is the role of antimalarial drugs in malaria elimination? Recall the concept of the basic reproduction ratio and the importance of shortening the duration of infection.
- ▶ What are the main operational problems with use of IRS and LLINs for vector control?

## 4.5 Presentation

Present the material in the participants' manual, but avoid in-depth discussion at this stage. The presentation should prepare the participants to engage in small group discussions to consolidate the information presented.

## 4.6 Small group exercise

Working in small groups, the participants are expected to do one to three exercises in about 45 min. One hour should be used for the group presentation and discussion (15 min for each of three groups and 15 min for conclusions). The groups will present their responses to the exercises in plenary.

## 4.7 Answers to learning exercises

### Exercise 4.1

#### *Operational conditions for IRS*

- ▶ IRS depends on the availability of operational national vector control services with adequate human, financial and logistical resources, including skilled spray teams, storage and transport facilities and spraying equipment. There should be clear policies for human resources (e.g. should sprayers be temporary workers or staff?) and the necessary administration for managing them.
- ▶ As it usually requires several years of consecutive rounds of IRS to achieve and sustain the full potential of this intervention, its adoption requires a medium- to long-term political and financial commitment by national programmes, local authorities and funding partners.
- ▶ IRS must be planned on the basis of accurate entomological and epidemiological information on insecticide resistance, identification and bionomics of vectors, including their feeding and resting behaviour and the dynamics of transmission (rhythm and intensity).
- ▶ Only insecticides to which vectors are susceptible should be used. The procurement decision must be based on relevant data on insecticide resistance within and near the target area. The decision should be consistent with and checked against national resistance management policies. This must be done early, as procurement delays are common.
- ▶ The number, nature and location of the premises to be sprayed and access must be determined by geographical reconnaissance.

#### *Operational conditions for use of LLINs*

- ▶ As mosquito nets are bulky, their storage and transport to target communities must be considered. The time required for procurement, storage and transport must be estimated, so that sufficient numbers of LLINs can be made available when and where they are needed.
- ▶ LLINs should be free and made available to target communities with no gap in the supply chain. Extra nets may be required after 1 year, because of migration, and they should usually be replaced after 3 years or through continuous channels.
- ▶ Distribution of LLINs should be based mainly on sociological and demographic information. A decision should be taken at an early stage about how many nets should be delivered per capita and how many per household with one, two...10 inhabitants. The size, colour, strength etc. should be decided.

- ▶ Resistance to pyrethroids is a serious threat in all types of malaria vector control and must be monitored continuously. Some information indicates that the effect of LLINs may be reduced in areas where the vectors are resistant, but the impact of resistance must be further assessed.

### Exercise 4.2

The factors include:

- ▶ vectorial capacity in the absence of vector control (receptivity),
- ▶ the risk of importation of malaria infections (vulnerability),
- ▶ the quality and capacity of the surveillance and response programme and
- ▶ the immune status of the human population.

A community that has not been exposed to malaria for a number of years will have little or no immunity to malaria; reinvasion can therefore result in sudden, explosive, catastrophic epidemics. Examples include the epidemics reported at various times after the withdrawal of spraying in Cameroon, Ethiopia, Madagascar, Sri Lanka and Sudan.

### Exercise 4.3

The participants should be encouraged to think of ideas for operational research on issues of parasitological diagnosis and antimalarial drug use and on evaluating possible interventions.

- ▶ The involvement of the private sector should be assessed in formative research on how malaria patients are managed, for example by using surrogate patients, or by substantive research such as controlled trials, for example by use of an incentive scheme.
- ▶ Adherence to the 14-day primaquine regimen could be studied by observing the treatment outcomes of vivax malaria patients who receive their treatment as a pack to be self-administered and those of patients who receive the treatment daily from a health worker. Patients could be visited at home and asked to show their primaquine package after, for example, 12 days.
- ▶ What is the importance of non-falciparum malarias in elimination in Africa?
- ▶ More research should be conducted on the adverse effects of primaquine in different groups and on the newly proposed low-dose of primaquine for treatment of falciparum malaria.
- ▶ New diagnostic tests for glucose-6-phosphate dehydrogenase (G6PD) deficiency are available and should be introduced, as the prevalence of this deficiency limits the potential use of primaquine as radical treatment of vivax malaria.
- ▶ Studies could be conducted on the knowledge, awareness and practices of patients and of public and private health care providers.
- ▶ The cost-effectiveness of IRS and LLINs could be compared in desk or field studies.
- ▶ A study could be conducted to determine the diagnostics used in the private sector and their sensitivity and specificity.

### Exercise 4.4

The options are:

- ▶ Set up a good local surveillance unit. Determine whether microscopy can be set up. If not, determine how long it would take to send slides to a reference laboratory.
- ▶ Do a sample survey.
- ▶ Screen the whole population and then decide.
- ▶ Go ahead with mass drug administration (MDA).
  1. MDA is rational under all circumstances. It will probably be based on screening with RDT and sending slides to a reference laboratory.
  2. MDA is not attractive, as positive cases could be missed; in other words: as the expected prevalence is low, a very large sample size would be needed.
  3. MDA is more attractive. Is it feasible with microscopy? RDT?
  4. Depending on the results, a considered opinion on MDA or not could be stated.

In relation to the safety issue: There are good reasons to include a single dose of primaquine. If the country already uses it on a large scale, it should be OK. Otherwise the 0.25mg/kg dose could be an option to prevent transmission. While the MDA takes place, a qualified clinician should be available, rapid evacuation for blood transfusion should be possible, if there is a concern that one of the dangerous types of G6PD deficiency is prevalent.

### Exercise 4.5

Preparation of the matrix should be simple, as it is an adaptation of the content of the participants' guide. When the group is filling in the cells, they should demonstrate critical thinking in deciding what to include and why in each of the four phases.

## 4.8 Conclusion

Summarize the main points in the learning unit and go through the learning objectives with the participants to confirm that they were met. Alternatively, ask three or more participants to state the main lessons they have learnt in this unit.





# LEARNING UNIT 5

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## Surveillance, including laboratory methods

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### Learning objectives

By the end of this unit, participants should be able to:

- Describe the role of surveillance in different phases of malaria elimination
- Describe the role of microscopic diagnosis in malaria elimination
- Interpret laboratory reports
- Describe key issues in the establishment and maintenance of quality assurance for microscopy
- Describe the role of geographical information in malaria elimination
- Use meteorological data in relation to malaria transmission (using Moshkovsky's method in temperate and subtropical areas)
- Organize case detection activities
- Conduct an investigation of a malaria case
- Classify cases of malaria
- Classify foci of malaria
- Explain epidemiological indicators used in surveillance
- Establish a surveillance system for malaria elimination

In view of its size and complexity, the material in this unit may be divided into blocks:

Block	Short name	Exercises	Duration (h)
1	Surveillance in different phases of malaria elimination	5.1	1
2	Role of laboratory diagnosis	5.2, 5.3	1
3	Geographical information	5.4, Annex 2 exercise, if Moshkovsky's method is taught	1
4	Malaria case detection and epidemiological investigation	5.5, 5.6	2
5	Data recording and reporting		1
6	Establishing a surveillance system	5.7	1

Prepare a PowerPoint presentation giving an overview of the learning unit and its objectives. This should be followed by a few slides for each of the six blocks, with learning objectives, essential points from the participants' module and the surveillance manual, difficult or contentious issues and the exercises. Then, review the overall objectives again and, with the participants, assess their attainment.

For each block, give a short introduction; then, ask small groups of participants do the exercise(s), using the learning unit and the surveillance manual as references, write a short report and discuss the findings or reports in plenary.

### **Block 1. Surveillance in different phases of malaria elimination**

To do *exercise 5.1*, the participants must understand the evolution of surveillance as the programme moves from control to elimination. The trends are:

- ▶ from generalized summaries to focused, detailed information;
- ▶ from paper documents to computer (unless this has already been done); and
- ▶ from storage of primary detailed case information at the periphery to its transmission to and use also at national level.

Concentrate on the differences in the epidemiology of malaria and approaches to its surveillance in control and elimination settings (table and boxes 1.1–1.3 in *Disease surveillance for malaria elimination*).

Advise the learners to list all conceivable surveillance activities in the first column of the table of the exercise. Each activity generates one or several documents, which should also be listed. For example, case detection generates registers of cases, which may be in the physical form of lists or cards or electronic tables or databases. The content of the registers depends on the phase of control or elimination, and the learner should describe this content in the remaining three columns of the table.

After a discussion, ask the participants to work on exercise 5.1, individually or in small groups. The form of the products of each group may differ considerably. Make sure that all the activities are covered. For example, the content of meteorological observations will depend primarily on geography, as it determines the relations between meteorological variables and malaria transmission. During the control phase, a general assessment of the suitability of the weather at particular time and place is sufficient, but, in the elimination phase, the suitability of weather for

transmission should be assessed rigorously for areas in which transmission is still or is suspected to be occurring.

The list in column 1 should include the following surveillance activities:

- ▶ registration of cases,
- ▶ maintaining a roster of foci with follow-up of their functional status,
- ▶ meteorological observations,
- ▶ quality assurance of diagnosis,
- ▶ quality assurance of treatment and
- ▶ rare events, like mortality.

## Block 2. Role of laboratory diagnosis

This field is developing rapidly. While the sensitivity and heat tolerance of RDTs are improving, no RDT can yet detect (*P. falciparum*) gametocytes. Molecular diagnostic tools for malaria are also developing rapidly, and you should keep abreast of these developments.

You may start by asking probing questions to ensure that there is consensus on the issues. Particular attention should be paid to:

- ▶ the requirement that every case be confirmed by laboratory testing,
- ▶ recording of gametocytes of *P. falciparum*,
- ▶ the role of RDTs and
- ▶ quantitative evaluation of parasitaemia.

Participants may have different opinions about the applicability of these requirements in their countries, and you should encourage an open but rigorous discussion, which may be continued in the groups. You should tell the participants that WHO recommendations may change as new techniques are introduced and validated.

### Exercise 5.2

This exercise will help participants to summarize the various aspects of case detection in malaria surveillance. They are expected to list all relevant methods and their details. For example, the table should include such items as thin and thick films, assessment of parasite density and the different types of RDTs and PCR.

You might remind the participants that the value of a method depends on the endemicity of malaria and the stage of malaria control or elimination. Some methods are useful for screening but not for a definitive diagnosis, e.g. detection of visible signs of anaemia. Methods that have limited or no use in elimination should also be discussed.

### Exercise 5.3

The aim of this exercise is to show participants how to extract the maximum information from a laboratory report. A report may state only that a slide is positive, or it may contain full details, the meaning of which the clinician does not understand.

Participants must list the following main items: species, stage for *P. falciparum* and parasite density. They should also give examples and their meaning, e.g.:

- ▶ *P. falciparum* gametocytes and asexual forms are present at the first blood examination, indicating that the case was detected late; an investigation should be conducted to find the reason:
  - ▶ at first contact, a medical worker did not order a blood examination,
  - ▶ a microscopist did not recognize parasites,
  - ▶ the patient did not appreciate the seriousness of his or her disease,
  - ▶ etc.
- ▶ *P. falciparum* gametocytes are present only with signs of anaemia (e.g. high density of reticulocytes) when multiplication of the parasite is likely to have stopped recently. Anti-gametocyte treatment should be given and probably also schizonticidal treatment, as the finding is compatible with treatment failure when asexual parasitaemia has not yet become patent.
- ▶ *P. falciparum* asexual forms are present at 100 000 per  $\mu\text{L}$  or  $\geq 5$  on preliminary evaluation, indicating a risk for precipitous deterioration and death.

And so on.

### Block 3. Geographical information

#### Exercise 5.4

This exercise, as formulated, requires reasonably good access to the Internet by all participants throughout the course. If this is not available, you may download some files before the course from Jansankhya Sthirata Kosh (jsk; see participants' module), study the corresponding area on Google Maps™ and create pictures for the use of participants.

The jsk website provides a good overview of health care; the administrative subdivisions are those used for health service organization. A primary health centre is usually staffed by at least one doctor, several nurses and midwives and various general health workers. A sub-centre is a small clinic usually staffed by one nurse or midwife, who supervises several village volunteers who provide primary care in villages. The maps are not very useful, because they do not show where villages are located. If a village is to be covered with a certain intervention, the distance file indicates how large the population is. This has several weaknesses. The information has not been updated; although it would be easy to update the demographic information according to growth rates, population distribution changes for many reasons. Also, in India, as in most parts of the world, many people listed as living in a certain village actually live in hamlets that may be several kilometres from the village centre.

Google Earth™ shows individual houses, waterways and landscape features such as forests and provides geographical coordinates and altitude above sea level. Many village names are also given. The precision varies from place to place, and this tool should never be assumed to be a reference. Once an important area has been delineated in Google Earth™, it can be visualized in Google Maps™, which show two main views: *satellite*, which shows important landscape features, and *map*, which gives labels and access roads. Both should be used for mapping a focus. The *map* view may be the easiest to use for pinpointing malaria cases and illustrating people's movements

by arrows on presentations. These maps should be filed as part of the documentation on a focus and updated regularly.

Teaching *Moshkovsky's method* requires some preparation by the tutor. The mathematics are simple, but the concepts must be absorbed. The method is probably useful nowadays only in Europe, Central Asia, the northern part of the Middle East, central China, the Korean peninsula, southern Africa and Ethiopia. When the participants are from other areas, the method should be mentioned, but not taught.

#### *Exercise in Annex 2*

This exercise requires some skill in using Microsoft Excel. At the start of the exercise, you should demonstrate how the spreadsheet works, preferably by projection. Explain carefully that some cells contain numbers, others formulae. You can explain the meaning of the formulae by showing the formula line. The instructions in the spreadsheet are self-explanatory.

### **Block 4. Malaria case detection and epidemiological investigation**

Most of these exercises pertain to the Russian Federation and western and central Asia. In training courses for other regions, tutors and facilitators should try to find alternative examples. If exercise 5.7 will be a major one, you should probably select only some of the situations in 5.5–5.6.

#### **Exercise 5.5**

This exercise is an introduction to exercise 5.6. It also provides an opportunity to discuss the activities to be undertaken in such situations.

Between the end of the 1990s and about 2005, the Russian Federation experienced considerable importation of *P. vivax* from neighbouring newly independent states. Tajikistan was the most severely affected: during the peak of the epidemic in 1997–2000, the estimated number of cases was about 100 000 per year. Local transmission of *P. falciparum*, which had been absent from the country since the late 1950s, also resumed (up to 1000 cases in 2000 and 2001). Importation led to local transmission of *P. vivax* in a number of territories, especially in the city and governorate of Moscow. Transmission in the Russian Federation peaked in 2001 and 2002 (134 and 138 cases, respectively); the situation was exacerbated by particularly hot weather in 2002 in the central part of the country. The situation described in the exercise occurred during this outbreak.

There had been no local transmission of malaria in the area described in the exercise since the mid-1950s. Local people were aware of the presence of malaria in the governorate, and fever cases were reported. Many recent cases of malaria had been in Tajik migrants. They often had antimalarial drugs with them, which they used readily. Many avoided contact with the local authorities and health services because they had no legal status. Some were also afraid of being hospitalized. On arrival, they often stayed for a short time in makeshift shelters belonging to Tajik contractors and moved on after the contractor secured a job for them.

The salient points for discussion are:

- ▶ What was the origin of infection in this village? A plausible explanation is that the cases were in the Tajik migrants in the self-styled settlement nearby. The chain of infection could probably

not be identified down to individual level, as parasite carriers could have moved elsewhere before the secondary cases appeared.

- ▶ What were the breeding places of vectors? There were many potential sites in this area, some of which were very productive, such as the dead channel in the photograph.
- ▶ Could the second case have originated from the first one? This is impossible, because the interval between the two cases is too short.
- ▶ Why was the second case found further from the supposed source than the first one? Mosquitoes disperse more or less randomly. The sporogonic period for *P. vivax* in July in central Russian Federation is at least 2 weeks. During this period, mosquitoes would have fed and laid eggs at least four times, each time migrating between the village and water bodies. They might therefore have dispersed over several kilometres during the sporogonic period.
- ▶ Could the village shop, where the migrants bought food, be the source of malaria transmission in the village (as some villagers believed)? No.
- ▶ What was special about this situation? Malaria was transmitted between two autonomous regions (members of the Federation). This made coordination of activities extremely difficult.

In conclusion, both cases in the village were introduced secondary to one or more unidentified cases among migrants. The focus of malaria infection in Drakino was newly active. The nearby immigrant settlement should be considered a separate focus, with its own characteristics, including a shifting population.

Participants often indicate that the response should be better case detection in the village, for example by active detection in periodic house-to-house visits. This would be wasteful, as the population was non-immune; thus, a detectable blood infection would necessarily be accompanied by fever. A more rational solution could be to assign a health worker to diagnose and refer cases.

Many participants suggest that surveys should be conducted among the migrants. This would not be useful, because new potential parasite carriers arrive all the time. Even screening on arrival would be of limited use, because most parasite carriers would carry undetectable hypnozoites. Besides, screening would be very difficult to enforce.

Many suggest larviciding in the dead channel. Unfortunately, this would have little effect because of the large surface of the water body, poor access to parts of it and the presence of many small breeding places elsewhere.

The most economic vector control strategy would probably be IRS. Participants who give this answer usually do not specify which structures should be sprayed. When asked, they often state that the entire village should be targeted. This would be wasteful, because IRS cannot prevent incoming vectors from infecting people. The most important sources would be the temporary shelters, which should be sprayed at the beginning of the transmission season. Care should be taken to check them periodically and spray new structures. Vehicles should be also sprayed, as they may be used for sleeping.



## Exercise 5.6

### Situation 5.6.1

The case of Miss M. was relapse of an imported case. If there had not been an early attack (caused by tachysporozoites), it would have been classified as a primary delayed manifestation. The relapse occurred in spite of treatment with primaquine, probably because of the well-known refractoriness of *P. vivax* of West Pacific origin to this drug.

The fact that this imported case was a relapse is not of epidemiological significance. From an epidemiological viewpoint, it is only important that it was imported.

The situation would be different if a patient living permanently in a residual non-active focus experienced a relapse or a delayed primary attack. When this occurs long after the infection was contracted, it is called a “relapsing case”. It may be difficult to establish with certainty whether the attack results from an old infection or a new one. This is often possible only after careful investigation of the case and the focus, and even then some uncertainty may remain. If the case is indeed a relapse or a delayed primary attack, the focus maintains its status as residual non-active; however, it would signify a relapse in the focus and should lead to heightened alertness. This is why a special term is used for such cases (see Box 2.3, point 4 in the surveillance manual for malaria elimination, p. 14). Note that most relapses (e.g. the case of Miss M.) are not classified as relapsing cases.

The distinction between relapses and relapsing cases may be difficult to understand. A relapsing case is due to hypnozoite activation after an unusually long interval. It occurs in a residual non-active focus and must be carefully distinguished from a new, locally transmitted infection. It should lead to heightened alertness.

The case of Dr B. was induced.

### Situation 5.6.2

The cases in the two brothers were indigenous. There were indications of lingering low-level transmission in Minbashly village (unspecified cases during the previous year and one case on 11 June during the current year). Consequently, the focus was active and residual.

Their relative in Molday probably contracted malaria at or about the same time when visiting Minbashly. Its independent origin cannot be ruled out but appears far-fetched, as there had been no evidence of transmission in Molday for 2 years. To focus operations during elimination, each case must be classified by the village of residence. The girl contracted malaria outside her village and imported the infection into this village. From the perspective of the Ministry of Health, all three cases were indigenous to the district, whereas for WHO they were indigenous to Azerbaijan and the USSR.

By the end of July 1972, Molday was a new potential focus. Mosquitoes could have been infected by case M. Development of *P. vivax* at the optimal summer temperatures in the plains of Azerbaijan would take about 2 weeks. Mosquitoes infected in July would die out within 1 month but could infect people during the rest of their lives, i.e. until mid-August. The incubation period for vivax infection induced by tachysporozoites is usually 14–16 days and no less than 10 days; consequently, secondary cases could emerge in August or September. About half of infections are,

however, by bradysporozoites, which induce infection with hypnozoites that remains latent for 9–12 months (for strains in temperate areas). Therefore, secondary cases could also be expected to emerge at any time during the next season, between May (for parasites contracted in August and that remain dormant for 6 months) and September (for parasites contracted in September that remain dormant for 12 months).

Therefore, the focus remained a new potential focus until the end of the season of 1973; it should have reverted to cleared-up status in 1974 if no new transmission occurred. On very rare occasions, however, hypnozoites remain dormant for more than 1 year. Cases emerging in 1974 might have been contracted in 1972, but it would be unwise to build up a system of surveillance on the basis of such a rare possibility. Should such cases have emerged in 1974 and later, they would be classified epidemiologically as relapsing cases in the sense referred to under situation 5.6.1. The focus would maintain its status as a residual non-active focus.

This observation is also interesting because the two cases started on the same day. Such time–space clustering was commonly observed in Azerbaijan at that time. It was hypothesized that the pattern was due to the habit of local vectors of biting nearby individuals if their feeding was interrupted.

Another interesting feature is the mode of detection of the case. Strictly speaking, this was neither active nor passive detection: information on the case was divulged voluntarily by a third party living in a different place. This shows the importance for epidemiology of listening to people.

#### *Situation 5.6.3*

Case A was an introduced case originating from a recently imported case, H. The possibility of contracting malaria elsewhere (for instance if the girl lied about her travel) could not be excluded but is far-fetched. The hypothesis that undetected transmission was occurring all the time in Shaumian (so that case A would be indigenous) is also unjustified.

Case H was imported.

By the end of October, there was evidence of transmission. The focus should be classified as a new active focus.

#### *Situation 5.6.4*

Case C.L. was imported (contracted overseas) and a relapse. Some participants argue that C.L. cannot be considered a case as parasites were not demonstrated when he was in the USA; however, the fact that many people contracted malaria from him is evidence that he had malaria parasites in his blood and this was therefore a case.

The other cases were induced. The idea that some of them contracted the infection from mosquitoes is far-fetched. In induced cases of vivax malaria, formation of hypnozoites and, consequently, relapses are impossible; however, gametocytes are produced, and the cases are infective for mosquitoes. In this situation, however, most of the cases occurred during the cold season, when infection of anophelines was impossible.

Foci should be considered potential ones. Natural transmission of malaria occurred in the valley of Sacramento before and after this episode; however, the probability of infection of mosquitoes should be assessed individually, with an evaluation of the temperatures in the places of residence of cases during illness.



The original publication is worth reading, as it includes much useful information about malaria in drug addicts.

#### *Situation 5.6.5*

The mid-1960s were the heyday of malaria eradication in India. Malaria transmission was interrupted in most densely populated areas but lingered mainly in remote and neglected areas.

The cases in the villages were classified as imported. The lag between the first and the last cases is too short to assume that some of the cases were due to transmission within the villages, especially as the temperatures during January are near the threshold of *P. vivax* development in mosquitoes.

The villages should be treated as new potential foci. Although there is no evidence of recent transmission, some local mosquitoes might have become infected. Furthermore, hypnozoites can be reactivated within a year or so, again leading to a risk for transmission. The area around the temple should also be considered a focus, even though it is not recognized as a human settlement administratively. Although humans were present only occasionally, infection of a mosquito population is evident. The sources were people coming from different places, in some of which malaria transmission had not been interrupted.

It had been suggested that the source was monkeys, which are abundant in the area. Macaques in India are often infected by a vivax-like parasite, *P. cynomolgi*, which can occasionally infect humans. This parasite is, however, unlikely to produce a high prevalence.

#### *Situation 5.6.6*

The surgical patient, A, was an induced case. B was an imported case, a relapse.

Having experienced many episodes of malaria while in Afghanistan, patient B probably developed pronounced immunity, keeping parasitaemia at a low level. Parasites were, however, present in his blood, and the blood recipient received small numbers of them. Because of the very small inoculum, the parasitaemia reached densities that were able to produce pyrexia in A quite late.

B showed no evidence of chloroquine resistance. Pyrexia is associated with mass destruction of parasites. The last paroxysm often occurs after treatment has been initiated and may be even worse than earlier paroxysms.

In induced malaria, when the donor has a very low residual parasitaemia, it may be difficult to identify the origin of the infection, as one patient may have received blood from many donors. In this case, the donor's parasitaemia was increasing and provoked the usual symptoms, although after a delay. This simplified identification of the source. The last blood transfusion was illegal and unjustified. Paid blood donors generally represent a high risk for transmission of a variety of pathogens. Fortunately, the donor had enough civic responsibility to disclose the fact of the donation.

#### *Situation 5.6.7*

Every year, cases of *P. vivax* and *P. falciparum* are imported to Oman by labourers from the Indian subcontinent. As a latent state of *P. vivax* for 4 years is highly improbable, case 1 was imported and case 4 introduced, probably contracted from case 1. Cases 8 and 9 were probably due to recent transmission. Cases 6, 7 and 10 might have been due to delayed activity of an infection acquired

on the Indian subcontinent, but a more serious alternative should be accepted in this case, which is that all the cases were the result of recent transmission. Some of the cases might have been infected elsewhere, but at least a few resulted from recent local transmission, which is sufficient to declare the focus of Izz a new active one, from the moment the evidence of local transmission was obtained (9 August). On 12 July, the focus would be classified as a new potential focus.

Lack of full evidence that all the cases were contracted in Izz is not critical for decision-making. Overall, the evidence indicates local transmission. Therefore, appropriate measures for enhanced case detection and vector control were introduced. The use of fogging was probably motivated by the fact that the migrant workers all slept in the open air, making IRS a questionable option. Fogging is generally not considered very effective for malaria control, and personal protection might have been more rational.

The presence of renewed transmission jeopardized certification of malaria elimination in Oman. The management of the event, however, demonstrated that the programme fully assumed its responsibilities.

## **Block 5. Data recording and reporting**

Review the indicators with the participants; then, ask the participants to select the indicators to be used in exercise 5.7

## **Block 6. Establishing a surveillance system**

### **Exercise 5.7**

Ask groups of participants to outline a plan for a surveillance system for malaria elimination for one country. The distribution of the participants for this group work may be by country or for two countries. The group work may constitute the main exercise of the course, in which everything that has been learnt can be applied. You may propose the following outline.

1. Brief description of the current malaria situation
2. Description of current macro-stratification
3. Description of malaria surveillance system, as currently designed (including surveys, not only day-to-day recording and reporting)
4. Identification of problems in performance and the reasons for such problems (e.g. reports from districts are incomplete because staff are too busy and not motivated)
5. Design of a suitable surveillance system for elimination, perhaps differentiated by stratum
6. A detailed plan of the activities necessary to set up the surveillance system, i.e. for changing from the current situation to an elimination surveillance system, including the norms that should be changed and weaknesses that should be addressed
7. Draft standard operating procedures, for example for malaria staff and for general health service staff (remember the private sector!)
8. Operational targets, milestones and timelines (realistic)
9. Costs
10. Risks and constraints, and alternative strategies

# LEARNING UNIT 6

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## Prevention of reintroduction

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### Learning objectives

By the end of this unit, participants should be able to:

- Explain the relations between receptivity, vulnerability and malariogenic potential and the likelihood that malaria will be re-established
- Define vigilance, and describe the patterns of vigilance required to prevent re-establishment of transmission in different settings
- Describe the required capabilities and organization of the health services in countries that have recently been freed from malaria transmission
- Determine the training required for adequate malaria vigilance in different settings

## 6.1 The tutor should prepare

A PowerPoint presentation of the learning objectives and definitions and a set of questions to refresh the participants' recall about the continuum of control to elimination and surveillance

## 6.2 Suggested time-frame

Allot 3 h to this learning unit: 1 h for presentation, 1 h for small group work and 1 h for class discussion.

## 6.3 Presentation

Start with a review of the learning objectives with the PowerPoint presentation, and ensure that they are fully understood. Then, review the concepts of receptivity and vulnerability, and present the material in the *Guide for participants*.

### Exercise 6.1

Whichever option you select for the exercise, emphasize the following elements:

- ▶ The challenge of maintaining essential malaria expertise at central level
- ▶ Creating and maintaining awareness in the general medical profession, especially private practitioners. Novel methods can be considered, such as:
  - ▶ using the press to describe unexpected cases that were not handled well;
  - ▶ web-based training, which could be made compulsory;
  - ▶ information about changes in the global or regional malaria situation;
  - ▶ events on World Malaria Day.

Such actions should be initiated long before a country reaches malaria-free status. In most countries, malaria transmission is interrupted in many areas before others, which are subject to the requirements of "prevention of reintroduction". This gives programmes the opportunity to pilot-test their vigilance approaches at subnational scale.

Promotion of chemoprophylaxis for travellers can be considered part of vigilance, as it depends on the same group of professionals: general medical practitioners.

# LEARNING UNIT 7

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## Health systems and inter-sectoral and cross-border collaboration

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### Learning objectives

By the end of this unit, participants should be able to:

- Explain how the various components of the health systems are related to effective malaria control and elimination
- Give examples of common weaknesses in health systems, which constrain malaria elimination, and identify ways to overcome those weaknesses
- Describe measures for re-orienting the health system towards malaria elimination
- Determine the roles of the private sector, the community, other sectors and inter-country collaboration
- Identify suitable topics for operational research on elimination

## 7.1 The tutor should prepare:

A PowerPoint presentation showing the learning objectives, definitions and Figs 7.1 and 7.2 in the participants' guide. You should also prepare a set of questions to determine strengths and weaknesses, such as: How is the health system defined? What are the basic components of the health system?

The answers are explicit in the participants' module.

*Define the terms "vertical disease programme" and "primary health care".*

"Vertical" is unofficially defined in the participants' module as a characteristic of a programme that is centrally directed and relies on programme staff. Any disease programme is vertical to some extent. As indicated, "malaria eradication programmes" were at their inception extremely vertical. "Primary health care" is not defined in the participants' module, because it should be well known (although the discussion may show that different people understand it in different ways). The original definition in the 1978 Alma-Ata Declaration is:

Essential health care based on practical, scientifically sound, and socially acceptable methods and technology made universally accessible to individuals and families in the community through their full participation and at a cost that the community and country can afford to maintain at every stage of their development in the spirit of self-reliance and self-determination. It forms an integral part of both the country's health system, of which it is the central function and the main focus, and of the overall social and economic development of the community.

Discuss with the participants how universal coverage and universal access are similar to or different from primary health care.

*How could weak health systems benefit from malaria elimination programmes?*

Where malaria cases present a significant burden to health facilities, a reduction in the number of malaria cases as a result of disease control will make more resources available for management of other diseases. When the elimination phase is initiated, the national malaria burden is low, but it may be high in small sub-populations, who are usually the least privileged. Thus, elimination often supports equity and universal coverage. For health services, one of the great advantages of elimination is that clinicians do not have to consider malaria all the time: they do not need to test samples, except from a fever patient with a relevant travel history. The challenge is to ensure that clinicians do not forget malaria! In the 1980s in Europe, the case fatality rate from falciparum malaria varied greatly from country to country, depending on the investment in maintenance of awareness by national departments of health.

The newly available resources could be used to strengthen some components of the health system, such as supply, logistics and health information systems, which are required to deliver a range of health interventions. For example, addressing supply chain problems to ensure regular availability of antimalarial medicines in health facilities could also improve the availability of essential drugs for other conditions, e.g. antibiotics for treatment of bacterial infections. This kind of strengthening is more frequent in the control phase.

In the advanced stages of malaria elimination, a surveillance system with rigorous monitoring and quality assurance could be useful for other programmes. In countries with weak health

systems, the mere introduction of a programme with rigorous standards can set an important example, as was observed in relation to malaria elimination in Turkmenistan.

The engagement of the private sector, the corporate sector and the military might also be good examples of health system strengthening. Too often, public health workers assume that the health system consists only of government-operated services. Horizontal collaboration is essential.

## 7.2 Suggested time-frame

Allot 3 h to this learning unit: 1 h for presentation, 1 h for small groups to do exercises 1.1–1.7 and 1 h for small group presentations and discussion.

## 7.3 Presentation

Start the presentation with a review of the learning objectives. Determine the extent of knowledge and experience of the participants on the subject by inviting answers to introductory questions. Avoid discussion of the subject, and do not provide answers to the questions. Note the areas that are already well known and any misunderstandings, which you will correct later.

Focus the presentation on what is not known and on correcting misconceptions.

## 7.4 Exercises and class discussion

Working in small groups, the participants should prepare answers to the exercise, which they will present to the class. The written exercise should be done as homework, each participant being required to search the literature, select an operational research project and prepare a summary.

## 7.5 Answers to exercises

### Exercise 7.1

Malaria managers face political or diplomatic challenges due to decentralization of health care. The concern of district and provincial health officers is understandable from their perspective but seems petty in a national perspective. Malaria managers might require some financial support from the central level but worry about how long it will be guaranteed. Most importantly, they must establish an excellent, trusting relationship with provincial and district authorities.

There are many ways to strengthen service provision in villages (see participants' module 7.4), and these should be thoroughly discussed. In this case, the culture and geography would favour community health workers or volunteers, who should be well supported with remuneration and supervision. If they are health workers, they should expect to receive a salary from the government. If they are volunteers, they should receive an incentive, which could be per RDT, per slide or per case detected and correctly treated. The pros and cons of these options should be discussed.

### Exercise 7.2

For collaboration with oil company health services and general health services, staff at both these entities should have been trained. The oil–gas workers who operated near Afghanistan should have been informed about the malaria risk and been provided with preventive measures, such as mosquito nets.



### Exercise 7.3

Little quantitative information on the health system is given in the main text, but annexes 2 and 3 (in *Eliminating malaria: Case-study. Moving towards sustainable elimination in Cape Verde*. [http://apps.who.int/iris/bitstream/10665/75849/1/9789241504386\\_eng.pdf](http://apps.who.int/iris/bitstream/10665/75849/1/9789241504386_eng.pdf)) provide excellent data, which suggest that the health care infrastructure and performance are adequate. For this country, it would appear that it is the programme rather than the health system that should be strengthened.

### Exercise 7.4

*Examples of operational research topics for malaria elimination*

- ▶ To what extent should microscopy be maintained after transmission has been interrupted? Where should RDTs and antimalarial medicines be deployed?
- ▶ This question is probably best addressed by a desk study of the costs and benefits of different models in a given country, such as the availability of microscopy and RDTs at the level of hospitals, health centres or dispensaries.
- ▶ What are the optimal modalities for managing human resources such as spraymen and those conducting active case detection: casual labourers or contractual staff? Spraying and active case detection require only a few days of training. Young people should not be encouraged to continue this kind of work for many years. These factors suggest that casual employment might be preferable, as both the employer and the employee can terminate the employment easily. In some countries, however, experience suggests that long-term contracts are advantageous for the government and employers. The question could be studied with a randomized design in which job satisfaction and supervisor satisfaction are the main dependent variables. The right answer to this question will vary from country to country. Human resource specialists at the ministry of health or other sectors should be involved.
- ▶ What kind of incentives should be given to village malaria volunteers? This issue also came up in exercise 7.1. There are various possibilities, as indicated in the participants' module. Health economists should be involved in making a decision, but experienced malaria managers may be equally capable of understanding the consequences of each option, corresponding to (small-scale) systems thinking. A randomized trial could be set up to test different options, with the numbers of suspected cases tested and the number of positive cases detected as the outcome variables, after checking that the people tested are those who should be tested.
- ▶ For surveillance, many issues could be investigated, such as the role of active case detection and other means for improving case-finding, possibly by prioritizing special risk groups. Furthermore, the criteria for testing could be refined. In the elimination phase, when malaria is rare, the usual guidance is to test people with fever that "has no other obvious explanation". While that may be clear to a medical doctor, small groups of experts often spend two afternoons in a comfortable air-conditioned meeting-room to produce algorithms for this purpose, and the guidelines are then reproduced in thousands of copies. Testing the intelligibility and acceptability of guidelines and algorithms, possibly with alternative options, could be an excellent topic for operational research.



### Exercise 7.5

If it has not already been done, participants must assess how much malaria (locally transmitted and imported) is expected in various parts of the country and how great will be the demands on human resources at different levels of the health system. Should new people be recruited? Will it be possible to recruit all those required? How will they be trained and supervised? Will they be needed once elimination has been achieved? If not, what will happen to them?

## 7.6 Conclusion

Summarize the main points in the learning unit, and go through the learning objectives with the participants to confirm that they were achieved. Alternatively, ask three or more participants to state the main lessons they have learnt from this unit.



# LEARNING UNIT 8

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## Assessment of the feasibility of malaria elimination

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### Learning objectives

By the end of this unit, participants should be able to:

- describe the purpose of a feasibility assessment
- describe the technical, operational and financial factors that should be considered in assessing the feasibility of malaria elimination
- clearly define the problem for a feasibility assessment in your own country
- carry out a feasibility analysis based on technical and operational data from your own country
- for African countries, apply the simplified elimination scenario planning method to assess feasibility, including a timetable for reducing the *P. falciparum* burden to a very low level
- formulate interim targets for malaria elimination on the basis of the analysis and
- analyse the financial feasibility of elimination in a given area, and explain how the cost–effectiveness of elimination and control could be compared

This unit requires a lot of preparation. If the course is mainly for participants from sub-Saharan Africa, the emphasis will probably be on the elimination scenario planning (ESP) framework, which was prepared and tested on the basis of African data. The tutor or facilitators should become thoroughly acquainted with WHO's *ESP manual* (<http://www.who.int/malaria/publications/atoz/9789241507028/en/>, accessed 14 September 2015). In other parts of the world, it might be preferable not to go into elimination scenario planning. If the model is not taught intensively, it might be advisable to focus on technical and operational feasibility, for example using the table in 8.5 as a basis for a qualitative analysis country by country. The extrapolation exercise under 8.7.10 might be of interest in any geographical region, provided some countries represented at the course have the requisite quality of surveillance data.

## 8.1 The tutor should prepare

A PowerPoint presentation of the main issues to be discussed, including learning objectives, definitions, essential figures and tables and the main steps in a feasibility assessment.

## 8.2 Suggested time-frame

One day. Decide how you will divide the time into work in groups and a plenary session in which the work of the groups will be presented and discussed.

## 8.3 Presentation

Start the session by going through the learning objectives with the participants and ensuring that they understand them. Ask questions to refresh their understanding of the reproductive ratio and vectorial capacity. Review the different meanings of elimination (subnational, national, species-specific, general). Discuss the concepts of receptivity and vulnerability and their implications, and carefully discuss the difficult issues of stratification, including the dilemma of distinguishing between smaller and larger units.

Introduce the participants to the ESP model, starting with the concepts of “baseline” and “fraction fully protected” and how to assess them. Discuss strategies for improving the mix of interventions and increasing the fraction fully protected; remind participants of the important role of case management and surveillance as an intervention. Describe the influence of vulnerability on elimination, and ask the participants to present concrete examples and to discuss strategies for addressing vulnerability.

Ask the participants to raise other issues that they find difficult or problematic.

## 8.4 Group exercises

The class should work in three or four small groups to prepare technical feasibility assessments for three or four different countries. They should use documented data as far as possible, but they could use estimates when the data are not available.

### Exercise 8.1

Consider how the region of interest should be stratified on the basis of operational and epidemiological considerations such as burden and vectorial capacity before intervention, remoteness and environment.

Divide the area of interest into operationally meaningful sub-regions that are reasonably homogeneous in terms of their suitability for malaria transmission.

Challenge participants to defend their choices in relation to alternatives. Discuss the use of administrative boundaries; these are often problematic in that they are unnatural, but they have the advantage that data are available to characterize them.

### Exercise 8.2

Assemble data on prevalence and coverage with malaria interventions within each sub-region over time from household surveys.

Estimate values for missing sub-regions from data for surrounding regions or other periods.

Estimate the baseline from the most recent survey in each sub-region before scaling up of antimalaria interventions.

If multiple surveys were conducted before scaling-up, evaluate the possibility of extrapolating any trends in the data.

Estimate the baseline from the most recent survey in each sub-region and the fraction of the population protected at that time:

- ▶ Estimate the proportion of the population effectively covered with interventions like LLINs or IRS.
- ▶ Look up the baseline in Figure 8.12 according to the observed prevalence and the fraction of the population effectively covered by interventions.

Compare the results of the two or three methods, and choose the most likely value for the baseline for each sub-region or a range of values.

Discuss with participants what the baseline really represents and the reliability of the coverage rates, i.e. fractions fully protected.

### Exercise 8.3

For each subregion, choose the curve from Fig. 8.13 in the *Guide for participants*) that most closely matches the estimated baseline. If the baseline falls between two figures, use the figure on either side to make an approximation.

On the figure, identify the minimum fraction of the at-risk population that must be fully protected from transmission in order to reduce the malaria prevalence from that baseline to a very low level (< 1%), and record that value for each sub-region.

Estimate the time required to reduce the prevalence from baseline to a very low level in each sub-region. Add 1–2 years to the value directly derived from Fig. 8.13 to reflect any additional time for gradual scaling up of interventions.

Does it appear to be technically feasible to reduce the prevalence of malaria from its baseline to a very low level in all sub-regions?

Discuss whether the results appear to be realistic and acceptable on the basis of experience in participants' countries or elsewhere. What are the policy implications at this stage, if any?

#### Exercise 8.4

For each sub-region, assess the types of population movement that might lead to importation from available knowledge and easily accessible data.

Quantify the importation rates, and classify them on a scale from very low to high. Remember that "imported" means anything originating from outside the sub-region.

For each sub-region or each type of population movement, assess by how much surveillance, chemoprophylaxis and other measures might reduce the importation rate.

Assess whether malaria-free status can be maintained on the basis of the number of imported infections that will be picked up by vectors despite the measures that can be implemented and the number of secondary cases arising from each imported infection.

If much of the importation appears to be from neighbouring sub-regions, explore whether these should be clustered as larger units.

This is the time for a renewed discussion on the role of importation and whether it might make elimination in the strict sense of the word impossible. It might be useful to review stratification and the concept of controlled non-endemic malaria. The timelines proposed for this final phase are based on experience; the acceptability of this practice can be discussed.

#### Exercise 8.5

For each sub-region, estimate the annual cost of strengthening any operational gaps in order to achieve elimination, including any capacity development for the elimination phase.

For each sub-region, estimate the cost of measures in the maintenance phase.

Calculate the annual cost per inhabitant of the sub-region, and compare it with the cost of a good control programme.

Evaluate whether the budgets could realistically be obtained mainly from domestic sources.

If you have prepared a realistic long-term annual cost assessment for two options, evaluate the cost-effectiveness of elimination and compare it with that of control.

Ask the participants how far they have gone in the planning part of this exercise. One or two groups may have something to present for discussion. Concentrate on the simpler analyses, such as total cost per year per person in the target population. If elimination is not more costly than control over this limited time-frame, is the analysis correct? Are the annual budgets after interruption of transmission realistic? How will the ministry of health planning department, potential donors and other stakeholders react? Are there entrepreneurs who have a stake in elimination that could be used for fund-raising?

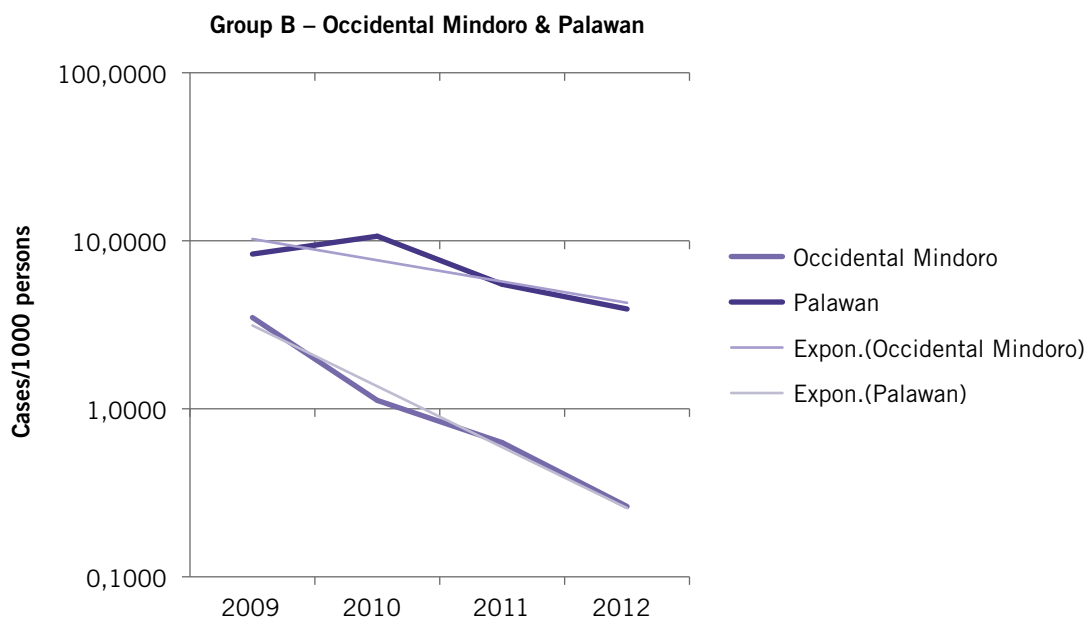
A cost-effectiveness analysis should be expected only if some participants already have some experience in this calculation. To help participants understand the text, you might present

some graphs illustrating comparative and incremental cost–effectiveness analysis at the end of the exercise.

### Exercise 8.6

Below is an example of application of an extrapolation exercise in a programme review in the Philippines in 2013. You may include this in the presentation, as part of the exercise or of the feedback after the exercises in plenary. Note that logarithms were not calculated for the graph below; instead, the incidence rates are plotted on a logarithmic scale. The trend lines are thus exponential, not linear.

**Figure 8.1.** Trend in malaria incidence rates per 1000, by province (Occidental Mindoro and Palawan), 2009–2012



### Mathematical extrapolation of time to achieve malaria elimination in Palawan

In 2012, Palawan had a malaria incidence of 3.81 per 1000 ( $\log_{10}(3.81) = 0.58$ ).

The slope of the regression line of the values of  $\log_{10}(\text{incidence})$  by year is  $-0.13$ .

As the population of Palawan is now 1 million, we can assume that malaria will be eliminated when there is one case per million (disregarding population growth for the moment), i.e. when there are 0.001 cases per 1000.

However, when the total case load in the province reaches 10 cases (corresponding to an incidence of 0.01 cases per 1000), elimination should be feasible within a few years.

$\log_{10}(0.01) = -2$ ; so, when  $y = -2$  and  $x$  is the number of years after 2012:

$$x * (-0.13) + 0.58 = y = -2 \Rightarrow x = 19.85$$

Thus, the exercise indicates that 10 cases per million will be reached about 20 years after 2012; it should then take only a few years to be rid of the last case. The current interventions in Palawan might be strengthened, e.g. by working more effectively with the most severely affected communities and applying new interventions and tools (discussed further in sections 4.2, 4.3 and 4.4 of *Malaria elimination field manual, Chapter 4. Tools and approaches*. The assumption of exponential decay is an oversimplification: over a period longer than 10 years, many factors may accelerate or retard progress towards elimination.



## 8.5 Discussion and conclusion

Review with the participants the strong and weak points of the analytical techniques that have been presented. Note that other models that are more generalizable than the ESP model will probably be published.

What other elements should be emphasized? Elimination is sometimes said to be politically attractive; therefore, malaria programme staff are under pressure to plan for elimination. In other cases, the staff is reluctant, fearing for their budgets. How should programmes manoeuvre, given such conflicts?

Summarize the session, invite final questions, and go back through the learning objectives with the participants to make sure they have been achieved.



# LEARNING UNIT 9

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## WHO certification of malaria elimination

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### Learning objectives

At the end of this unit, the participants should be able to:

- explain the concept of burden of proof in the context of certification of malaria elimination
- describe the steps in the certification process and
- explain the reporting requirements for countries that have been certified malaria-free

## 9.1 The tutor should prepare

A PowerPoint presentation of the learning objectives and of definitions and documents on WHO certification of achievement of malaria-free status

## 9.2 Suggested time-frame

Allot 3 h to this learning unit.

## 9.3 Presentation

Start the presentation by reviewing the learning objectives, and ensure that they are fully understood. Review the steps, requirements and documents for WHO certification, making sure that the participants fully understand the concepts.

## 9.4 Group work

This exercise should be done in small groups. Help the participants to retrieve information about countries that were recently certified as malaria-free. Encourage them to study different examples of elimination programmes. Each group should study one country and, in their presentation, emphasize how the country met the certification criteria.

## 9.5 Conclusion

Summarize the main points in the learning unit, and go through the learning objectives with the participants to confirm that they were met. You might ask three or more participants to state the main lessons they learnt in this unit.





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