Trends in Parasitology

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REVIEWS

Review

A Historical Review of WHO Certification of Malaria Elimination

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A malaria-free world remains the vision of the global community. Malaria elimination within the territory of a country is a pathway to achieving the ultimate goal of eradication. Certification of malaria elimination in a country is the official recognition of this important achievement. The concepts of eradication and elimination, and criteria for certification of malaria elimination, have guided national programs in their efforts to achieve and maintain elimination. They have evolved from the experiences and setbacks of the global eradication program, and on the contemporaneous understanding of the concepts of achieving and maintaining elimination. WHO's certification has been successful, with the majority of certified countries remaining malaria free, but to operationalize the criterion for preventing re-establishment of transmission remains challenging.

Highlights

The global strategies for fighting malaria have changed but the ultimate goal of eradication remains unchanged. Malaria elimination within a country is the pathway to achieve the ultimate eradication goal. Certification of elimination is an official recognition of an important public health achievement obtained by a country.

The concepts of elimination and eradication, and criteria for certification of malaria elimination, have evolved over years from experiences and lessons learnt. The majority of certified countries have managed to maintain malaria-free status, demonstrating the technical soundness of the criteria for certification.

Assessment of the absence of local transmission through surveillance has been satisfactory, but to operationalize the criterion for preventing re-establishment of transmission, or to assess the likelihood that malaria-free conditions can be maintained in a given system, is challenging.

A Brief History

One year before the creation of the World Health Organization in 1948, the Expert Committee on Malaria was constituted and met in Geneva to discuss opportunities for **malaria eradication** (see Glossary). The concept was not new, as it had already been suggested back in 1917 that malaria eradication was feasible [1]. During the first decade of the 20th century, significant progress was seen in some parts of the world, particularly in Europe and North America. Over the past seven decades, the strategies used to fight malaria have evolved but the ultimate goal, the eradication of this disease and the vision of a malaria-free world, have remained unchanged. In the course of this strenuous journey, a substantial number of countries have managed to eliminate malaria from their territories, and some have been formally certified malaria free by WHO, the official recognition of this public health achievement.

The definition of **malaria elimination**, and criteria for certification of malaria elimination, have guided countries in their journey towards elimination since their first establishment by the WHO during the Global Malaria Eradication Program in the 1960s. After a 20-year hiatus (from 1987 to 2007), during which no country was certified malaria free by WHO, the certification process has been reactivated, with nine more countries being certified since 2007, a reflection of renewed interest in malaria elimination. The definition and criteria for malaria elimination have evolved over the years. Understanding the changes in definition and criteria are important as these reflect contemporary understanding of malaria elimination, and maintaining elimination, and will inform the future evolution of this process. We believe that this review will not only bring this important evolutionary process, mostly 'hidden' in the WHO library, to the attention of a broader audience but will also inspire programs and individuals who are currently engaging in malaria elimination.

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Malaria Eradication since the Inception of WHO

Encouraged by the efficacy and the residual effect of the insecticide dichlorodiphenyltrichloroethane (DDT), and chloroquine as a safe and highly effective drug for treatment and prophylaxis, the Global Malaria Eradication Programme (GMEP) was launched in 1955 in the belief that, with the availability of these new tools, eradication was both technically feasible and a financially attractive proposition. The emergence of vector resistance to DDT, first reported in Greece in 1951, was also a stimulus for the launch of the GMEP as experts feared the loss of this potent intervention. 'We have the tools, we know what needs to be done, it is simply a matter of going out to do it', claimed the then Director General (DG) of WHO, Marcelino Candau, during the 8th World Health Assembly held in Mexico in 1955. A detailed evaluation of the GMEP is beyond the scope of this paper. Suffice to say that although the program did not achieve its stated objective, it had a major impact on the global landscape of malaria, succeeding in eliminating malaria from most of Europe, North America, the Caribbean, and parts of Asia and South-Central America. The campaign also achieved a remarkable reduction in morbidity and mortality due to malaria across vast regions of the tropical and subtropical world. In India, malaria morbidity was reduced from an estimated 75 million cases a year to about 100 000 cases a year, and deaths due to malaria were reduced from 800 000 to zero [2]. Furthermore, the campaign made important contributions beyond its malaria-specific impact, for example, on general improvements in health and the development of peripheral health services[i]. However, sub-Saharan Africa was not included in the GMEP, and GMEP had little impact in this region.

Although malaria eradication remained the ultimate overarching objective, the 1969 World Health Assembly (WHA) resolution was a recognition that malaria control, defined as implementation of measures of indefinite duration aimed at reducing the incidence of malaria, was necessary. Between 2000 and 2015, significant progress in reducing morbidity and mortality from malaria was achieved globally, due to the massive scale-up of core malaria interventions [3]. More than half of the 106 countries that were malarious in 2000 achieved a >75% reduction in malaria cases by 2015, and a number of countries progressed all the way to elimination, led by the United Arab Emirates (UAE) requesting WHO to certify its malaria-free status in 2003. Within this context, the Global Technical Strategy (GTS) for malaria 2016–2030, adopted by the World Health Assembly in 2015 retains the ultimate vision of achieving a malaria-free world and includes a specific goal of at least 35 countries eliminating malaria by 2030 [4].

Today more than 90 countries remain endemic for malaria. Every year there are over 200 million new cases and in excess of 430 000 deaths, a very long way away from a malaria-free world [5,6]. However, the number of countries progressing towards elimination continues to grow: the 2018 World Malaria Report (WMR) noted that 46 countries, distributed throughout all six WHO regions, reported fewer than 10 000 malaria cases in 2017, up from 37 countries in 2010 [6]. Encouraged by this impressive progress, discussion of the global eradication goal was renewed, and at the request of the WHO DG, a strategic advisory group (SAG) was constituted to analyze future scenarios for malaria, including eradication. The first SAG report affirmed WHO's longstanding commitment to eradication, but without specifying an end date.

Evolution of the Concept of Eradication, Elimination, and Criteria for Certification

The GMEP defined malaria eradication as 'the ending of the transmission of malaria and the elimination of the reservoir of infective cases in a campaign limited in time and carried out to such a degree of perfection that when it comes to an end, there is no resumption of transmission'[ii]. This concept of eradication reveals the difference in objectives between a control program and an eradication program. The definition of control, described as 'the

Glossary

Malaria elimination: interruption of local transmission (reduction to zero incidence of indigenous cases) of a specified malaria parasite species in a defined geographical area as a result of deliberate activities. Continued measures to prevent re-establishment of transmission are required [8]. Note: The certification of malaria elimination in a country will require that local transmission is interrupted for all human malaria parasites.

Malaria eradication: permanent reduction to zero of the worldwide incidence of infection caused by all human malaria parasite species as a result of deliberate activities. Interventions are no longer required once eradication has been achieved [8].

Receptivity: receptivity of an ecosystem to transmission of malaria. Note: A receptive ecosystem should have features such as the presence of competent vectors, a suitable climate and, a susceptible population.

Re-establishment of transmission: renewed presence of a measurable incidence of locally acquired malaria infection due to repeated cycles of mosquito-borne infections in an area in which transmission had been interrupted [8]. Note: A minimum indication of possible reestablishment of transmission would be the occurrence of 3 or more indigenous malaria cases of the same species per year in the same focus, for three consecutive years.

Vectorial capacity: number of new infections that the population of a given vector would induce per case per day at a given place and time, assuming that the human population is and remains fully susceptible to malaria [26].

Vulnerability: the frequency of influx of infected individuals or groups and/or infective anopheline mosquitoes. Note: Also referred to as 'importation risk'. The term can also be applied to the introduction of drug resistance in a specific area [8].

reduction of the disease to a prevalence where it is no longer a major public health problem', implies the continuous nature of a malaria-control program, whereas the definition of eradication infers the finite nature of active work and its eventual termination[iii].

Renewed discussions on disease eradication in the 1980s–1990s led to a new definition of eradication, according to which eradication was the 'permanent reduction to zero of the worldwide incidence of infection caused by a specified agent as a result of time-bound, deliberate efforts' [7]. Once eradication has been achieved, intervention measures are no longer needed. Thus, malaria elimination was defined as 'interruption of local transmission (reduction to zero incidence of indigenous cases) of a specified malaria parasite species in a defined geographical area as a result of deliberate activities' [8]. It was retrospectively recognized that the GMEP should not be considered as an eradication program as it had never incorporated a global perspective, having failed to include Africa in its plan. Instead, the GMEP can be seen as a series of elimination programs.

The 6th WHO Expert Committee on Malaria established the initial criteria for malaria eradication in 1957, as previously discussed. At that time the term did not imply a global reach, but could be applied at a national or even subnational level[ii]. The Committee recognized that malaria might be imported into a country and cause a few secondary cases, but as long as there was no re-establishment of disease transmission, the country could be considered malaria free. The key element was the presence of an adequate surveillance system in operation within the country capable of detecting and preventing malaria transmission throughout the whole area. Given that relapse caused by *Plasmodium vivax* infections might occur within 2½ to 3 years after the interruption of transmission, the Committee considered malaria eradication to be achieved 'when an adequate surveillance system has not discovered any evidence of transmission or residual endemicity despite careful search for three consecutive years'[iv]. In addition, the Committee required that no specific general measures or anopheline control should have been practiced for the last 2 years, since 'the best test of disappearance of the reservoir is failure of the disease to re-establish itself when specific organized measures against the anophelines are discontinued'[ii]. However, such criteria proved difficult to apply in the field due to unclear definitions of 'adequacy' of surveillance, what 'careful search' for cases meant, and how and when cessation of spraying should be applied.

Even though, in subsequent meetings, the Expert Committee struggled to provide guidance on when to stop spraying, the 'adequacy of surveillance' was further elucidated[v]. The Committee considered a passive detection mechanism to be adequate, when diagnosis and treatment were easy to access and used by the entire population. Active detection should be included where quality-assured diagnosis was not accessible. Furthermore, an annual blood-examination rate (ABER) of at least 10% of the population covered by surveillance was suggested as a minimal level of testing for a surveillance system. Later, a 1% blood-examination rate per month during transmission seasons was sanctified by the 10th Expert Committee. The 10% ABER threshold was difficult to justify from an epidemiological perspective but was probably related to the estimated fever rate in the general population and was largely based on practical experience from different national eradication programs in the 1950s–1970s [9]. In fact, an ABER of less than 10% was acceptable in settings with particularly high-quality surveillance, such as in the ex-Union of Soviet Socialist Republics [10,11]. The role of ABER in certification was not specified in later WHO publications because of the difficulty in identifying and quantifying the population at risk. The Committee stated that not only epidemiological quantitative data but the quality of performance of interventions should be assessed to confirm elimination. For example, the quality of microscopical diagnosis should be as high as possible[v].

As eradication programs entered the consolidation phase, some areas experienced malaria resurgence in the 1960s–1970s, which led to the recognition of the importance of maintaining an adequate general health service[vi]. The Committee urged all countries to be vigilant until global eradication was achieved, given the long-term risk of malaria importation due to increased domestic and international travel[vii]. In this context, while the Committee emphasized registration in the official register 'should be considered as an operational accomplishment, rather than as a guarantee of a permanent epidemiological situation[viii], the probability that the malaria-free status could be maintained should be assessed. Another criterion for certification was added: a detailed plan for vigilance activities to maintain the achieved malaria elimination tailored to the local context and updated regularly to accommodate changes in **receptivity** and **vulnerability**. Thus, the basis of the WHO criteria for malaria elimination was formed. Key changes of criteria for WHO certification of malaria elimination and WHO terminologies relevant to certification are summarized in Table S1 in the supplemental information online and in the Glossary, respectively.

The recommendations from the Expert Committees on criteria of certification of malaria elimination evolved from experiences and setbacks of the eradication programs, and on the basis of contemporaneous understanding on elimination and maintaining elimination. After GMEP the criteria have been evolved only slightly [8] but a major endeavor has been to illustrate and to operationalize these criteria so that they can be applied in the field. Progress has been made in some areas, for example, clearer guidance on quality assurance of microscopical diagnosis is available [12]. Proof of absence of indigenous transmission relies largely on surveillance data showing no indigenous cases occurring in the past three consecutive years and on the assessment of coverage and quality of surveillance. Such a method has proved to be satisfactory for the certification of malaria elimination up till now. The usage of other methods for certification, including molecular analysis [13] and serological methods [14,15], has been suggested. Molecular analysis can help to identify the geographic source of the parasite and might be useful when tracing the source of infection is difficult by epidemiological investigation. Serological methods are currently not suggested as an approach to support malaria elimination by the WHO [8] partly due to an inconclusive result from a WHO-led longitudinal seroepidemiologic study in Tunisia, aiming to test the disappearance of malaria transmission [16], and a similar comment on the utility of serological data for certification during the certification evaluation mission to the UAE.

It remains challenging to assess the likelihood that **re-establishment of transmission** can be prevented in a given country, particularly those countries located in tropical or subtropical areas where **vectorial capacity** is high. On one hand, concepts of receptivity, vulnerability, and the risk of re-establishment, initially developed during the GMEP, have never been clearly defined and hence the vigilant activities required are largely based on practical experience. Initially, certification required a period of zero indigenous cases for 2 years after vector control had been withdrawn, as stated in the 6th Expert Committee report. Presumably, this criterion was intended to test the efficiency and capacity of the health system to detect and respond to imported cases and prevent onward transmission, without protection from vector control. However, experience showed that withdrawal of vector control should be approached cautiously as it might lead to resurgence in some areas where receptivity is high[ix]. Data on the infectivity of *Plasmodium* to local species of *Anopheles* can provide valuable information on this aspect as there may be geographical differences in susceptibility to infection within the same species [17], and studies should be encouraged to generate more data in this area. On the other hand, at the time point when countries are being certified, many are experiencing an integration process, with the malaria surveillance and response systems undergoing some changes. To assess and predict the capacity of such an evolving system to manage the risk of

re-establishment (also a dynamic concept itself) is not a simple task. Lessons learnt from the past malaria resurgence [18] and regular review on the prerequisite for preventing re-establishment of malaria transmission will be instructive for future certification.

The Evolution of the Procedures for WHO Certification of Malaria Elimination

Soon after the establishment of the GMEP, a WHO Study Group was convened to explore the practicability of maintaining a register of areas where malaria has been eliminated[x]. This led to a resolution at the 13th WHA requesting 'the Director-General to establish an official register listing areas where malaria eradication has been achieved, after inspection and certification by a WHO evaluation team'.

Guidance on the methodology for certification and registration was first provided in the 8th Committee report and was shared with all member states in a WHO DG's note circulated in 1966. Initially, certification could be requested and granted to subnational areas within a country, as long as the region was no smaller than 50 000 km^2. Certification has been granted only to an entire country since 1974[viii]. Before 1980, the dossiers for certification were systematically put before the Expert Committee for review. As the meetings of the Expert Committee had become irregular by 1980, the discussion on certification had changed to be through correspondence. No certification process was operated between 1987 and 2007 since the strategies of combating malaria had shifted from eradication to control after GMEP.

Between 2007 and 2017, the certification process included an initial WHO assessment mission to ensure that countries met the minimum criteria, an independent evaluation mission conducted by experts recruited as consultants, and two rounds of review of the evaluation report developed by the evaluation team [19]. In 2017, WHO established a malaria-elimination certification panel to recommend certification or postpone certification with clearly defined terms of reference [8]. This revised process for certification is illustrated in Figure 1. It follows a similar scheme published in 2014 [19] but the constitution of a standing certification committee allows debate, reflection, and discussion on each certification process, and regular review on the criteria for certification, and should therefore promote the improvement and elaboration of the criteria.

A new concept, subnational verification of malaria elimination, was introduced in 2017 as an option for countries that have achieved interruption of local transmission in certain parts of the country. Subnational verification contributes to strengthening surveillance and response and provides momentum for achieving the national elimination goal. It also serves as a pathway to national certification. The criteria for subnational verification follow national certification, but the methodology and procedure involved may be different from national certification, and WHO does not verify or certify subnational elimination.

Brief Summary and Update of the Official Register and Supplementary List

The official register of certified countries was created in 1960 to provide information on malaria-free countries [20]. It is restricted to those countries and territories that have eliminated malaria by specific measures and have been certified malaria free by the WHO. The updated list of the official register now includes 36 countries and territories (Table 1)[xi]. Uzbekistan is the most recently certified country. Argentina and Algeria are currently undergoing a process of certification. Malaria-free countries where 'malaria had never existed or had disappeared without specific measures' are included in a supplementary list. The

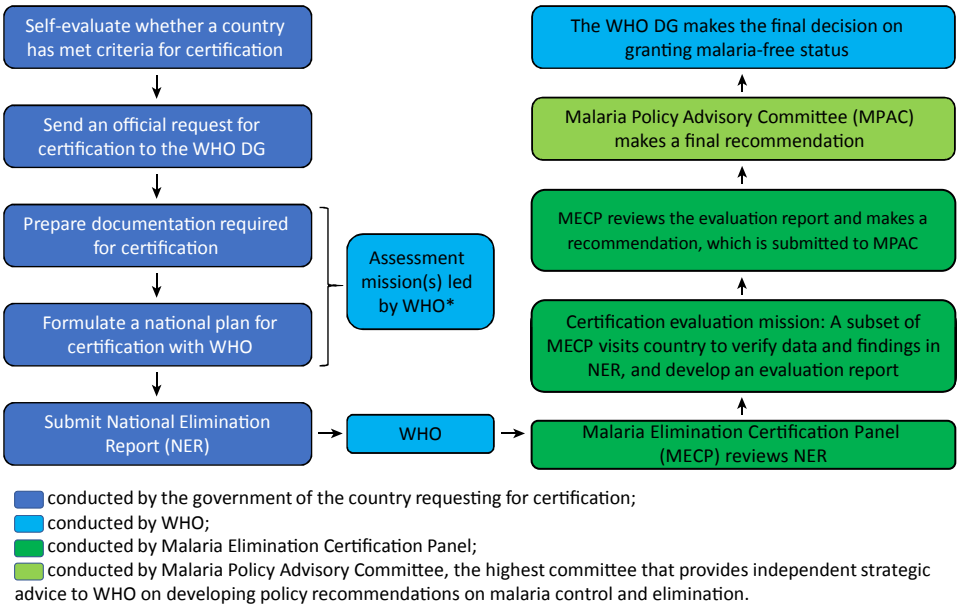

Figure 1. Flowchart Illustrating the Current Process of WHO Certification of Malaria Elimination. Specific certification-related activities are conducted by a party concerned, as indicated by different colors. *Note that there might be several assessment missions led by the WHO to support countries in preparing for certification and to ensure that the country meets the minimum requirements. DG, Director General.

supplementary list, first published by the WHO in 1963 [21], now includes 92 countries and territories, with its latest addition in 2012 [22].

Most countries have maintained their malaria-free status since their entry into the official register, indicating that the criteria established in the 1960s–1970s are generally sound. A few countries experienced outbreaks or epidemics after certification although transmission was not re-established based on the minimum indication. Singapore experienced an outbreak in April–May 1993, but transmission was interrupted within a few weeks [23]. In 2006, 44 years after malaria was eliminated, Jamaica experienced an outbreak caused by *P. falciparum* but managed to interrupt transmission by 2009 [24]. It was the malaria-free certification to Mauritius in 1973 that received criticism as it was considered to be responsible for a relaxation in case-detection activities [25], which partly caused the resurgence 2 years after certification. The decades-long endemic transmission in Mauritius, which started from a few imported cases, should also be attributed to increased breeding sites created by the results of the cyclone and the substantial increase in *Anopheles arabiensis* density due to reduced vector control. However, it should be noted that the criterion for preventing re-establishment was not yet established by the time Mauritius was certified. In fact, the Expert Committee concluded that Mauritius had high malariogenic potential, but the country could maintain elimination should a high level of vigilance be maintained[viii]. Since 1998, Mauritius has maintained the absence of local transmission despite the continued presence of *Anopheles arabiensis* and ongoing importation of malaria parasites. The lessons of resurgence highlight the importance of maintaining vigilance and surveillance, and a response system to imported cases in all malaria-free countries, especially those with high malariogenic potential.

Table 1. Countries and Territories[a] Certified Malaria Free by the WHO

WHO region	Name of country	Year entered official register
Africa	Mauritius	1973
	La Réunion (France)	1979
Eastern Mediterranean	Morocco	2010
	United Arab Emirates	2007
Europe	Armenia	2011
	Bosnia and Herzegovina	1973
	Bulgaria	1965
	Croatia	1973
	Cyprus	1967
	Hungary	1964
	Italy	1970
	Kyrgyzstan	2016
	Montenegro	1973
	Netherlands	1970
	The former Yugoslav Republic of Macedonia	1973
	Poland	1967
	Portugal	1973
	Romania	1967
	Serbia	1973
	Slovenia	1973
	Spain	1964
	Turkmenistan	2010
	Uzbekistan	2018
America	Cuba	1973
	Dominica	1966
	Grenada	1962
	Jamaica	1966
	Paraguay	2018
	Saint Lucia	1962
	Trinidad and Tobago	1965
	United States of America	1970
South-East Asia	Maldives	2015
	Sri Lanka	2016
Western Pacific	Australia	1981
	Brunei Darussalam	1987
	Singapore	1982

[a]For the purpose of this publication, reference is made to the official name of the WHO Member States as of June 11, 2018. La Réunion is a French overseas region which was certified malaria free independently from Metropolitan France.

Concluding Remarks

The goal of malaria eradication that dates back to the GMEP remains the vision of the WHO and the global malaria community. Malaria elimination within the territory of a country is a pathway to achieving the ultimate goal of global malaria eradication. Certification of malaria elimination officially recognizes an important public health achievement obtained by countries. Moreover, it builds confidence and sustains the momentum of global community in defeating this preventable and treatable disease. Assessment of the absence of indigenous transmission through a strong surveillance system has proven to be satisfactory for all countries certified in the past. The measurement of risk of re-establishment, as well as an understanding of the determinants of resurgence, remain topics for debate and further discussion (see Outstanding Questions). Regular review of the certification criteria – its process, and updated evidence or data on each technical topic related to malaria elimination and maintaining elimination – will improve the subjectivity and credibility of certification.

Outstanding Questions

How should malariogenic potential be measured, and what are the required vigilant activities accordingly?

What are the determinant factors that contribute to malaria resurgence after elimination has been achieved?

What method could we use to better define or quantify the population at risk of malaria infection?

Is there any other new analysis or method that can be used to prove the absence of local transmission?

Resources

[i]www.who.int/iris/handle/10665/79012
[ii]www.who.int/iris/handle/10665/64537
[iii]www.who.int/iris/handle/10665/40401
[iv]www.who.int/iris/handle/10665/64592
[v]www.who.int/iris/handle/10665/40477
[vi]www.who.int/iris/handle/10665/40670
[vii]www.who.int/iris/handle/10665/39822
[viii]www.who.int/iris/handle/10665/41087
[ix]www.who.int/malaria/publications/atoz/scale-back-vector-control.pdf
[x]www.who.int/iris/handle/10665/64540
[xi]www.who.int/malaria/areas/elimination/malaria-free-countries/en/

Supplemental Information

Supplemental information associated with this article can be found online at https://doi.org/10.1016/j.pt.2018.11.011.

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