



A GLOBAL STRATEGY TO

Eliminate Yellow Fever Epidemics (EYE) 2017 – 2026



ELIMINATE
YELLOW FEVER
EPIDEMICS



A global strategy to Eliminate Yellow fever Epidemics 2017–2026
ISBN 978-92-4-151366-1

© World Health Organization 2018

Some rights reserved. This work is available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; <https://creativecommons.org/licenses/by-nc-sa/3.0/igo>).

Under the terms of this licence, you may copy, redistribute and adapt the work for non-commercial purposes, provided the work is appropriately cited, as indicated below. In any use of this work, there should be no suggestion that WHO endorses any specific organization, products or services. The use of the WHO logo is not permitted. If you adapt the work, then you must license your work under the same or equivalent Creative Commons licence. If you create a translation of this work, you should add the following disclaimer along with the suggested citation: “This translation was not created by the World Health Organization (WHO). WHO is not responsible for the content or accuracy of this translation. The original English edition shall be the binding and authentic edition”.

Any mediation relating to disputes arising under the licence shall be conducted in accordance with the mediation rules of the World Intellectual Property Organization.

Suggested citation. A global strategy to Eliminate Yellow fever Epidemics 2017–2026. Geneva: World Health Organization; 2018. Licence: CC BY-NC-SA 3.0 IGO.

Cataloguing-in-Publication (CIP) data. CIP data are available at <http://apps.who.int/iris>.

Sales, rights and licensing. To purchase WHO publications, see <http://apps.who.int/bookorders>. To submit requests for commercial use and queries on rights and licensing, see <http://www.who.int/about/licensing>.

Third-party materials. If you wish to reuse material from this work that is attributed to a third party, such as tables, figures or images, it is your responsibility to determine whether permission is needed for that reuse and to obtain permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

General disclaimers. The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of WHO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by WHO in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by WHO to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall WHO be liable for damages arising from its use.

Printed in Switzerland

A GLOBAL STRATEGY TO

Eliminate Yellow Fever Epidemics (EYE)

2017 – 2026



ELIMINATE
YELLOW FEVER
EPIDEMICS

Contents

| | |
|--------------------------------|---|
| Foreword | 6 |
| Executive summary | 7 |
| Acronyms | 9 |

| | |
|-----------------------------------|----|
| Part 1: Introduction | 10 |
|-----------------------------------|----|

| | |
|--|----|
| Part 2: Evolution of global YF risk | 13 |
| 2.1. Recent changes in transmission dynamics | 13 |
| 2.2. Risk specific to urban outbreaks | 15 |
| 2.3. Updated risk classification | 15 |

| | |
|---|----|
| Part 3: Public health measures for YF prevention and control | 19 |
| 3.1. YF disease surveillance and laboratory capacity | 19 |
| 3.2. Vector surveillance and control | 19 |
| 3.3. Vaccination against YF | 20 |
| 3.4. Targeting travellers and improving IHR compliance | 23 |
| In summary | 23 |

| | |
|---|----|
| Part 4: Lessons learned from prior programs: obstacles to progress | 25 |
| 4.1. Vaccine supply | 25 |
| 4.2. Regional and country buy-in | 26 |
| 4.3. Implementation issues | 26 |
| 4.4. The global emergency stockpile | 26 |
| 4.5. Programme governance and resources | 27 |
| 4.6. A global problem | 27 |

| | |
|---|----|
| Part 5: EYE vision and strategic objectives | 28 |
| 5.1. Strategic objective 1: Protect at-risk populations (No epidemics) | 29 |
| - Action 1: Where risk is high, vaccinate everyone | 29 |
| - Action 2: Vaccinate every child | 29 |
| - Action 3: Risk assessments | 30 |
| 5.2. Strategic objective 2: Prevent international spread (No exportation) | 31 |
| - Action 1: Protect high-risk workers | 31 |
| - Action 2: Apply the IHR | 31 |
| - Action 3: Build resilient urban centres | 32 |
| 5.3. Strategic objective 3: Contain outbreaks rapidly (No sustained transmission) | 33 |
| - Action 1: Detect early | 33 |
| - Action 2: Vaccine supply is ready at all times | 34 |
| - Action 3: Respond immediately | 35 |

| | |
|---|----|
| Part 6: Keys to success | 36 |
| 6.1. Affordable vaccines and sustained vaccine market | 36 |
| 6.2. Strong political commitment at global, regional and country levels | 37 |
| 6.3. Robust governance and strong partnerships | 37 |
| 6.4. Synergies with other programmes and sectors | 38 |
| 6.5. Research and development for better tools and practices | 39 |

| | |
|--|----|
| Part 7: Implementation, monitoring and evaluation | 40 |
| 7.1. Key milestones | 41 |
| 7.2. Regular updates | 41 |

| | |
|-----------------------------------|----|
| List of EYE partners | 42 |
| Group photo | 48 |

Foreword

In 2016 Angola was hit by an unprecedented yellow fever urban outbreak which spread to neighbouring countries and generated local transmission, including in the Democratic Republic of the Congo's capital Kinshasa. The epidemic created an urgent need for more than 28 million doses of yellow fever vaccines total, which exhausted the existing global vaccine supply. It also diverted public health authorities from tackling other public health issues – with an impact on health systems.

In response to the Angola outbreak, the comprehensive global strategy to Eliminate Yellow fever Epidemics (EYE) was developed by WHO and partners in a matter of a few months given the on-going urgency and the looming risk of spillover to Asia, as 11 cases were exported to China.

Part of the complexity of the global issue of yellow fever epidemics is the multifactorial and evolving nature of risk and its inherent unknowns. The risk of large yellow fever epidemics and exportation to Asia or other areas with potential for yellow fever transmission – such as Zika- or dengue-prone areas – remains daunting. Yellow fever outbreaks could easily turn into public health emergencies of international concern (PHEICs) and must be prevented to not only minimize mortality, morbidity, and disruption of health systems, but also to preserve economies and social development.

The strategic principles described herein were validated by the Strategic Advisory Group of Experts (SAGE) on Immunization in October 2016 and approved by the Gavi Board in December 2016. They capture the risk as perceived at that time and are meant to be tailored to an evolving global risk balanced against global vaccine supply and demand. The priorities will continue to be fine-tuned as global risks are analysed and monitored, multi-year work plans and forecasts are developed, and as countries successfully implement vaccination activities.

The EYE strategy aims at building a global coalition of countries and partners to tackle the increased risk of yellow fever epidemics in a coordinated manner and is an opportunity to demonstrate new ways of managing the complex world of re-emerging infectious diseases. The development and implementation of the strategy would not have been possible without the collective effort of global partners and all stakeholders. We are very grateful to them for their input, expertise, commitment, support and partnership – all of which will ensure that the world achieves the goal of global elimination of yellow fever epidemics. We are particularly grateful to the core EYE partners Gavi, the Vaccine Alliance, and the United Nations International Children's Emergency Fund (UNICEF) that form the governance and implementation body for EYE along with WHO.

Sylvie Briand, *Director*
Infectious Hazard Management (IHM) Department
WHO Health Emergencies (WHE) Programme

Executive summary

The global health community is facing an increased risk of urban outbreaks of yellow fever (YF). The risk of international spread, YF's changing epidemiology and resurgence of mosquitoes pose an emerging global threat that requires new strategic thinking.

This document describes the reasoning behind and need for an updated, long-term (2017-2026) and global strategy to “Eliminate Yellow fever Epidemics” (EYE). The strategy includes **three strategic objectives: (1) protect at-risk populations, (2) prevent international spread and (3) contain outbreaks rapidly.**

The document is intended to be used at national, regional and global level by partners, donors, public health officers, national health authorities, and technical or non-technical experts seeking an overview of the EYE strategy.

The EYE strategy is comprehensive, multi-component and multi-partner. In addition to recommending vaccination activities, it calls for building resilient urban centres, planning for urban readiness, and strengthening the application of the International Health Regulations (2005) (IHR).

The EYE strategy is an unprecedented initiative as it brings together multiple partners willing to support countries to achieve a common goal of making the world safer. It targets the countries and regions that are considered most vulnerable to YF outbreaks. The classification of countries' risk was revised to account for criteria associated with the changing epidemiology of the disease such as environmental factors, population density and vector prevalence. A total of 40 countries (27 countries in Africa and 13 countries in the Americas) are considered to be at highest risk for YF. In these countries, large scale access to yellow fever vaccines is critical to establish and maintain high levels of immunity among adult and childhood populations. In Africa, 5 countries still need to introduce the vaccine into their routine immunization schedules and 12 countries should complete national mass preventive campaigns. All countries at risk for YF in the Americas have introduced the vaccine into routine vaccination programmes, but 11 of them should plan catch-up campaigns targeting unprotected pockets of their populations.



Rapid containment of outbreaks is essential to ensure they do not amplify into devastating epidemics. Reactive vaccination programs should be part of the outbreak response as well as surveillance strengthening to enhance early detection of cases, vector control and community mobilization. That will require improving laboratory capacity, building on existing surveillance networks and extending the currently limited laboratory diagnostic in-country options.

A revolving mechanism will be put in place to give countries facing emergency needs for YF vaccine access to the internationally managed stockpile. Over the coming decade, vaccine manufacturers are expected to be able to meet the global demand of 1.38 billion doses needed to eliminate the risk of YF epidemics. This will require maximizing their production, particularly in the first 5 years.

Cross-cutting core support activities will be initiated from the start of EYE to ensure success through **(1)** availability of accessible, affordable vaccines procured in a sustained vaccine market, and mechanisms to cope with surges in YF vaccine demand; **(2)** political commitment at regional and country levels fostered by strong advocacy; **(3)** robust governance and strong monitoring; **(4)** synergies with other programmes and sectors; and **(5)** research to support better tools and informed practices.

The EYE strategy was scientifically validated by the Strategic Advisory Group of Experts on Immunization (SAGE) in October 2016 and approved by the Gavi Board in December 2016. The strategy will succeed by engaging countries and multidisciplinary partners, and by coordinating efforts well. No country or institution can tackle the global issue of YF epidemics alone.

Acronyms

| | | | |
|---------------|---|---------------|--|
| DRC | Democratic Republic of Congo | PI | Population Immunity |
| EDCARN | Emerging Diseases Clinical Assessment and Response Network | PMVC | Preventive Mass Vaccination Campaign |
| ELISA | Enzyme-Linked Immunosorbent Assay | PPC | Programme and Policy Committee |
| EPI | Expanded Programme on Immunization | PRNT | Plaque Reduction Neutralization Test |
| FNV | French Neurotropic Vaccine | RED | Regional Emergency Directors |
| EYE | Eliminate Yellow fever Epidemics | RITAG | Routine Immunization Technical Advisory Group |
| GAVI | Global Alliance for Vaccine and Immunization | RI | Routine Immunization |
| GOARN | Global Outbreak and Alert response Network | SAGE | Strategic Advisory Group of Experts on Immunization |
| GRYF | Scientific and technical advisory group on geographical YF risk mapping | TAG | Technical Advisory Group |
| GVAP | Global Vaccine Action Plan | UNICEF | United Nations Children’s Fund |
| HQ | Headquarter | UNPD | United Nation Population Division |
| ICG | International Coordinating Group for vaccine provision | US CDC | United States Centers for Disease Control |
| IHM | Infectious Hazards Management | VCAG | Vector Control Advisory Group |
| IHR | International Health Regulations (2005) | VIS | Vaccine Investment Strategy |
| LAC | Latin America and the Caribbean | WHO | World Health Organization |
| MSF | Médecins Sans Frontières | WUENIC | WHO/UNICEF Estimates of National Immunization Coverage |
| PCR | Polymerase Chain Reaction | YF | Yellow Fever |
| | | YFI | Yellow Fever Initiative |

Part 1.

Introduction

This strategic document focuses on activities recommended in Africa and Latin America and the Caribbean (LAC), where the disease is endemic. Many experts worry that the disease will reach other continents, especially **Asia**, and settle into autochthonous transmission there. This risk is difficult to estimate, and relates to factors such as the number of incoming viraemic travellers, the efficiency of local YF transmission (itself linked to environmental conditions, vectors' competency to transmit YF), as well as possible cross-immunity acquired through exposure to other flaviviruses such as dengue. The EYE strategy aims at limiting the risk of YF exportation by protecting populations in areas currently endemic for YF, where the source of the disease is, and by protecting travellers who could spread it.

In 2016, two linked urban yellow fever (YF) outbreaks – in Luanda (Angola) and Kinshasa (Democratic Republic of the Congo; DRC), with wider international exportation from Angola to other countries, including China – have shown that YF poses a serious global threat requiring new strategic thinking.

The world has largely forgotten the threat posed by YF, but little more than a century ago it was a source of terror, decimating the populations of cities, destroying economies and driving political choices. Extensive, repeated epidemics in North American and European port cities during the 18th and 19th centuries spread panic, shutting down the cities and killing hundreds of thousands of people, not just from the disease but also from its economic and other impacts, such as starvation. An estimated 150 000 people died during epidemics in the United States alone, with the then capital Philadelphia losing 10% of its population in the 1793 outbreak, during which the American President, George Washington, fled the city with his government.

The major leaps in biomedical research at the end of the 19th century led to identification of mosquitoes as the source of YF transmission and experiments to identify the infective agent. With the newly opened Panama Canal markedly increasing population movements through YF endemic territory, the Rockefeller Foundation's International Health Commission decided to set up teams to investigate YF eradication, first in South America, then later in Africa. This led to isolation of the YF virus strain in 1927, which in turn led to development of two vaccines, one grown in mouse brain (the "French neurotropic vaccine"; FNV) and later, by the Rockefeller team, the live attenuated 17D vaccine – a version of the safe, highly effective vaccine still used today, requiring only one shot to confer lifelong immunity and excellent cost-benefit ratios.

The French neurotropic YF vaccine was a good mass campaign vaccine because it was administered by scarification, permitting vaccination of up to 800 people per hour, or about 5000 per day. By 1953, 56 million Africans had been vaccinated. This led to a dramatic drop in cases in the francophone countries of Africa where vaccination was performed, whereas the disease remained epidemic in neighbouring Anglophone countries that did not practice vaccination, providing evidence that an effective vaccination strategy can achieve elimination of epidemics. However, the FNV caused some severe neurological adverse effects, which led to discontinuation of its use (production ceased in 1983), including its use in mass campaigns in Africa.

In the early 2000s, an increase in outbreaks in West Africa, with clusters of cases reported in urban settings, led to the launch of the YF Initiative¹, supported by Gavi, to reduce the risk of urban outbreaks. This three-pronged strategy, which began in 2005, included the introduction of the YF vaccine into routine child immunization programmes in endemic countries, mass preventive campaigns in at-risk areas, and the setting up of a global vaccine stockpile to permit rapid emergency mass campaigns in response to outbreaks. This led to vaccination of 114 million people and has prevented epidemics in West Africa since 2010. However, reduction of risk in West Africa did not alter risk in central and eastern African countries, where most recent outbreaks have occurred. A modelling study based on African data sources estimated that the burden of YF during 2013 was 84 000–170 000 severe cases and 29 000–60 000 deaths².

Changes in outbreak drivers – urbanization and peri-urbanization, ease and speed of population movements, changes in work (e.g. mining and construction), with large numbers of workers being recruited internationally (e.g. Chinese workers in Angola) – have led to large urban outbreaks with international spread. Ebola has already demonstrated graphically what happens when a pathogen – even one not very transmissible – gets into a crowded, mobile, urban population. The West African Ebola outbreak of 2014–2015 began in a remote area but when it arrived in urban areas it spread explosively and was transported internationally.

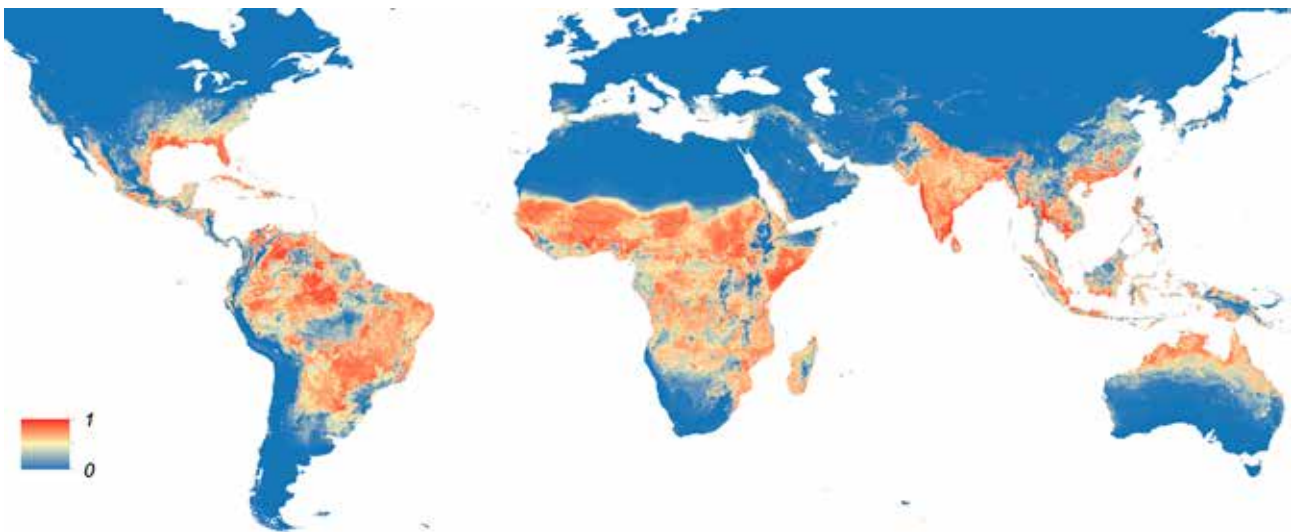
¹ YFI, <http://www.who.int/csr/disease/yellowfev/introduction/en/>

² Garske T. et al. Yellow fever in Africa: Estimating the burden of disease and impact of mass vaccination from outbreak and serological data. *PLoS Med.* 2014;11(5):e1001638

These are just warnings of much bigger outbreaks to come – including the potential for Asian outbreaks in countries such as India and China, which harbour *Aedes* mosquitoes and are home to 2 billion people who are immunologically naïve for YF (**Figure 1**).

EYE goes beyond immunization activities to address the increased risk and adapt to changing YF epidemiology. An efficient surveillance system and the control of international dissemination are essential pillars complementing population protection. This can only be achieved through strong partnerships and collaborations across agencies, disciplines and sectors.

Figure 1: Probability of occurrence of the *Aedes aegypti* mosquito under current environmental and land cover conditions



The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

© WHO 2017. All rights reserved.

Part 2.

Evolution of global YF risk

2.1. Recent changes in transmission dynamics

In the latter half of the 20th century the most frequent YF virus transmission patterns were either: **(1)** sylvatic – where the animal reservoir (non-human primates living in the forest or jungle) – infects tree-dwelling mosquitoes such as *Haemogogus* (in the Americas) and *Aedes spp.* in Africa, which in turn bite humans who enter the forest to hunt or work; **(2)** intermediate – where various *Aedes* mosquitoes species moving between the forest and human settlements are implicated, with humans serving as the hosts in the transmission cycle. This cycle can occur in rural villages and small towns, in what is called the “Emergence zone” in Africa, but large outbreaks have occurred when infected people from these rural settlements travelled to urban centres; or **(3)** urban, transmitted by *Aedes aegypti* which is capable of human to human transmission without needing to go back to the wildlife reservoir. Urban outbreaks are particularly deadly and disruptive and are more likely to cause international spread (**Figures 2** and **3**). More recently, although YF virus transmission patterns per se have not changed, the sequence has been increasingly short-circuited from sylvatic directly to urban, inter-human transmission. In Africa,

Figure 2: YF transmission cycles



virtually all intermediate type outbreaks have led to outbreaks involving the *Aedes aegypti* (urban) vector. In contrast to Africa, no intermediate cycle was recognized in LAC and YF cases have been nearly exclusively sylvatic with very few small urban outbreaks, although large, unvaccinated coastal populations are at potential risk as was demonstrated during the 2017 yellow fever outbreak in Brazil.

Vectors: The worldwide resurgence of the primary vector responsible for urban outbreaks – *Aedes* species mosquitoes – means that globally, more cities and countries are at risk. The current global outbreak of Zika virus disease and continuing outbreaks of dengue fever and chikungunya disease, all caused by viruses primarily transmitted by *Aedes spp.*, are indicative of the success of, and threat posed by, *Aedes aegypti*. Wherever and whenever Zika, Chikungunya and dengue virus occur, this should alert countries to the possibility that YF virus could also be successfully transmitted in their communities.

Environmental risk: Deforestation, climate change, more incursions into forests and jungles for mining and oil extraction, construction and to clear land for agriculture are all increasing contacts between humans, the animal reservoir and the mosquitoes transmitting YF virus. Humans no longer stay at the edge of forests but move in, work there and move rapidly back to cities or large settlements (in a matter of hours), thus contributing to the potential rapid spread of YF virus. All these risk-amplifying factors – urbanization, large population movements, climate change and increasing exposure of workers to infected mosquitoes in jungles and forests (particularly those working in mining, oil extraction and forestry) – are driving the change in YF epidemiology.

Figure 3: Increased risk of YF urban outbreaks with international spread



Human risk: Movement of populations for commerce and due to civil unrest can often lead to lower population immunity, particularly in urban centres, as previously unvaccinated persons move to areas that might have benefited from vaccination campaigns earlier (e.g. Abidjan in Ivory Coast experienced outbreaks several years apart with a notable decrease in population immunity between outbreaks).

2.2. Risk specific to urban outbreaks

In urban outbreaks, population density, crowding, low levels of population immunity, daily population movements in and out of, and around, the city, as well as conditions conducive to high vector density such as plentiful breeding sites in and around houses, all contribute to increasing transmissibility, raising the risk of large-scale outbreaks.

Urban outbreaks are characterized by their rapid amplification, capacity for international spread, and impact not only on public health but also on economic, social and political life. The West African Ebola outbreak showed that when a pathogen spreads to capital cities it can amplify into a major epidemic on a scale never observed before. The public health impact of such outbreaks is huge and so too are the economic losses: in the Republic of Korea, an outbreak of Middle Eastern respiratory syndrome in June 2015 caused only 185 cases but paralysed the capital, Seoul, for several weeks, precipitating losses of millions of dollars in a matter of days.

Responding to outbreaks in large urban settings is challenging and costly and, in a globalized world, such outbreaks have impacts on travel and trade beyond the health consequences alone.

2.3. Updated risk classification

While the YF virus has caused outbreaks in many countries in past decades, it is still difficult to assess the risk of re-emergence. Such re-emergence depends on a convergence of factors, requiring virus circulating in the animal reservoir, infection in mosquitoes, and transmission to humans. Many unknowns remain. In this challenging context, specific criteria were applied to classify at-risk countries and propose preventive strategies. Given growing concern and perception of globalized risk, the number of reviewed countries was inclusive.

Forty-seven countries (34 in Africa, and 13 in Central and South America) are either endemic for, or have regions that are endemic for, YF³. In addition to these 34 African countries, Zambia was included where north-western and western provinces are areas of low exposure⁴.

³ YF: Yellow fever: Fact sheet. Geneva; World Health Organization; updated May 2016; <http://www.who.int/mediacentre/factsheets/fs100/en/>

⁴ Jentes ES et al. The revised global yellow fever risk map and recommendations for vaccination, 2010: consensus of the Informal WHO Working Group on Geographic Risk for YF. *Lancet Infect Dis.* 2011; 11:622–322014;11(5):e1001638

The risk of YF epidemics varies within countries and the implementation of YF prevention measures need to be tailored accordingly. Most risk-reduction approaches need to be national in scope to account for population movements, feasibility, efficiency, consistency and sustainability. When a localized or age-specific risk is documented, some interventions might be targeted at a sub-national level or to a specific population (e.g., mass preventive or catch-up campaigns). For practical considerations, some national interventions will also be implemented by subnational increments.

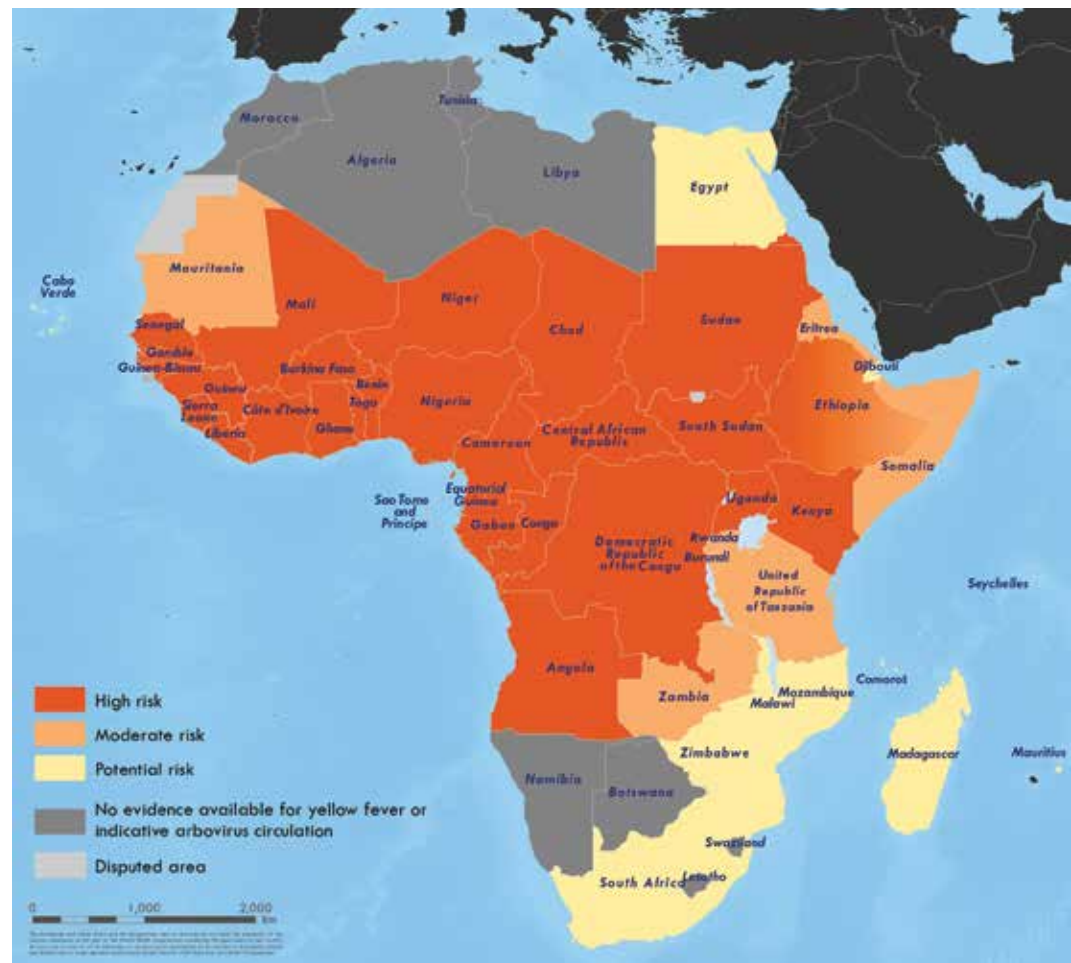
Importantly, the maps displayed in figures 4 and 5 illustrate a public-health-intervention oriented YF risk approach at country level. Their purpose is different from the YF risk area maps developed for travellers in the context of the International Health Regulations (2005) (IHR) – such as those available from http://gamapservr.who.int/mapLibrary/Files/Maps/ITH_YF_vaccination_americas.png.

Africa

For Africa, a **three-step approach** was used to reclassify the 35 countries into different risk categories (high – moderate – potential) and to propose preventive strategies accordingly.

The first step is using estimation of crude risk for YF transmission based on timing and intensity of YF virus circulation in the country, estimates of the transmission potential in terms of the basic reproduction number, assessment of urban outbreak risk based on

Figure 4: Yellow Fever (YF) risk classification, by country as per the EYE Strategy: Africa, 2016



reports of recent or current outbreaks of *Aedes aegypti*-transmitted viral diseases. This analysis enabled identification of 27 “**high-risk**” and eight “**moderate-risk**” countries (Figure 4).

The second step is based on the estimation of the actual risk for YF disease cases and urban outbreaks, while the third step is to prioritize countries based on their level of risk.

The analysis also identified countries that neighbour areas with risk of YF and have reports of recent or current outbreaks of *Aedes aegypti*-transmitted viral diseases and characterized them as having “**potential for YF virus transmission**” and sustained urban outbreaks of YF.

Latin America and the Caribbean (LAC)

For **LAC**, YF is a significant public health problem for the 13 countries with endemic areas, and all are considered to be at **high risk** (Figure 5).

Over the last 30 years and through 2016, YF virus activity has been restricted to the enzootic area shared by the Pluri-national State of Bolivia, Brazil, Colombia, Ecuador, French Guyana, Guyana, Panama, Peru, Suriname, Trinidad and Tobago, and the Bolivarian Republic of Venezuela.

Figure 5: Yellow Fever (YF) risk classification, by country as per the EYE Strategy: Latin America and Caribbean, 2016



Since late 2007, the region has experienced intense circulation of the YF virus with extensive epizootics (animal outbreaks) and outbreaks of human cases. In 2008, cases of YF were reported in the metropolitan area of Asuncion, Paraguay. Prior to this, the last confirmed urban outbreak of YF in LAC had occurred in 1942 in Brazil. This event, in addition to the proliferation of *Aedes aegypti* in the region, shows the high risk of migration that still exists in LAC. The endemic area was extended to include Paraguay and northern Argentina, because of human cases and epizootics detected in 2008. As of 2016, every country in the region with enzootic areas has added the YF vaccine to its national immunization schedule. In Argentina, Brazil and Panama, the vaccine is only administered in areas of potential risk, with enzootic activity - but this distribution might change after the large YF outbreak which hit Brazil in 2017.

YF circulation has not been identified to date in the Caribbean countries and territories, which are not endemic for the disease, except in Trinidad and Tobago⁵. Yet the intense and rapid spread of both the Chikungunya and Zika viruses and recurrent dengue epidemics in large, densely populated regions of South America, Central America and the Caribbean outside the enzootic zone make them countries with “**potential for YF transmission**”, on the same basis as the risk categorization proposed for Africa.

⁵ only on the island of Trinidad

Part 3.

Public health measures for YF prevention and control

There are several measures that are integral to a long-term strategy aimed at eliminating outbreaks of YF, including surveillance and laboratory testing, vector surveillance and control, and vaccination.

3.1. YF disease surveillance and laboratory capacity

Sustained YF control strategies must rely on strong surveillance and diagnostic capacities to allow for early detection of outbreaks and rapid implementation of control measures that can help **mitigate the risk of spread and the use of extensive resources**. The recent Angola epidemic highlighted how limited surveillance and laboratory capacity worsen both the epidemic burden and spread: by delaying the detection of YF cases and clusters, the outbreak got out of control, reached a magnitude that required very resource-intensive containment measures and spread internationally by land and air through unimmunized travellers working in Africa. Strong surveillance and diagnostic capacity also enable an understanding of where the risk of YF is and to inform the allocation of appropriate resources. Surveillance informs targeting and intervention priorities by providing information on the evolving risk and the impact of preventive and control measures. In the case of YF, insufficient surveillance participated to the limited evidence of risk and lack of interest in controlling the disease.

Appropriate surveillance approaches for YF differ based on the level of risk of urban YF outbreaks, ranging from case-based, sentinel approaches to integrated disease surveillance and response (IDSR) approaches.

3.2. Vector surveillance and control

Both vector surveillance and control are components of the prevention and control of vector borne diseases, especially for transmission control in epidemic situations. For YF, vector surveillance that identifies prevalence of *Aedes aegypti* and other *Aedes stegomyia* species will help inform level of risk of an urban outbreak. Understanding the distribution of these mosquitoes within a country would allow a country to prioritize areas in which to strengthen their human disease surveillance and laboratory testing for yellow fever, including intensification of vector control activities.

There is currently a limited public health arsenal of safe, efficient and cost-effective insecticides that can be used against adult vectors. This is mainly due to the resistance of major vectors to common insecticides and the withdrawal or abandonment of certain pesticides for reasons of safety or the high cost of re-registration.⁶

Sylvatic vector control (i.e. that occur in wild areas) is not feasible and urban vector control has proved challenging with limited impact on disease prevalence. As currently implemented, it has been unable to prevent epidemic Dengue, Chikungunya and Zika.

Behaviour change communication is an important element to ensure individuals are aware of their own role in protecting themselves from mosquito bites through personal preventive measures such as clothing minimizing skin exposure and repellents to avoid mosquito bites. The use of insecticide-treated bed nets is limited by the fact that *Aedes* mosquitos bite during daytime.

3.3. Vaccination against YF

There has been an effective and safe vaccine available to prevent YF since the 1930s. One dose of the vaccine provides lifelong immunity. The YF vaccine is affordable for public health programs funded by governments, costing an average of US\$ 1.07 per dose in 2016, in 5- and 10-dose presentations.⁷

Vaccine coverages greater than 80%, with a 60-80% security threshold, are necessary to interrupt local transmission (human-mosquito-human) of YF virus within a community and to ensure that sporadic unvaccinated cases do not generate additional cases.

There are four potential ways to improve vaccination coverage in high risk areas:

1. Implementing and strengthening coverage rates of childhood YF RI which is a long term approach to maintain population immunity as it takes 30 years to reach appropriate population immunity.
2. Conducting preventive mass vaccination campaigns which provide a shorter term and rapidly increased population immunity.
3. Implementing catch up campaigns which is a risk mitigation measure to close immunization gaps.
4. Maintaining a stockpile for reactive campaigns which ensures vaccines equity for YF outbreak response.

⁶ <http://www.who.int/whopes/questions/en/>

⁷ http://www.unicef.org/supply/files/Yellow_Fever.pdf

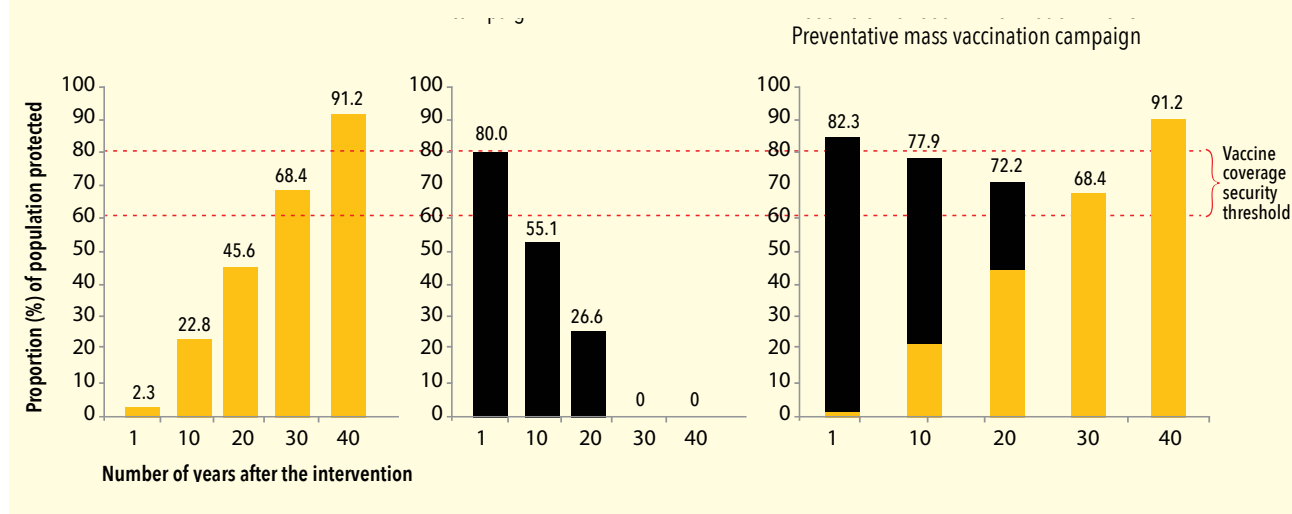
Each approach, as per described below, has potential obstacles and different costs.

Approach 1: Implementing and strengthening coverage rates of childhood YF vaccination

YF vaccine can be integrated into national routine immunization schedules and delivered through EPI in an integrated approach with other vaccines. Infant YF routine immunization is administered at nine months in Africa and 12 months in LAC, jointly with the first dose of measles-containing vaccines, at low operational costs and under feasible conditions.

When well implemented by strong health systems, YF routine immunization in the EPI can provide sufficient population immunity. However, it **takes about 30 years** to build the population immunity to adequate levels to potentially stop large scale outbreaks (see below **Box 1**). Once high level population immunity is established, the continued routine vaccination of new birth cohorts is a **sustainable long-term** approach to maintaining high levels of population immunity. If recently introduced or insufficiently implemented, routine immunization alone does not represent a safe approach to controlling the risk of YF epidemics, as recently demonstrated in **Angola**.

Box 1: Population protected by routine immunization, preventive mass campaigns and combined vaccination strategy



Current patterns of population movements, with frequent exchanges between sylvatic (or forest) and rural areas, are such that subnational approaches to risk control might not be adequate in all countries, especially if vaccination of travellers within a country is suboptimal. In these countries, a national approach might be more appropriate given the need for a comprehensive risk mitigation strategy.

Approach 2: Conducting preventive mass vaccination campaigns

Preventive mass vaccination campaigns (PMVCs) are **the most efficient** approach to **rapidly increasing population immunity** levels in high-risk areas and controlling the risk of YF epidemics on a **short-term** basis. However, population protection wanes rapidly, becoming non-existent after 25 to 30 years (see above **Box 1**).

Preventive mass campaigns target the at-risk population older than nine months. They have low vaccine wastage rates of around 5 to 10%. These one-time comprehensive campaigns are associated with operational costs of approximately US\$ 0.65 per dose delivered. They are resource-intensive and require strong commitment at all levels (from political to community) as well as intense coordination between partners. By actively seeking to reach everyone and attaining high vaccine coverages, preventive mass campaigns contribute to strengthening **health equity**. Most countries are accustomed to campaign implementation and typically reach high coverages (>90%). However logistical challenges remain, particularly regarding waste management and monitoring of adverse effects following immunization. The capacity of a health system to overcome these challenges directly affects the quality of a mass campaign.

Approach 3: Implementing catch-up campaigns

Where there is low routine vaccination coverage and potential gaps in preventive campaign vaccination coverage due to population movements, mounting targeted “catch-up campaigns” would enable reaching under-vaccinated cohorts or pockets. These catch-up campaigns may target age-specific vaccination gaps or geographic areas where population immunity is low.

Catch-up campaigns are a reasonable **risk mitigation** measure in high-risk areas to **close immunization gaps**. They are resource-intensive, particularly as vaccination coverage surveys might need to be performed to determine areas with low coverage, and require the same amount of coordination and fixed costs as large-scale preventive mass campaigns. Catch-up campaigns are **not a substitute** to well-functioning routine immunization systems. Countries should be engaged to perform periodic assessments of their vaccination coverage in areas at-risk for outbreaks of disease in order to identify gaps in coverage and respond proactively. Assessments could be performed at regular intervals (e.g., every 5-10 years) or in response to large population movements or other factors that might impact coverage.

Approach 4: Maintaining a stockpile for reactive campaigns

A large supply of readily available YF vaccine can be kept for any future emergency response. Vaccine stockpiles enable a rapid access to a limited supply of vaccines, allowing countries to **respond to YF outbreaks** in a timely fashion. In a limited vaccine supply context, the international management of vaccine stockpiles is necessary to ensure an **equitable distribution**. Until optimal vaccination strategies are implemented to control the risk of YF and prevent epidemics, YF vaccine stockpiles will be necessary.

3.4. Targeting travellers and improving IHR compliance

The recent Angola epidemic highlighted how YF can spread internationally by land and air through unimmunized travellers (workers from China, Kenya and DRC). In Angola in 2008, there were 400 000 migrant workers from DRC, at least 220 000 Portuguese, and about 260 000 Chinese – figures which have since increased. In LAC, unimmunized “eco-tourists” lodging in forest areas are a recognized source of introduction of YF virus into non-forested areas.

The YF immunization status of travellers needs to be confirmed upon arrival into and departure from areas at risk for YF to prevent YF exportation to immune-naïve populations where the potential for local transmission exists.

Although little data is available, the International Health Regulations (2005)⁸ are inconsistently applied in countries at risk for YF, upon airport arrival and at land border crossing. As experienced during the 2015 Ebola epidemic, personal data and health checks are difficult at points-of-entry. Nevertheless, lessons can be learnt from those experiences to inform strengthening of IHR compliance⁹.

The recent Angola–DRC YF epidemics also highlighted the need for uniform vaccination cards that are cheap but hard to counterfeit: viraemic unimmunized migrant workers used counterfeited cards to cross land borders and spread YF into immune-naïve populations.

Although cost figures are not available, they should be fairly low compared to vaccination and surveillance activities.

In summary

YF cannot be eradicated, but epidemics can be eliminated if population immunity levels are effectively raised through mass vaccination and sustained by routine childhood immunization. Different approaches enable detection of YF and mitigation or prevention of the risk of YF epidemics. They can be used alone or in combination, with varying impact. The most appropriate and cost-effective combinations of approaches depend on the level of risk of YF in a country.

It is important to emphasize that immunization programmes must maintain high levels of population herd immunity, and that cessation of routine immunization will eventually lead to a return of outbreaks, as happened in Senegal in 1965, about five years after routine immunizations were stopped.

⁸ The main IHR (2005) provisions on vaccination and related certificates are Annexes 6 and 7 and Article 36. See the WHO International Health Regulations (2005), Second edition, 2008. Available at:

1. <http://www.who.int/ihr/publications/9789241596664/en/>
2. Meeting of the Strategic Advisory Group of Experts on immunization, April 2013 – conclusions and recommendations. Weekly epidemiological record. 2013;88(20):201–216 (<http://www.who.int/wer/2013/wer8820.pdf>, accessed 18 March 2014).
3. Resolution WHA67.13.

⁹ Points of entry under the IHR (2005): http://www.who.int/ihr/ihr_brief_no_3_en.pdf

In West Africa, the **three-pronged approach** – including YF vaccine in routine immunization, performing mass vaccinations in at-risk countries/populations, and responding rapidly to outbreaks – has successfully controlled the disease. This three-pronged approach works and still provides the basic ingredients needed for an effective strategy. However, the change in risk both in vulnerable, fragile countries and internationally, and the resurgence of vectors, means the way in which these public health tools are strategically applied needs to be scaled up and tackled globally.

The risk-driven combination of strategic options to detect and control YF is proposed in **Table 1**.

Table 1: Public health goal and combination of strategic options for YF detection and control by risk level

| Country risk level | Public health goal | Combination of strategic options |
|--|--------------------------------------|---|
| High | Protect at risk population | <ul style="list-style-type: none"> • Three-pronged vaccination approach to maintain high population immunity levels (routine immunization, catch-up campaigns, preventive mass campaigns); • Monitoring of population immunity. |
| | Contain outbreaks rapidly | <ul style="list-style-type: none"> • Rapid response to outbreaks; • Case-based surveillance and laboratory testing; • Vector surveillance and control. |
| | Prevent international spread | <ul style="list-style-type: none"> • Targeting travellers and improving IHR adherence (upon entry and departure); • Readiness and health systems strengthening. |
| Moderate | Contain outbreaks in high risk areas | <ul style="list-style-type: none"> • Sentinel surveillance and laboratory testing; • Rapid response to outbreaks. |
| | Prevent international spread | <ul style="list-style-type: none"> • Improving IHR adherence; • Readiness and health systems strengthening. |
| Currently not considered at risk but potential for YF transmission | Detect suspected cases early | <ul style="list-style-type: none"> • Integrated surveillance and laboratory testing; • Improving IHR adherence. |
| | Prevent introduction of YF | <ul style="list-style-type: none"> • Readiness and health systems strengthening. |

Part 4.

Lessons learned from prior programs: obstacles to progress

4.1. Vaccine supply

A major block to achieve YF vaccine implementation has been the limited vaccine supply. Between 2013 and 2015, 15 countries among the 34 that introduced the YF vaccine into their routine immunization programmes reported YF vaccine stock-outs¹⁰ at national level, with consequences for national coverage. The problem is chronic related to supply and resource constraints as well as inadequate planning.

Vaccine supply has been continually challenged mainly by: **(i)** a sharp increase in demand after the YF investment case; **(ii)** regulatory and prequalification suspensions; and **(iii)** production problems leading to a situation in which supply has been below demand.

Global demand for YF vaccines has increased from approximately 20 million doses in 2001 to 90 million doses on average from 2012 onwards. This growth is mainly due to the demand generated by the resurgence of YF epidemics in Africa and the support provided by Gavi to endemic countries to access the vaccine. Due to growing population mobility and more frequent travels from endemic zones to non-endemic areas, the need for YF vaccine has increased.

To achieve effective YF control, demand and supply must match to allow a timely and effective risk reduction strategy. This will require the sustained engagement of the various stakeholders as well as robust mechanisms for need forecasting and market shaping.

Manufacturers need to continue ongoing efforts to increase overall production, but at the same time, a long-term consistency of demand must be achieved and commitment on number of doses and prices must be obtained. Successive YF vaccine roadmap efforts have not provided enough security to the manufacturers to justify investment and scaling up of production.

¹⁰ Defined as > 30 days.

4.2. Regional and country buy-in

Due to competing vaccine introduction priorities and limited political will, no new countries have introduced the YF vaccine into their national routine immunization programmes since 2008. The level of YF risk has not been strongly communicated. The absence of a regional goal and well-communicated strategy has left countries without direction on this issue. Regional and national technical advisory groups (TAGs) have a critical role in supporting countries to introduce the yellow fever vaccine into their routine programmes.

4.3. Implementation issues

Following the early success of the YF investment case, the Gavi Board endorsed additional support for African countries at medium risk of YF outbreaks in December 2013 through a Vaccine Investment Strategy (VIS) process. This was intended to extend support for mass preventive campaigns and routine immunization. Twenty-four countries in Africa have introduced the vaccine into routine immunization and 14 countries have conducted a PMVC since the beginning of the YF Initiative.

However, countries have been slow to apply to Gavi for support. Furthermore, in many countries vaccine coverage has stagnated. LAC countries follow the recommendations of the regional TAG to control YF in the region, which include the introduction of the YF vaccine into national immunization programs for children aged 9 to 12 months in every country with endemic areas.

In addition to supply insecurity, reasons cited for low vaccine coverage include weak vaccine management, inadequate or overly rigid vaccination practices, such as no vaccination given after 11 months, and unwillingness to open a 10 or 20 dose vial for one child only. Vaccine supply priority is always given to outbreak response.

As a result of these obstacles, childhood immunization coverage for yellow fever is too low to maintain sufficient immunity. Specific reasons for low coverage need to be analysed, addressed and monitored. Differences between measles and YF vaccine coverage (both given at nine months in Africa) also need to be monitored and reasons for lower coverage of YF better understood. In 2015, the median coverage in 22 African countries with both vaccines in national routine immunization programmes was 75% for the first dose of measles and 70% for YF¹¹.

4.4. The global emergency stockpile

Since 2004, the global emergency vaccine stockpile managed by the International Coordinating Group (ICG) for vaccine provision and funded by Gavi is at the level of 6 million doses. Until the 2016 epidemic in Angola and DRC, 6 million doses had been sufficient to control YF outbreaks in a one-year period. Only once had the 6 million doses been depleted (in 2008, to control an outbreak in Brazil and Paraguay). In 2016, the YF emergency stockpile has been replenished twice in order to respond to the increasing need

¹¹ Source: WHO/UNICEF Estimates of National Immunization Coverage; WUENIC

of vaccine to control outbreak and interrupt transmission, bringing it up to 18 million doses. Gavi made an exceptional decision to cover the costs of stock replenishment, and therefore in 2016 the ICG stockpile financed by Gavi was 12 million doses out of the 18 million. Other contributors were the Central Emergency Response Fund, Bio-Manguinhos, the Government of Angola and the ICG revolving fund.

The rapid replenishment and increase of the stockpile has been possible thanks to excellent coordination and collaboration among vaccine manufacturers (reprioritizing their production plans) and the WHO-UNICEF working group, which has worked with affected countries to reprogram Expanded Programme on Immunization (EPI) vaccine routine shipments and thus avoid country stock-outs, while at the same time maintaining 6 million doses in the stockpile, and finally to Gavi who has provided critical financial support for these exceptional requests.

In the future, a plan will be required for rapid scale up of production if demand exceeds the vaccine stocks.

4.5. Programme governance and resources

The longer term oversight of the YF initiative was provided to some degree by the YF partnership, made up of key public health partners around the world. The main focus of the group was to assist in the implementation of the preventive mass vaccination campaign, improve adverse event following immunization surveillance within countries conducting the campaign, and discuss YF virus disease activity and need for reactive campaigns. However, the group lacks the appropriate authority and infrastructure to address some of the key deficiencies in surveillance, laboratory capacity and case management and to address countries' hesitations to engage in activities to improve their YF vaccination coverage. Although partners within the group often worked together to address gaps (e.g., development of YF risk assessment protocol), the group lacked the ability to systematically identify and address research gaps. Strong participative governance will be key to the success of the strategy for eliminating YF epidemics as well as appropriate human resources and sustainable financial commitment at all levels.

4.6. A global problem

The control programme needs to be global, not only because the risk goes beyond national borders, but also because the supply issue needs to be addressed globally, for example by supporting Gavi-eligible countries in South America in the VIS. All countries need to be included in the global vision and provided with support, including by having access to the emergency stockpile.

Part 5.

EYE vision and strategic objectives

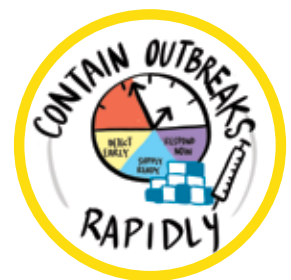
To respond to the increased risk of large urban outbreaks with international spread that could threaten global health security, a comprehensive, multicomponent, global long-term strategy has been developed to target the most vulnerable countries and regions, while addressing global risk by building resilience in urban centres and readiness in areas with potential for outbreaks, and ensuring reliable vaccine supply based on forecasted needs and demands, and shaped vaccine production.

Our vision: A world without yellow fever epidemics.

Our mission: Coordinate international action and to help at-risk countries to prevent yellow fever outbreaks and to prepare for those which might still occur, minimizing suffering, damage and spread by early and reliable detection as well as a rapid and appropriate response.

To achieve this, EYE strategy has **three strategic objectives**:

- 1. Protect at-risk populations,**
- 2. Prevent international spread, and**
- 3. Contain outbreaks rapidly.**



The EYE strategy will only be successful if core activities are initiated immediately to provide cross-cutting support to the three central objectives. These activities are:

- 1. Affordable vaccines and sustained vaccine market**
- 2. Strong political commitment at global, regional and country levels**
- 3. Robust governance of the project with strong partnerships**
- 4. Synergies with other programmes and sectors**
- 5. Research and development for better tools and practices**

5.1.

Strategic objective 1: Protect at-risk populations (No epidemics)



Action 1: Where risk is high, vaccinate everyone

Preventive mass vaccination campaigns

To rapidly reduce the risk of outbreaks, it will be important to target areas at high risk of YF virus transmission and inadequate population-level herd immunity.

While the primary goal is to build a barrier of human immunity in sylvatic areas and protect populations in the zone of emergence, the preventive strategies have to be national in scope to account for the reality of frequent and rapid population movements and to prevent urban outbreaks. A possible exception is Ethiopia, for which the south-western part of the country is scheduled for a PMVC as seroprevalence surveys and confirmed epidemics have indicated virus circulation in this area only.

Catch-up campaigns

Reported immunization coverage will be monitored and the overall vaccine-induced population immunity (PI) acquired through routine EPI, reactive and preventive campaigns will be calculated regularly, indicating which countries should be targeted for catch-up. An acceptable PI threshold for protection could be 70% (being the midpoint of the consensus threshold range for YF herd immunity of 60–80%). Further operational guidance will be sought on this aspect.

In-country prioritization

In countries with large target populations, national PMVCs will be mounted in multiple phases of subnational increments over several years, in a similar way to the introduction of the meningococcal meningitis A vaccine. In those circumstances, in-country prioritization of at-risk areas will be required. Campaign phasing will be developed with the countries themselves, on a country-by-country basis, based on factors including ecological criteria, population immunity and pragmatic consideration.



Action 2: Vaccinate every child

Including YF vaccination in routine immunization schedules

The best way to maintain high levels of immunity in high-risk countries is to ensure that all new cohorts are immunized in infancy. High coverage in successive cohorts of children will gradually ensure that the PI does not decrease after mass vaccination campaigns.

In Africa, all 27 countries at high risk need to protect all infants against YF by introducing the vaccine into their national routine vaccination schedule and ensure that high coverage is achieved. Most countries at high risk have introduced the vaccine into the national routine immunization schedule already. However, as of September 2016, five out of the 27 countries had not yet done so (Ethiopia, Kenya, South Sudan, Sudan and Uganda). It is expected that these countries will have introduced the YF vaccine into their routine immunization schedules by 2020.

Improving routine immunization performance

Simply introducing YF vaccine into routine immunization programmes is not sufficient to prevent YF outbreaks. In many countries routine immunization coverage is low at national or district levels. Exploration of, and an effective response to, reasons for this poor coverage – which are likely to vary between localities – will be key to successfully implementing this element of the EYE strategy.

Some important approaches include ensuring that the YF vaccine stock is reliable and that health facilities are well supplied, increasing political will to ensure that children are vaccinated, improving the knowledge and awareness of health care workers about the importance of childhood YF vaccination, linking prevention of measles and YF, and clearly defining targets and indicators. Demand creation has to be particularly strengthened, in liaison with stronger community engagement at all levels, communication and social mobilization efforts.

Special attention must be paid to reaching vulnerable, marginalized populations (e.g. street children, displaced populations and refugees) and those living in remote areas.



Action 3: Evaluate risk to prioritize resources

Risk assessment are critical **(1)** to allocate resources based on evidence, **(2)** to set priorities for interventions and vaccine implementation – catch up campaigns and mass vaccination – based on identified risks, **(3)** to inform on IHR classification if needed, and **(4)** to obtain clear records.

A comprehensive risk assessment methodology has been designed and applied in a number of countries in the last five years¹². Country results have been successfully used to guide preventive interventions and recommend – or not – preventive campaigns or introduction of YF vaccine into the routine EPI.

In Africa, it is currently not recommended to systematically conduct such risk assessment in the countries. The risk assessment exercise has value, in case of perception of changing risk in countries at moderate risk or with no evidence of YF virus circulation; or of country or regional request for revised classification, in particular for the IHR. Countries outside the current at-risk country list might also benefit from such an assessment, for the same reasons. The same applies in LAC. Further, in countries such as Brazil for instance, a risk assessment could also include obtaining clear records of already vaccinated individuals.

An overall **shift of paradigm** for the risk analysis is recommended, with a greater focus on **regular** priority setting and decision-making for **resources' allocation at global level** - taking into account factors such as recent population dynamics (migration and urbanization) and evolving ecological conditions in addition to programmatic issues.

¹² http://www.who.int/csr/disease/yellowfev/risk_assessment/en/

5.2.

Strategic objective 2: Prevent international spread (No exportation)

The 2016 Angolan outbreak showed that a large urban outbreak in a transport hub increases the risk of local transmission and can rapidly spread to distant countries (11 cases were exported to China where dengue is endemic and population is immune-naïve for YF). Fortunately, this occurred during a period when temperatures in China were too low for YF vector activity. Actions are needed to prevent serious risk of international spread.



Action 1: Protect high-risk workers

Globalization means that workers in a wide range of extractive industries (such as the oil and mining industries) and other sectors (such as construction and forestry) move into and out of YF endemic areas regularly and are at risk of both developing the disease and spreading it internationally. These workers are particularly exposed to sylvatic transmission when the activity is in forests or recently deforested areas.

Within the EYE governance mechanism (see **Part 6, Keys of success** for more details), ad hoc consultations involving companies from the major sectors affected (e.g. the extractive, construction and forestry industries, and the transportation sector) and public health experts is needed to develop strategies ensuring that all at risk workers, whether international or local, are protected. The private sector should be involved in this effort and ensure that staff and their families are protected.



Action 2: Apply the IHR

Because epidemic risk might exist through imported cases, strict implementation of the IHR for travellers in and out of countries at-risk for YF, as well as increased surveillance and preparedness, will be paramount to prevent, detect and respond to potential epidemic threats. YF vaccination requirements are clearly stated in the IHR, but are not being fully applied. Port and border control authorities need to be engaged to identify gaps and ensure that the vaccination status of all travellers entering and leaving endemic areas is known and appropriately managed. This is particularly important at points of entry in the at-risk countries.

All countries need to engage transportation agencies (e.g. the International Air Transport Association), airlines and border control agencies/customs to strengthen the control of YF immunization status, in line with the IHR, based on area of origin and destination, at entry and departure.

A particular problem is the production of falsified immunization cards or certificates as well as non-official card selling points. In addition to specific country control measures, a solution needs to be proposed at the global level to move towards a unique registration system and the creation of non-falsifiable cards.



Action 3: Build resilient urban centres

Large cities are vulnerable to epidemics due to the fact that viruses are more likely to be introduced and dense urban populations are more able to rapidly amplify transmission. Epidemics in urban settings are particularly disruptive. Building resilience to epidemic risks in large cities is essential for global health security and can be achieved through readiness plans and sustained vector surveillance and control programmes in cities.

Readiness plans

The risk reduction of epidemics in urban centres can be achieved through increased readiness (e.g. development of urban readiness plans) and the development of risk assessment and intervention plans for transportation hubs.

Urbanization has led to rapid demographic growth in capital cities where the risk of YF urban outbreaks is very high. Some countries have already identified this risk of epidemics and have developed emergency management plans. These are led by specialized agencies (such as the Lagos State Emergency Management Agency¹³), with possible focus on high-risk infrastructures such as airports and other transportation hubs,¹⁴ or health care centres.¹⁵

Large urban centres at risk for YF outbreaks or at potential for YF transmission should be prepared to respond to YF outbreaks and develop readiness plans focusing on rapid implementation of an emergency vaccination campaign and control of transmission in transportation hubs (bus and railway stations, airports, ports). These plans should identify key resources and a highly trained core team of health care professionals (public health officers, laboratory experts, patient care and vector control specialists) who will be prepared to manage the entire outbreak response – including rapid risk assessment – and to tap into appropriate networks of experts and resources (e.g. the ICG, Global Outbreak and Alert response Network (GOARN), Emerging Diseases Clinical Assessment and Response Network (EDCARN)). Plans will detail coordination between agencies (roles and responsibilities, communication channels) in the preparedness phase (e.g. maintaining an appropriate pool of trained health care workers) as well as during the epidemic (e.g. leadership roles, decision-making, and engagement with partners).

Mass vaccination campaigns have proved to be particularly challenging in urban settings due to the size of area to be covered, the mobility of the population and logistic challenges of the operation. Specific preparedness efforts and plans are needed to ensure timely and rapid vaccination during urban outbreaks.

¹³ Lagos State Emergency Management Agency: <http://lasema.lagosstate.gov.ng/>

¹⁴ “Preparing and responding to a public health event: Montreal Airport”, Public Health Agency of Canada

¹⁵ <https://www.health.ny.gov/environmental/emergency/>

Sustained vector surveillance and control programmes in cities

Aedes aegypti indices should be calculated regularly in cities at risk or with potential for YF. This monitoring should be integrated into urban emergency planning and trigger activities based on the estimated level of risk. These measures should be part of broader arbovirus surveillance and readiness in countries at-risk for Dengue, Zika, and Chikungunya as well.

Vector control of adult and larval forms requires sustained efforts to maintain low mosquito density, particularly re. *Aedes* vectors, which are well adapted to humans. Qualitative research should be used to understand what does and what does not work for *Aedes* control. Strategies involving all parties need to be developed.

5.3.

Strategic objective 3: Contain outbreaks rapidly (No sustained transmission)

The risk of large urban YF outbreaks has increased due to a combination of factors including rampant informal urbanization. The fast pace at which African cities are growing is challenging the capacity of health systems to provide adequate services including timely epidemic detection and response and prevention of international spread. The recent Angolan outbreak illustrated the heavy demand on international resources and capacity required to respond to large YF urban outbreaks.

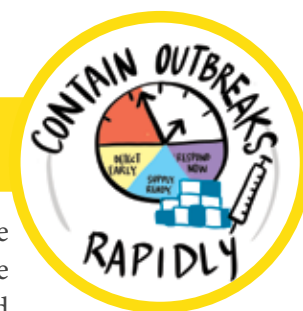
Outbreaks are unusual events that require additional resources and partners. Planning is essential for a successful response as well as a good coordination of partners.

Rapid containment of an outbreak is essential to prevent amplification into devastating epidemics. It is dependent on early detection and confirmation; emergency vaccine stockpiles and rapid response.

Action 1: Detect early

As work proceeds to raise population immunity levels, outbreaks are likely to continue to occur. Strengthened surveillance and improved laboratory capacity should be in place to detect outbreaks early and contain them rapidly. In addition, better surveillance and diagnostic capacity provides more information to permit assessment of the evolving risk as well as the impact of preventive and control measures.

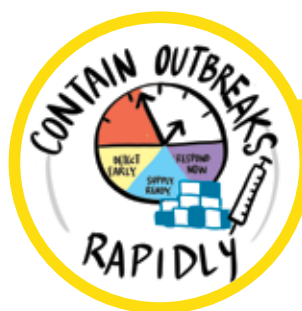
In all countries, the IDSR framework could be a foundation for YF surveillance. Means of optimizing YF detection and confirmation and integrating activities (training, sample transportation, laboratory confirmation, etc.) need to be explored and defined in each country. Community-based surveillance through initiatives such as community risk management and early warning social networks could be promoted. YF surveillance and testing capacities need to be integrated with those of other systems, such as for other arboviruses (e.g. Zika and Chikungunya), viral haemorrhagic fevers (e.g. Ebola) or other diseases for which stronger capacity was built over time (e.g. HIV).



All **high-risk** countries should be part of regional surveillance networks. The eight African countries considered to be at **moderate risk** need to raise their detection and confirmation capacities. A sentinel surveillance approach could be a practical and efficient choice to limit pressure on resources while achieving adequate capacity.

In Africa, a network for detection and laboratory confirmation of YF cases in the WHO African Region was established in 2001, with 21 Member States currently participating. This has enabled surveillance objectives, case definitions, investigation and laboratory methods, and other tools to be standardized across the network and to use the same information flow. However, the laboratory capacity in some countries is still too low to ensure early detection of initial cases. In LAC, the regional network of laboratories is integrated with arbovirus surveillance (Red de Laboratorios de Dengue de las Américas). Both networks need to be reactive and include an alert component.

The countries at **potential risk** for YF epidemics are not required to join the regional network but they should, as part of the country control plan, ensure that suspected cases with severe disease (e.g. people with haemorrhagic symptoms) are detected and investigated for YF.



Action 2: Vaccine supply is ready at all times

Emergency stockpiles ensure timely and equitable access to vaccines during emergencies. This is a critical element to contain outbreaks. In the VIS approved by the Gavi Board in 2013, the emergency stockpile estimation was a decreasing number of doses over the years from 6 million to a minimum level of 2 million doses in 2022. This estimation was made under the assumption that after mass preventive vaccination campaigns in the 12 highest-risk countries and the decreasing number of YF outbreaks in the period 2011–2015, the need for a large stockpile would decline.

After the large urban outbreak in Luanda and the risk of international spread, the ICG members (July 2016) reviewed the vaccine needs for the emergency stockpile and discuss a forecast for the next 10 years. Taking into consideration the rapid change in YF epidemiology in Africa and Latin America, the option of increasing the size of the stockpile has been reconsidered. Maintaining a large stockpile was not considered as the best investment given the low frequency of large outbreaks and decision was made to retain the emergency stockpile at the level of 6 million doses. The main difference with the previous stockpiles is in the availability of vaccine.

The new stockpile model will maintain a stock of 6 million doses at all times: a **Revolving Emergency Stockpile**. The stockpile will be replenished after its use to respond to an outbreak as soon as a vaccine becomes available. This strategy will allow responding to large urban or long-lasting outbreaks. Vaccine manufacturers should always have a constant level of vaccine in stock ready for shipment within 48 hours. UNICEF Supply Division (SD) and partners will closely work with the vaccine manufacturers to ensure and monitor the fact that 6 million doses of vaccine are always in stock.

The global emergency stockpile will be part of the annual demand for PMVC; therefore, UNICEF SD and vaccine manufacturers will rotate the stocks between the emergency, the vaccine for preventive campaigns and routine EPI stocks. With this revolving concept, there will be no wastage due to expiration of vaccines. To rapidly replenish the stock during long emergencies, of over 3 months, WHO and UNICEF SD will also work with vaccine manufacturers to optimize vaccine supply in 20 dose vials presentation, which could later be used in mass preventive campaigns..

The stockpile forecast will continue to be reviewed on a yearly basis as it is expected that in the context of the EYE strategy the risk of large epidemics will be eliminated, and need for vaccine for emergency response will diminish.

Action 3: Respond immediately

An effective yellow fever outbreak response revolves around rapid detection of cases, reactive vaccination, good case management, vector control and community mobilization.

Strengthened outbreak response capacity can be achieved through:

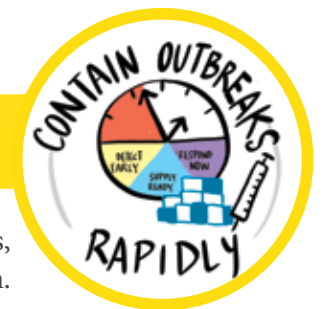
1. Streamlined YF investigation with an emphasis on assessing the risk of spread in relation to transportation hubs and population movements, PI and vector density;
2. Rapid laboratory confirmation and adaptation of the case definitions if needed;
3. Vector control interventions; and
4. Partnership and coordination involving multidisciplinary teams to conduct investigation and response interventions.

Fractional dose

In emergencies, when vaccine supplies are limited, use of a minimum effective dose – one fifth of the normal dose – may be considered. In October 2016, the Strategic Advisory Group of Experts on immunization (SAGE) supported its use as part of an exceptional response in a time when there is a large outbreak and a shortage of vaccine, to protect at-risk populations that would otherwise be left unprotected¹⁶. The minimum effective dose, administered as a fraction of the volume of the normal dose, should induce a protective immune response equivalent to a full dose. Its use in Kinshasa during the 2016 DRC outbreak proved logistically and operationally feasible. Follow-up studies on immunogenicity and vaccine failures will provide further evidence to guide further practice.

Pre-emptive campaigns

Within the context of response to an on-going YF outbreak, public health officers may launch pre-emptive vaccination campaigns in anticipation of imminent epidemic threat in areas that are not affected by YF (i.e., where YF cases have not been confirmed) but face heightened risk and vulnerability, and where population immunity is low. The targeted areas are close to the ones affected by the outbreak and should be chosen according to a local risk assessment: population movement, vector density, surveillance capacity, etc.



¹⁶ Summary of the October 2016 meeting of the Strategic Advisory Group of Experts on immunization (SAGE): http://www.who.int/immunization/sage/meetings/2016/october/SAGE_October_2016_Meeting_Web_summary.pdf?ua=1

Part 6.

Keys to success

The change in risk shows that the need for YF vaccine has increased. However, the EYE will be successful only if demand and supply are aligned to allow a timely and effective risk reduction strategy. This will require the sustained engagement of the various stakeholders as well as robust mechanisms for need forecasting and market shaping.

6.1. Affordable vaccines and sustained vaccine market

Since the inception of the YFI supported by Gavi, YF vaccine supply has improved significantly. In 2001, only two manufacturers were producing WHO-prequalified YF vaccine. This has now increased to four manufacturers: Sanofi Pasteur (France), Institut Pasteur de Dakar (Senegal), Bio-Manguinhos (Brazil), and Chumakov Institute (Russian Federation). Vaccine production capacity has quadrupled from 20 million to 80 million doses annually.

However, vaccine supply has remained one of the major obstacles to implementing mass vaccination campaigns, especially in countries with large targeted populations. Vaccine supplies available for preventive campaigns have been limited to 15 million people per year, and therefore some countries have had to phase their campaigns over two or three years, slowing down the risk reduction strategy.

Global supply outlook 2017–2026

The global supply of YF vaccines is expected to increase to between 105 and 132 million doses in 2017, to between 116 and 159 million doses in 2021, and to between 162 and 183 million doses in 2026.

Production capacity

The market for YF vaccine is not very attractive for manufacturers: it is small compared with that for other vaccines and the profit margin is low, providing little incentive for manufacturers to produce it. Apart from travellers, the vaccine is only used in endemic countries and only one dose is needed. The demand for YF vaccine is also unpredictable and very much driven by outbreaks, another disincentive for vaccine manufacturers. It is not expected that any new manufacturers will begin production in 2017, although production by existing suppliers is expected to increase starting 2017 as one of the manufacturers will be able to increase production through contracting out. Although the global production capacity is expected to rise uncertainty around the expected figures remains.

Reliable production

The YF vaccine production process is technically challenging and prone to unexpected quality or yield issues. It will also remain relatively inflexible to increased demand. In 2017, reliability is expected to improve because all manufacturers have made investments in production equipment and facilities between 2012 and 2016. Over the past five years, actual supply has been significantly lower than theoretical production capacity due to production reliabilities issues as a result supply was 10–20% below demand.

The increased capacity expected during 2017–2020 should be achieved by prioritizing and optimizing YF vaccine production and contracting manufacturer operations for filling and freeze-drying. New production capacity is mainly expected after 2021, when new facilities of two manufacturers will start production.

6.2. Strong political commitment at global, regional and country levels

In countries at greatest risk of YF epidemics, it is essential that leadership is committed to preventing epidemics and embraces the need to establish new synergies by providing local expertise and resources to implement EYE. Campaigns and strategies can only work if country ownership is genuine. Where public health strategies, including vaccination, are successful, it is primarily because local people have worked hard to improve the health of their communities and are committed to improving the nation's health. EYE will only achieve its goal of eliminating epidemics if it is the people in affected countries who “lead the charge” against YF epidemics.

To achieve political commitment and country buy-in, the EYE strategy must include raising awareness at all levels, from the community to national and international leaders and partners. Understanding of the potentially devastating nature of YF epidemics should increase the eagerness of countries and communities to adhere to the opportunity that EYE offers to prevent this once and for all. At regional level, endorsement by political (regional committee) and technical (TAG) bodies will be instrumental to ensure EYE success.

6.3. Robust governance and strong partnerships

The development and the implementation of a YF long-term strategy require the coordination of a number of partners and countries as well as a transparent and effective mechanism for decision-making on tactical and operational issues. This mechanism should be flexible enough to adapt to the evolution of the risk. Through the implementation of EYE, solid governance need be underpinned by appropriate, sustained human resources at central and regional levels.

Based on the existing mechanism in place such as the YF partnership and the lessons learnt and other disease programmes, the EYE strategy brings together the following components:

The **EYE Secretariat** based at WHO (IHM) provides organizational support and ensures a smooth and efficient running of all activities of the leadership group, the program implementation group and the contributing partners. It collects and analyses data to monitor the EYE strategy, and disseminates information and knowledge. The secretariat will have focal points in the regions where yellow fever is present.

Oversight is provided by the **Leadership Group** composed of key high-level members from the core institutions that form the governance of EYE in addition to WHO: UNICEF and Gavi. The Leadership Group provides political and strategic direction to the Programme Management Group, and final decisions' approval. It also engages and identifies partners and donors in high-level discussions related to the strategy.

The technical direction of the EYE strategy is led by the **Programme Management Group**, also formed by members from Gavi, UNICEF and WHO. The Programme Management Group coordinates all activities to ensure timely implementation of the strategy and that goals and objectives are achieved, it provides overall technical guidance and ensures vaccine implementation.

The Programme Management Group is advised by working **groups** and **experts**, and is supported by **implementing and contributing partners** from a wide range of expertise and institutions – such as (but not limited to) those represented in the prior YF partnership¹⁷. The group of EYE partners will be broad enough to provide expertise relevant to the many areas involved (eg, vector surveillance and control, social mobilization, IHR, urban resilience, case management and risk communication), and flexible enough to integrate new partners as needed (e.g. the African Union and private sector partners from the extractive, construction and forestry industries, and the transportation sector). Experts may come from the yellow fever partnership, advisory groups and experts groups such as the Vector Control Advisory Group (VCAG) for vector control and surveillance, or the scientific and technical advisory group on geographical yellow fever risk mapping (GRYF) for IHR. There might also be formal Call for Experts as needs demand.

Articulation of EYE with standing committees such as the regional technical advisory groups (TAG) for Africa and the SAGE and ICG is being designed and coordinated to allow integration, complementary roles, building on existing expertise and forums. The Programme Management Group, in particular, is a strong interface with ICG so that the management of emergency interventions and longer term preventive drives are integrated.

6.4. Synergies with other programmes and sectors

To optimize EYE's efficiency and sustainability, conceptual and practical synergies with existing programmes/initiatives are sought and integration will be prioritized. Linkages can go both ways, and the EYE strategy can serve as a driver to raise awareness and preparedness in urban settings for other outbreak prone diseases.

¹⁷ WHO, Yellow fever vaccine: a global partnership: <http://www.who.int/csr/disease/yellowfev/yfvaccine/en/>

Possible linkages include:

- Resilient cities programs such as steered by the Rockefeller Foundation, which could serve as platforms to develop urban readiness plans.
- Linkages with the private sector and occupational health units, involving companies from the major sectors affected (e.g. the extractive, construction and forestry industries, and the transportation sector) to ensure that at-risk workers and their families are immunized against YF and that facilities and networks exist to diagnose those suspected of being affected.
- Health systems and immunisation strengthening (HSIS) programs, to address discrepancies identified between YF and MCV1 or DTP3, improve overall routine immunization performance and build capacity.
- Vector-borne diseases activities, particularly for diseases involving *Aedes* spp. such as Dengue, Zika, Chikungunya, and possibly West Nile virus: synergies should be furthered regarding vector control activities and research, community engagement/behavioural change, social mobilization strategies for targeted interventions.
- IHR-related activities to enhance consistency between IHR maps and EYE risk assessment, and improve YF vaccination status control at land-border crossing. On this point, useful experience could be gained from the screenings done at informal, land border crossing during the West Africa Ebola outbreak in 2014-2016.
- IDSR: YF symptoms may be unspecific and integration efforts need to ensure that samples from patients presenting with haemorrhage and/or jaundice are tested systematically, even when not specifically mentioned. To this regard, options need be explored to build on the laboratory capacity, infrastructures and extensive networks developed for the polio and HIV programs.

6.5. Research and development for better tools and practices

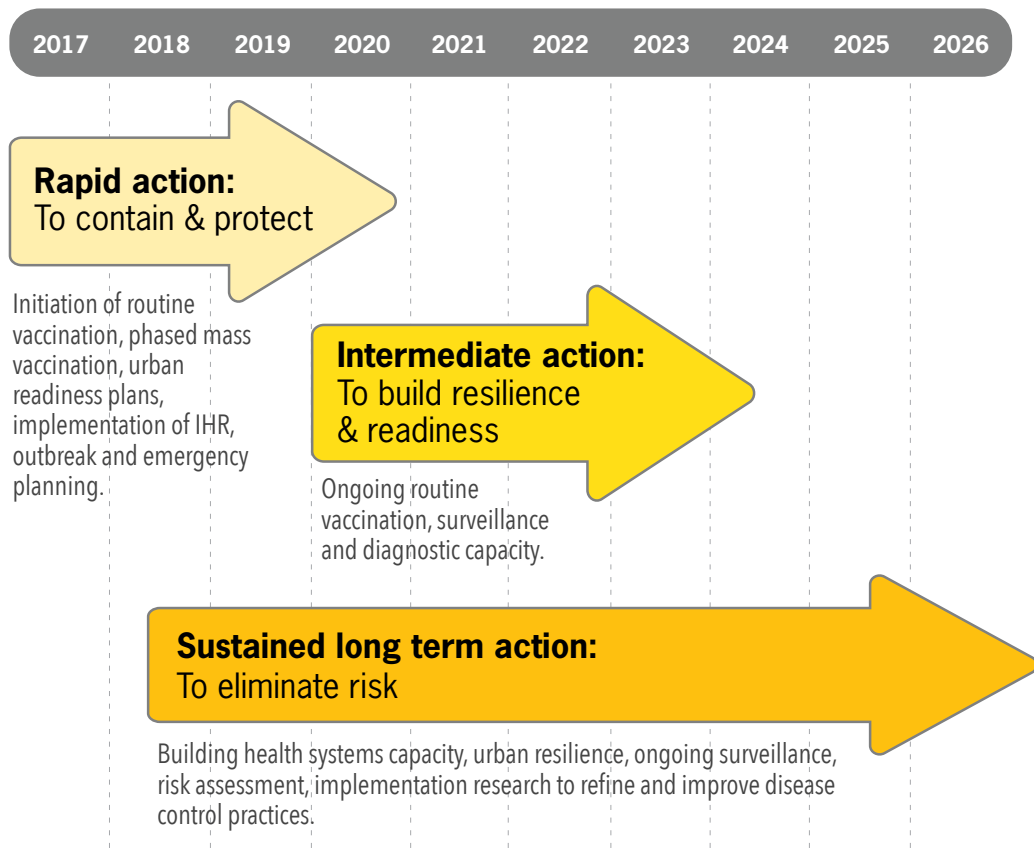
A broad global coalition of experts with stakeholders, including public health agencies (particularly those in affected countries), academia, the biotech sector, industry, regulators, funding agencies and ethics committees will be formed as a specific working group under the umbrella of the governance body. Beside current priority research areas such vaccine, vector control, diagnostic and case management issues, the group will identify public health research priorities and activities. It will also ensure that the identified priorities and activities are considered within initiatives such as the WHO Research & Development Blueprint for Action to Prevent Epidemics or the Coalition for Epidemic Preparedness Innovations (CEPI).

Part 7.

Implementation, monitoring and evaluation







Urgent global action is needed to manage the threat posed by the potential spread of YF into urban areas and internationally to new populations. Whilst the EYE strategy requires sustained implementation over the course of 10 years, the majority of key actions must be initiated and swiftly advanced over the next four years (Figure 6). An initial urgent focus on vaccination strategies, urban readiness, IHR and protecting travellers and migrant workers moving into and out of at-risk areas, will be paired with securing of a vaccine stockpile for emergencies and strengthening of early warning and response systems. Systems and process to ensure long term sustainable global control of Yellow Fever will include strengthened routine vaccination programmes, expanded laboratory diagnostic capacity, improved vector and disease surveillance with effective data collation and information sharing, and implementation research to constantly refine and improve disease control practices.

Figure 6: EYE timeframes for implementation



7.1. Key milestones

The risk of YF transmission and the risk factors which drive it continue to evolve, so the implementation of the EYE strategy will need to be flexible to adapt to an emerging picture, incorporating ongoing risk analysis and reprioritisation, within and between regions, throughout the duration of the strategy.

| | | |
|----------------|---|--|
| By end of 2017 |  | <ul style="list-style-type: none">• EYE governance body is fully operational• The implementation plan including indicators and deliverable is ready• At-risk countries are engaged in the EYE strategy implementation |
| By end of 2018 |  | <ul style="list-style-type: none">• 3 African reference laboratories are fully functional with confirmation |
| By end of 2020 |  | <ul style="list-style-type: none">• All African high-risk countries have introduced the YF vaccine into routine immunization• Campaigns have been completed or are well underway in 3 EYE priority countries (including Nigeria)• 6 African sub regional reference laboratories are fully functional and an EQA/QC is fully functional for both serology and molecular diagnostic procedures |
| By end of 2022 |  | <ul style="list-style-type: none">• At least 50% of the target population of high-risk countries of Africa has been protected through national preventive mass vaccination campaigns |
| By end of 2024 |  | <ul style="list-style-type: none">• All African high-risk countries have diagnostic capacity to detect and confirm YF |
| By end of 2026 |  | <ul style="list-style-type: none">• All high-risk countries have completed national preventive mass vaccination campaigns |

A mid-term evaluation is scheduled for 2021 to assess the progress and draw the way forward.

7.2. Regular updates

Assessing risk and setting priorities

Risk and priorities for implementation of the strategy will be reviewed annually by the EYE leadership group: it is expected that risk of YF epidemics will evolve throughout the 10-year implementation of EYE as a result of a combination of factors reducing risk, such as increased PI, and factors increasing risk, such as major population movements, state collapse, or climate change. As risk changes, immunization activity priorities will need to be adjusted accordingly.

Learning as we go

Experience gained from EYE's development, implementation, monitoring and evaluation at all levels should be recorded, analysed, and made available on a regular basis with support from the EYE Secretariat, to **build knowledge** and serve as a source of inspiration and resources for other programmes and initiatives.

List of EYE Partners

Ms Karine Ammar El Kerdi

Vaccine Programmes Manager
GAVI the Vaccine Alliance
Geneva, Switzerland

Dr Michael Attlan

Senior Director
Endemic and New Technologies
Franchise
Sanofi Pasteur
Lyon, France

Prof Alan Barrett

Director
Sealy Center for Vaccine
Development
University of Texas Medical Branch
(UTMB)
Galveston, United States of America

Dr David Barash

*Executive Director of the Global
Health Portfolio and Chief Medical
Officer*
GE Foundation
Boston, United States of America

Dr Seth Berkley

Chief Executive Officer
GAVI the Vaccine Alliance
Geneva, Switzerland

Mr Hans Christiansen

Contracts Manager
United Nations Children's Fund
(UNICEF)
Supply Division
Copenhagen, Denmark

Mr Michael Clark

Market Shaping Specialist
GAVI the Vaccine Alliance
Geneva, Switzerland

Dr Andrew Clements

Senior Technical Advisor
Global Health Division
United States Agency for International
Development (USAID)
Washington, United States of America

Dr Alfred da Silva

Executive Director
Agence de Médecine Préventive (AMP)
Paris, France

Ms Heather Deehan

Chief of Vaccine Centre
United Nations Children's Fund
(UNICEF)
Supply Division
Copenhagen, Denmark

Dr Victor Del Rio Vilas

Public Health Advisor
School of Veterinary Medicine
University of Surrey
Guildford, United Kingdom

Dr Debora De Oliveira Dos Santos

Bio Manguinhos/Fiocruz
Rio de Janeiro, Brazil

Dr Richard Dewdney

Deputy Director
Africa Regional Department
Department for International
Development (DFID)
London, United Kingdom

Dr Antoine Diatta

Quality Control Manager
Yellow Fever Vaccine Division
Institut Pasteur
Dakar, Senegal

Dr Malick Diara

Public Health Manager
Global Medicine and Occupational
Health Department
ExxonMobil
Houston, United States of America

Ms Emma Diggle

Vaccine and Epidemic Adviser
Save the Children
London, United Kingdom

Ms Claire Esbenschade

*Corporate Responsibility & SRI
Specialist*
ArcelorMittal
London, United Kingdom

Dr Téné-Alima Essoh

Regional Director Africa
Agence de Médecine Préventive
(AMP)
Paris, France

Dr Jeremy Farrar

Director
Wellcome Trust
London, United Kingdom

Prof Niel Ferguson

Head
Department of Infectious Disease
Epidemiology
Imperial College
London, United Kingdom

Dr Maria da Luz Fernandes Leal

Quality Deputy Director
Bio Manguinhos/Fiocruz
Rio de Janeiro, Brazil

Dr Kimberley Fox

Infectious Disease Specialist
Centers for Disease Control and
Prevention (CDC)
Atlanta, United States of America

Ms Lauren Franzel

Senior Specialist of Demand Forecasting
GAVI the Vaccine Alliance
Geneva, Switzerland

Dr Tini Garske

Lecturer in Infectious Disease Analysis
MRC Centre for Outbreak Analysis and
Modelling
Department of Infectious Disease
Epidemiology
Imperial College
London, United Kingdom

Mr Allen Gidraf Kahindo Maina

Public Health Officer
United Nations High Commissioner for
Refugees (UNHCR)
Geneva, Switzerland

Mr Guillermo Gimeno

Contracts Specialist, Vaccine Center
Campaign Vaccines Unit
United Nations Children's Fund
(UNICEF)
Supply Division
Copenhagen, Denmark

Dr Pascale Gonnet

Director
Analytical Project & Technology
Sanofi Pasteur
Lyon, France

Mrs Françoise Griguer

Senior Director
Commercial Global Health
Organizations Accounts
Sanofi Pasteur
Lyon, France

Professor Duane Gubler

Chair
Department of Tropical Medicine
University of Hawaii
Hawaii

List of EYE Partners, cont.

Dr Marie Thérèse Guigui

*Health Specialist for Measles YF
& Health Emergencies (Epidemics)*
United Nations Children's Fund
(UNICEF)
Regional Office for West and Central
Africa
Dakar, Senegal

Ms Jennifer Harris

Health Communication Specialist
Centers for Disease Control and
Prevention (CDC)
Atlanta, United States of America

Dr Trina Helderman

Senior Health Advisor
Medair
Geneva, Switzerland

Dr Myriam Henkens

International Medical Coordinator
Médecins sans Frontières (MSF)
Brussels, Belgium

Mr. Heiko Hering

Senior Public Health Officer
United Nations High Commissioner
for Refugees (UNHCR)
Geneva, Switzerland

Dr Kurt Heuvelmans

Occupational Health Manager
ExxonMobil Petroleum & Chemical
Antwerp, Belgium

Dr Guy Houillon

Medical Director
Sanofi Pasteur
Lyon, France

Dr Terri Hyde

Epidemiologist
Centers for Disease Control and
Prevention (CDC)
Atlanta, United States of America

Ms Manon Jacquot

Mission Permanente de la France
Geneva, Switzerland

Dr Kevin Jean

Research Associate
Imperial College
London, United Kingdom

Dr Hope Johnson

Director
Monitoring & Evaluation
GAVI the Vaccine Alliance
Geneva, Switzerland

Dr Marc Jouan

International Director
Institut Pasteur
Paris, France

Ms Sviatlana Kavaliova

Procurement Specialist
United Nations Development
Programme (UNDP)
New York, United States of America

Dr Robert Kezaala

Head
Measles and Rubella Programme
United Nations Children's Fund
(UNICEF)
Programme Division
New York, United States of America

Dr Nadia Khelef

Senior Advisor for Global Affairs
Institut Pasteur
Paris, France

Ms Ekaterina Korduban

Deputy Director on Business
Federal State Budgetary Scientific
Institution (FSBSI)
Chumakov Federal Scientific Center for
Research & Development of Immune-
and-Biological Products Russian
Academy of Medical Sciences
Moscow, Russia

Mr Jason Lane

Senior Health Advisor
Department for International
Development (DFID)
London, United Kingdom

Ms Laura Laughlin

*Head, Multilateral Organisations and
Executive Engagement*
Sanofi Pasteur
Paris, France

Ms Meng Li

Director of International Cooperation
China National Biotech Group
Beijing, China

Mr Matthew Lim

Deputy Head Attaché
U.S. Mission to the United Nations
& International Organisations in
Geneva
Geneva, Switzerland

Dr Marlo Libel

Senior Advisor
Skoll Global Threats Fund
San Francisco,
United States of America

Ms Denise Maria Lobo Crivelli

*New Business & Marketing Division
Manager*
Bio Manguinhos / Fiocruz
Rio de Janeiro, Brazil

Ms Tina Lorenson

Programme Officer
Bill & Melinda Gates Foundation
Seattle, United States of America

Dr Ricardo Lourenço de Oliveira

Researcher
Fiocruz
Rio de Janeiro, Brazil

Ms Melissa Malhame

Head of Market Shaping
GAVI the Vaccine Alliance
Geneva, Switzerland

Mr Andrew Malkin

Quality Manager
Federal State Budgetary Scientific
Institution (FSBSI)
Chumakov Federal Scientific Center for
Research & Development of Immune-
and-Biological Products Russian
Academy of Medical Sciences
Moscow, Russia

Ms Amanda McLelland

Senior Officer
International Federation of Red Cross
and Red Crescent Societies (IFRC)
Geneva, Switzerland

Dr James Meegan

Director, Office of Global Research
National Institutes of Health (NIH)
Bethesda, United States of America

Dr Reinaldo de Menezes Martins

Scientific Consultant
Bio-Manguinhos
Rio de Janeiro, Brazil

Mr Wilson Mok

Strategy Specialist
GAVI the Vaccine Alliance
Geneva, Switzerland

Dr Thomas Monath

Chief Operating Officer (COO)
BioProtection Systems/NewLikh
Genetics Corp.
Devens, United States of America

Ms Lyn Morgan

Senior Director, Public Affairs
Sanofi Pasteur
Lyon, France

List of EYE Partners, cont.

Ms Patience Musanhu

Senior Programme Manager
GAVI the Vaccine Alliance
Geneva, Switzerland

Dr Robin Nandy

Principal Advisor & Chief of Immunizations
United Nations Children's Fund (UNICEF)
Programme Division
New York, United States of America

Prof Matthias Niedrig

Virology Professor
Robert Koch-Institut
Berlin, Germany

Ms Rebecca Nuun

Health Advisor
Department for International Development (DFID)
London, United Kingdom

Ms Sandra Perion

Director, Product Planning Leader
Sanofi Pasteur
Lyon, France

Ms Cassandra Quintanilla

Programme Manager
GAVI the Vaccine alliance
Geneva, Switzerland

Prof Helen Rees

Chair
Regional Immunization Technical Advisory Group (RITAG)
Johannesburg
South Africa

Dr George A. Robertson

Senior Technical Advisor, Manufacturing and Quality
PATH – Center for Vaccine Innovation and Access
Washington, United States of America

Dr Cathy Roth

Senior Research Fellow
Department for International Development (DFID)
London, United Kingdom

Dr Nathalie Robineau

Director, Production of Yellow Fever vaccine unit
Institut Pasteur
Dakar, Senegal

Dr. Yodit Sahlemariam Yeshineh

Health Specialist
United Nations Children's Fund (UNICEF)
Programme Division
New York, United States of America

Dr Amadou Sall

Director
Institut Pasteur
Dakar, Senegal

Dr Thomas Scott

Director
Mosquito Research Laboratory
Department of Entomology
University of California
Oakland, United States of America

Dr Joy Shumake-Guillemot

Officer-in-Charge
World Meteorological Organization (WMO)
Geneva, Switzerland

Prof Claire-Anne Siegrist

Head
Vaccinology and Immunology Unit
University Hospitals
Geneva, Switzerland

Ms Alexandra Sinyugina

Deputy Director on Production
Federal State Budgetary Scientific
Institution (FSBSI)
Chumakov Federal Scientific Center for
Research & Development of Immune-
and-Biological Products Russian
Academy of Medical Sciences
Moscow, Russia

Dr Stephen Sosler

Immunization Technical Advisor
GAVI the Vaccine Alliance
Geneva, Switzerland

Dr J. Erin Staples

Medical Epidemiologist
United States Centers for Disease
Control and Prevention (US CDC)
Fort Collins, United States of America

Dr Philippe Stoeckel

Chairman of the Board
Agence de Médecine Préventive (AMP)
Paris, France

Mr Dudley Tarlton

Programme Specialist
Bureau Policy and Programme Support
United Nations Development
Programme (UNDP)
Geneva, Switzerland

Mr Michael Thomas

Director, Vaccine Implementation
GAVI the Vaccine Alliance
Geneva, Switzerland

Dr João Toledo

Advisor, Surveillance Secretariat
Ministry of Health
Brasilia
Brazil

Prof Oyewale Tomori

President
Nigerian Academy of Science
Lagos, Nigeria

Dr Michel Van Herp

Medical Epidemiologist
Médecins Sans Frontières (MSF)
Brussels
Belgium

Prof Pedro Fernando da Costa Vasconcelos

Head
National Institute of Science and Technology
for Viral Hemorrhagic Fevers
Instituto Evandro Chagas (IEC)
Ananindeua, Brazil

Dr Kathleen Victoir

General Secretary of Scientific Programmes
Department of International Affairs
Institut Pasteur
Paris, France

Dr Douglas Webb

Team Leader
Health and Innovative Financing at the HIV
Health and Development Group
United Nations Development Programme
(UNDP)
Geneva, Switzerland

Dr Charlie Weller

Departmental Coordinator
DRI & Vaccines
Wellcome Trust
London, United Kingdom

Mr Greg Widmyer

Deputy Director
Vaccine Delivery
Bill & Melinda Gates Foundation
Seattle, United States of America

List of EYE Partners, cont.

Dr Teresa Zakaria

*Migration Health Emergency
Operations Officer*
International Organization for
Migration (IOM)
Geneva, Switzerland

Dr Hervé Zeller

*Head of Emerging and Vector-borne
Diseases Programme*
European Centre for Disease
Prevention and Control (ECDC)
Solna, Sweden

**WHO Regional and Country
Offices**

Dr Sylvain Aldighieri

Unit Chief
Infectious Hazard Management
AMRO/PAHO

Dr Annick Dosseh

Technical Officer
Immunization and Vaccine
Development (AF/RGO/FRH/IVD)
AFRO

Dr Ibrahima-Soce Fall

Director
Health Emergencies programme (AF/
RGO/WHE)
AFRO

Dr John Fitzsimmons

Chief
Revolving Fund Special Programme
for Vaccine Procurement (RFV)
AMRO/PAHO

Dr Yohannes Ghebrat

National Professional Officer
Technical Units
(AF/ACO/SSR/ERI/ER3)
Country Office Eritrea
AFRO

Dr Mamoudou Harouna Djingarey

*Epidemiologist Infectious Diseases and
Nutrition*
Infectious Hazard Management
(AF/RGO/WHE/IHM)
AFRO

Dr Mamunur Malik

Manager
Infectious Hazard Management
(EM/RGO/WHE/IHM)
EMRO

Dr Jairo Mendez Rico

Advisor
Viral Diseases
AMRO/PAHO

Dr Richard Mihigo

Medical Officer
Family and Reproductive Health
(AF/RGO/FRH/FRU)
AFRO

Dr Vital Mondonge Makuma

National Professional Officer
Technical Units
(AF/ACO/SRC/COD/CD3)
Country Office Democratic Republic
of the Congo
AFRO

Ms Alba Maria Ropero Alvarez

Advisor
Immunization
AMRO/PAHO

Dr Cuauhtemoc Ruiz Matus

Unit Chief
Comprehensive Family Immunization
AMRO/PAHO

Dr Mary Stephen

Technical Officer
Country Health Emergency
Preparedness & IHR
(AF/RGO/WHE/CPI)
AFRO

Dr Ambrose Talisuna

Health Security Advisor
Country Health Emergency
Preparedness & IHR
(AF/RGO/WHE/CPI)
AFRO

Dr Nadia Abd El-Aziz Teleb Badr

Regional Adviser
Vaccine Preventable Diseases &
Immunization (EM/RGO/DCD/VPI)
EMRO

WHO Headquarters

Dr Sophie Allain Ioos

Technical Officer
Detection, Verification
& Risk Assessment
(HQ/WHE/HIM)

Dr Lidia Alexandrova Ezerska

Technical Officer
Detection, Verification & Risk
Assessment
(HQ/WHE/HIM)

Dr Kaushik Banerjee

Medical Officer
Expanded Programme on
Immunization Plus
(HQ/FWC/IVB/EPI)

Dr Mathieu Bangert

Technical Officer
Control of Neglected Tropical Diseases
(HQ/CDS/NTD)

Dr Philippe Barboza

Manager
Detection, Verification & Risk
Assessment
(HQ/WHE/HIM)

Dr Justus Benzler

Consultant
High Threat Pathogens
(HQ/WHE/IHM/PAT)

Ms Viviane Bianco

Consultant
Infectious Hazard Management
(HQ/WHE/IHM)

Dr Sylvie Briand

Director
Infectious Hazard Management
(HQ/WHE/IHM)

Dr Laurence Cibrelus Yamamoto

Technical Officer
High Threat Pathogens
(HQ/WHE/IHM/PAT)

Dr Tania Cernuschi

Manager
Expanded Programme on Immunization
Plus (HQ/FWC/IVB/EPI)

Dr Diana Chang Blanc

Manager
Expanded Programme on Immunization
Plus (HQ/FWC/IVB/EPI)

Dr Thomas Cherian

Coordinator
Expanded Programme on Immunization
Plus
(HQ/FWC/IVB/EPI)

Dr Sebastien Cognat

Team Leader
Preparedness, Readiness & Core
Capacity Building
(HQ/WHE/CPI/PCB)

Dr Alejandro Costa

Scientist
Experts Networks & Interventions (HQ/
WHE/IHM/ENI)

List of EYE Partners, cont.

Dr Carmen Dolea

Medical Officer
IHR Global Functions
(HQ/WHE/IHR)

Ms Kara Durski

Technical Officer
High Threat Pathogens
(HQ/WHE/IHM/PAT)

Mr Patrick Drury

Manager
Operational Partnerships
(HQ/WHE/EMO/OPR)

Dr Florence Fouque

Unit Leader
Vectors, Environment & Society
(HQ/CDS/TDR/VES)

Ms Erika Garcia

Technical Officer
High Threat Pathogens
(HQ/WHE/IHM/PAT)

Dr Gaya Gamhewage

Manager
Experts Networks & Interventions
(HQ/WHE/IHM/ENI)

Mrs Sandra Garnier

Technical Officer
Infectious Hazard Management
(HQ/WHE/IHM)

Ms Tracey Goodman

Manager, Immunization Policies and Strategies
Expanded Programme on
Immunization Plus (HQ/FWC/IVB/
EPI)

Dr Joachim Hombach

Senior Health Adviser
Immunization, Vaccines and
Biologicals (HQ/FWC/IVB)

Ms Lingaw Kalinde Mangachi

Resource Mobilization Officer
Resource Mobilization
(HQ/WHE/EXR/RMB)

Ms Marianne Kargbo

Resource Mobilization Officer
Resource Mobilization
(HQ/WHE/EXR/RMB)

Dr Asheena Khalakdina

Technical Officer
High Threat Pathogens
(WHE/IHM/PAT)

Dr Tessa Knox

Technical Officer
Entomology & Vector Control
(HQ/CDS/GMP/EVC)

Dr Philipp Lambach

Medical Officer
Initiative for Vaccine Research
(HQ/FWC/IVB/IVR)

Ms Margaux Mathis

Technical Officer
Infectious Hazard Management
(HQ/WHE/IHM)

Mr Daniel Lins Menucci

Team Leader
Preparedness, Readiness & Core
Capacity Building
(HQ/WHE/CPI/PCB)

Ms Anne Menthon

Assistant
High Threat Pathogens
(HQ/WHE/IHM/ENI)

Ms Véronique Millot

Assistant
High Threat Pathogens
(HQ/WHE/IHM/PAT)

Ms Sylvie Mortier

Assistant

Infectious Hazard Management
(HQ/WHE/IHM)

Dr Miguel Mulders

Scientist

Expanded Programme on
Immunization Plus
(HQ/FWC/IVB/EPI)

Dr Bernadette Murgue

Project Manager

WHO RnD Blueprint
(HQ/IVB)

Ms Damari Naidoo

Technical Officer

Experts Networks & Interventions
(HQ/WHE/IHM/ENI)

Dr Kyohei Nishino

Technical Officer

High Threat Pathogens
(HQ/WHE/IHM/PAT)

Mr Tim Nguyen

Team leader

Experts Networks & Interventions
(HQ/WHE/IHM/ENI)

Dr Jean-Marie Okwo-Bele

Director

Immunization, Vaccines and
Biologicals
(HQ/FWC/IVB)

Dr William Perea

Manager

Epidemic in Vulnerable Settings
(HQ/WHE/IHM/EVS)

Ms Corinne Ponce

Technical Officer

IHR Global Functions
(HQ/WHE/IHR)

Dr Marie-Pierre Preziosi

Medical Officer

Initiative for Vaccine Research
(HQ/FWC/IVB/IVR)

Dr Olivier Ronveaux

Medical officer

Epidemic in Vulnerable Settings
(HQ/WHE/IHM/EVS)

Ms Shalini Singaravelu

Consultant

High Threat Pathogens
(HQ/WHE/IHM/PAT)

Dr Nahoko Shindo

Manager

Experts Networks & Interventions
(HQ/WHE/IHM/ENI)

Ms Anastasia Smirnova

Technical Officer

Detection, Verification
& Risk Assessment
(HQ/WHE/HIM)

Dr Raman Velayudhan

Coordinator

Vector and Ecology Management
(HQ/CDS/NTD/VEM)

Dr Sergio Yactayo

Team Leader

High Threat Pathogens
(HQ/WHE/IHM/PAT)



Group photo from the September 2016 EYE partners meeting



World Health Organization
20 Avenue Appia
1211 Geneva 27 - Switzerland

For further information
www.who.int/csr/disease/yellowfev/eye-strategy/en/



ISBN 978-92-4-151366-1

