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China–Africa Cooperation Initiatives in Malaria Control and Elimination

Zhi-Gui Xia¹, Ru-Bo Wang¹, Duo-Quan Wang¹, Jun Feng¹, Qi Zheng¹, Chang-Sheng Deng², Salim Abdulla³, Ya-Yi Guan¹, Wei Ding¹, Jia-Wen Yao¹, Ying-Jun Qian¹, Andrea Bosman⁴, Robert David Newman⁴, Tambo Ernest⁵, Michael O’leary⁶, Ning Xiao^{1,*}

¹National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention; Key Laboratory of Parasite and Vector Biology, MOH; WHO Collaborating Centre for Malaria, Schistosomiasis and Filariasis; Shanghai, People’s Republic of China

²Guangzhou University of Traditional Chinese Medicine, Guangdong, People’s Republic of China

³Ifakara Health Institute, Dar es Salaam, Tanzania

⁴Global Malaria Programme, World Health Organization, Geneva, Switzerland

⁵Centre for Sustainable Malaria Control, Faculty of Natural and Environmental Science; Center for Sustainable Malaria Control, Biochemistry Department, Faculty of Natural and Agricultural Sciences, University of Pretoria, Pretoria, South Africa

⁶World Health Organization, China Representative Office, Beijing, People’s Republic of China

*Corresponding author: E-mail: ningxiao116@126.com

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Abstract

Malaria has affected human health globally with a significant burden of disease, and also has impeded social and economic development in the areas where it is present. In Africa, many countries have faced serious challenges in controlling malaria, in part due to major limitations in public health systems and primary health care infrastructure. Although China is a developing country, a set of control strategies and measures in different local settings have been implemented successfully by the National Malaria Control Programme over the last 60 years, with a low cost of investment. It is expected that Chinese experience may benefit malaria control in Africa. This review will address the importance and possibility of China–Africa collaboration in control of malaria in targeted African countries, as well as how to proceed toward the goal of elimination where this is technically feasible.



1. BACKGROUND

Malaria, one of the most important human parasitic diseases globally, has a significant impact on not only the health of affected populations, but also the social and economic development of the areas where it is present (Guinovart et al., 2006). In Africa, many countries have faced severe challenges in controlling malaria, in part due to major limitations in public health systems and poor infrastructure. According to the *World Malaria Report 2013* published by the World Health Organization (WHO), in 2012, there were an estimated 207 million cases of malaria (uncertainty interval 135–287 million), which caused approximately 627,000 deaths (uncertainty interval 473,000–789,000). An estimated 3.4 billion people continue to be at risk of malaria, mostly in Africa and southeast Asia. Approximately 80% of malaria cases and 90% of malaria deaths occurred in Africa (WHO, 2013).

Malaria once affected the social, economic and political development in the People's Republic of China (P.R. China). According to the statistics, more than 30 million malaria cases were recorded annually during the 1940s and the mortality rate was about 1%. After the establishment of P.R. China in 1949, the government invested significant resources in the control of malaria which was listed as one of the five top parasitic diseases in the country. The reduction of malaria leading to its elimination in P.R. China, the evidence-based prevention strategies, and related malaria prevention and control policies have been synthesised for the National Malaria Control Programmes (NMCPs). As a result, a network of scientific research and surveillance has been established, thousands of professional technical teams have been trained, and the coordination of malaria control within specific zones has been created for the past six decades. Through these

interventions, a remarkable achievement of the NMCPs has taken place since the early 1950s. From the 1970s to the 1990s, the annual number of malaria cases significantly declined from 2.4 million to tens of thousands, the endemic regions were sharply shrunk, and falciparum malaria has been eliminated in all regions except for Yunnan and Hainan provinces. By 2009, the national number of malaria cases had been reduced to 14,000. Among 24 malaria-endemic provinces, the malaria incidence in 95% of the counties has dropped below 1 per 10,000 population with only 87 counties over 1 per 10,000. The data indicate that P.R. China has transitioned from malaria control phase to elimination phase (Tang, 1999; Tang, 2009).

To effectively improve public health, promote economic development, achieve the health-related Millennium Development Goals (MDG), and contribute to the ultimate global goal of malaria eradication (Butler, 2012; Bhutta et al., 2014), the Chinese government embarked upon the National Malaria Elimination Action Plan in 2010, with a goal of eliminating malaria by 2015 in a majority of regions with the exception of the border region in Yunnan province, and to completely eliminate malaria from P.R. China by 2020 (National Health and Family Planning Commission of P.R. China, 2009). In the implementation of this action plan from 2010 to 2012, the total number of malaria cases was reduced from about 8,000 to about 2,700. The number of local cases has been reduced significantly to less than 200 annually in the country, and locally transmitted falciparum malaria has not been reported in Hainan Province since 2010 (Yin et al., 2013).

A set of control strategies and measures for NMCPs in different local settings has been implemented successfully over the last 60 years in P.R. China. This experience has included collaboration between China and Africa in the field of malaria control, in the larger context of China's contribution to development in Africa as a major trading and investment partner. In July 2012, the WHO Director-General Dr. Margaret Chan emphasised the importance of health cooperation between Africa and China during her visit to P.R. China, and the Chinese leader of the central government gave a positive response. In early 2013, the government of P.R. China has promised to continue increasing its investment in Africa, which includes medical assistance as well as promotion of sustainable development (Wang, 2013). Recently, the National Health and Family Planning Commission (previously Ministry of Health) and the Ministry of Commerce of P.R. China have proposed to provide technical support for malaria control and elimination in Africa, which would further promote South–South cooperation through mutual exchanges in the field of malaria control and elimination.

The cooperation between China and Africa will not only strengthen China's capacity in engagement in global health, but will also provide a platform to share health products (e.g. quality control in production and delivery of antimalarial drugs), techniques (e.g. diagnostics) and intervention strategies. Based on multilateral communication, P.R. China intends to develop malaria prevention and control projects in several African countries together with international experts working in Africa. As one component of China–Africa health collaboration, this review will address the importance and possibility to strengthen the control of malaria in targeted Africa countries, as well as to proceed toward the goal of elimination where technically feasible.



2. EXISTING CHINA–AFRICA COLLABORATION ON MALARIA CONTROL

Fifty years ago, multilateral and bilateral medical collaboration between China and Africa was limited. However, over the years, an amicable relationship has developed between China and countries in Africa in the areas of medicine and health. During the 50 years since the government sent the first medical-aid team to Africa in 1963, P.R. China has sent about 20,000 medical doctors to 51 African countries, which has sustained a longstanding friendship with Africa (Zuo, 2013). China–Africa medical and health cooperation including in the area of malaria has grown through sending medical teams, training programmes, donations of medicines and medical equipment, joint research and academic exchanges.

In the competitive setting of global pharmaceutical production and distribution, some of China's enterprises have been successful in the process of pharmaceutical sale registration in dozens of countries in Africa, which provides an opportunity for Chinese-produced medicines to be used in the African market. The donation of antimalarial medicines, diagnostic kits and equipment, and the provision of experts and on-site training have demonstrated the increasing commitment on the part of the Chinese government to the malaria control and elimination programme in Africa. An outstanding example was Chinese government support in building antimalaria centres in 30 African countries and donating antimalarial medicines through bilateral cooperation since 2006 (Annex 1). Antimalaria centres have played not only a role in diagnosis and treatment, but also have contributed to communication and capacity building, including improvement of capacity in local medical research and treatment.

Experiences with the malaria control centres are variable, e.g. some have been successful, while others are faced with the challenges of financing and the lack of local contribution. Another successful example was in Comoros, where a pilot malaria elimination programme had achieved a significant reduction in malaria transmission with the support of China ([Chinese Medical Cooperation in Africa, 2011](#)).

The P.R. China has also provided academic exchanges and training programmes for African officials and technical personnel each year during the last 10 years. The National Institute of Parasitic Diseases (NIPD) of Chinese Center for Disease Control and Prevention (CDC) launched five training workshops over the last three years such as ‘Infectious diseases prevention and control’ and ‘Prevention and control of malaria and schistosomiasis in developing counties’. More than 150 technical staff members and officials from more than 20 African countries have been trained in P.R. China in strategies and measures for malaria prevention and control.

Recently, more institutions in P.R. China have strengthened cooperation with various international agencies and foundations (e.g. the Bill and Melinda Gates Foundation; WHO; the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM); Canada’s International Development Research Centre; the Department for International Development of the United Kingdom) under multilateral or bilateral mechanisms, which have provided more opportunities to explore new ways of control and prevention of malaria. Building on these experiences and the renewed interest provided by the Forum for China–Africa Cooperation, there are further opportunities to strengthen the China–Africa cooperation in malaria control and elimination through multilateral partnerships, supported by national and international agencies.



3. THE CHALLENGES AND NEEDS FOR MALARIA CONTROL IN AFRICA

3.1 Epidemiology of malaria

According to the *World Malaria Report 2013* ([WHO, 2013](#)), approximately 80% of malaria deaths in 2012 were estimated to occur in just 17 countries, about 80% of cases in 18 countries, and most of them in Africa. The Democratic Republic of the Congo and Nigeria together accounted for 40% of the global total of estimated malaria deaths and 32% of cases. International targets for reducing cases and deaths will not be attained unless considerable progress can be made in these countries.

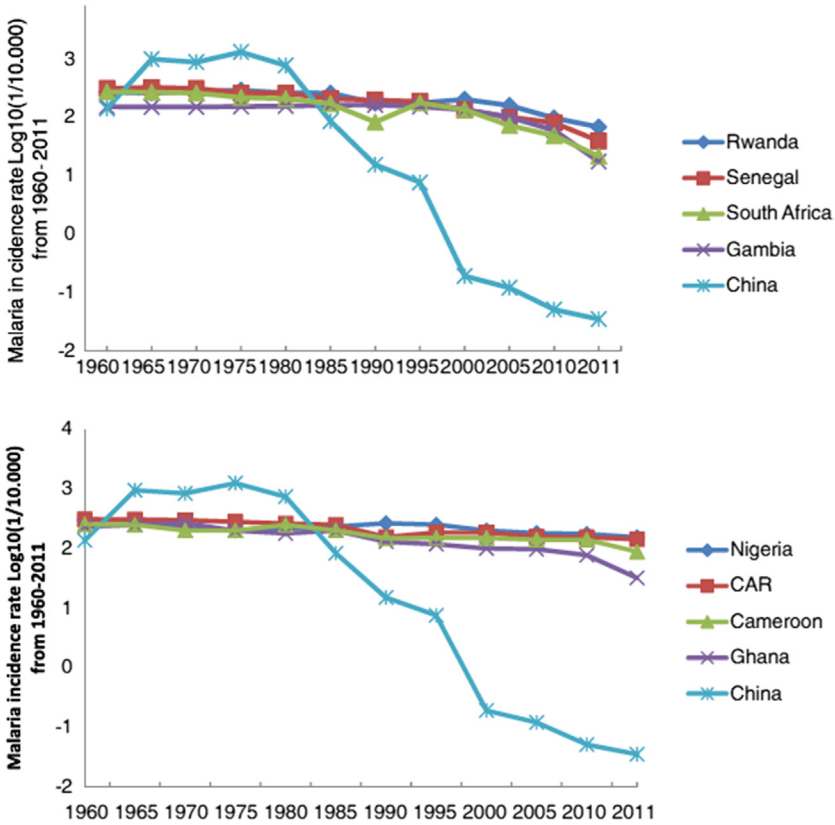


Figure 12.1 Trend in malaria incidence rate Log₁₀(1/10,000) in selected African countries and P.R. China from 1960 to 2011. (1) Substantial scaling-up impact on malaria incidence in P.R. China and some African countries. (2) Scaling-up impact on malaria incidence in P.R. China and low/moderate outcomes in some African countries (Tambo et al., 2012).

When analysing the trends in malaria events from 1960 to 2011, highlighting the achievements, progress and challenges in research for moving malaria from epidemic status towards elimination in both sub-Saharan Africa and P.R. China, it was found that the gap in malaria incidence between selected African countries and China will widen in the absence of enhanced intervention in Africa (Figure 12.1). Political commitment and financial investment of stakeholders in sustaining the scaling-up impact of malaria control interventions, and networking between African and Chinese scientists and their Western partners, are urgently needed to uphold the recent gains, and to translate lessons learnt from the Chinese malaria control achievements and successes into practical interventions in malaria endemic countries in Africa and elsewhere (Tambo et al., 2012).

3.2 Malaria control and elimination

According to the *World Malaria Report 2013* (WHO, 2013), of 43 countries in the African Region with ongoing malaria transmission, eight countries (Botswana, Cabo Verde, Eritrea, Namibia, Rwanda, Sao Tome and Principe, South Africa and Swaziland) and the island of Zanzibar (United Republic of Tanzania) are on track to achieve reductions in reported malaria case incidence or malaria admission rates of 75% or more. A further two countries (Ethiopia and Zambia) are projected to achieve reductions in malaria admission rates of 50–75% by 2015, and one country (Madagascar) by <50%. An increase in locally acquired cases, from 35 in 2000 to 59 in 2012, was reported from Algeria. Cabo Verde is in the pre-elimination phase, and continues to progress towards eliminating malaria. Algeria is in the elimination phase. Both Algeria and Cabo Verde implement active case detection, case investigation and a quality assurance (QA) system for diagnostic testing guided by a national reference laboratory; they also provide treatment with primaquine for the radical cure of *P. vivax* and clearance of gametocytes in *P. falciparum* infections. Eight countries in southern Africa are signatories to the elimination eight (E8) regional initiative launched in March 2009, a goal of which is to achieve the eventual elimination of malaria in the region, with elimination in four countries (Botswana, Namibia, South Africa and Swaziland) by 2015. With continued investments in malaria control, it is expected that these countries will continue to progress towards elimination, although they do not yet meet the case management and surveillance criteria to be classified as being in the pre-elimination phase.

3.3 Malaria programmes

Many Africa countries have developed strategic plans for malaria control and elimination, and WHO has developed technical guidance and support tools for planning and programme reviews. NMCPs in Africa have received major support from the international community over the past decade, primarily from the GFATM, the U.S. President's Malaria Initiative, US Agency for International Development, the United Kingdom of Great Britain and Northern Ireland's Department for International Development and the World Bank, allowing for a rapid scaling-up of lifesaving malaria prevention and control interventions. This core support has been supplemented with additional assistance from a number of foundations, as well as bilateral and multilateral partners (WHO, 2013).

To support countries in their efforts to achieve the health-related MDG indecies and other global targets as the 2015 MDG deadline nears, WHO in 2012, along with the Roll Back Malaria (RBM) and other partners,

launched a malaria situation room (MSR) to provide focused strategic support to 10 high-burden countries in sub-Saharan Africa, namely Burkina Faso, Cameroon, Côte d'Ivoire, the Democratic Republic of the Congo, Ghana, Mozambique, Niger, Nigeria, Uganda and the United Republic of Tanzania. The MSR experts collated and synthesised malaria-related information on financial flows, commodities, intervention coverage and disease trends; track challenges and progress; and identify bottlenecks that hinder country scale-up of malaria control interventions (Zofou, et al., 2014). Relevant partners are then approached to help resolve the problems identified, and progress in bottleneck resolution is monitored (WHO, 2013).

3.4 Challenges and gaps

There are several reasons why Africa bears an overwhelming proportion of the malaria burden. Most malaria infections in Africa south of the Sahara are caused by *P. falciparum*, the most severe and life-threatening form of the disease. This region is also home to the most efficient, and therefore deadly, species of mosquitoes that transmit the disease. Moreover, in many African countries, especially in rural areas, poor infrastructure, substandard sanitation, and lack of funding for vector control, diagnostic testing and treatment remain challenges (Agomo et al., 2013; Butler, 2012). Many countries lacked the infrastructure and resources necessary to mount sustainable campaigns against malaria; as a result, few benefited from historical efforts to eradicate malaria. In Africa, malaria is understood to be both a disease of poverty and a cause of poverty (Ajayi, et al., 2013; Bi & Tong, 2014). Annual economic growth in countries with high malaria transmission has historically been lower than in countries without malaria. Malaria also has a direct impact on Africa's human resources. Not only does malaria result in lost life and lost productivity due to illness and premature death, but malaria also hampers children's schooling and social development through both absenteeism and permanent neurological and other damage associated with severe episodes of the disease (Malaria in Africa; Chima et al., 2003).

The current funding gap is affecting campaigns for long-lasting insecticidal nets (LLIN), and there is a risk of malaria resurgence in several Africa countries; moreover, there are major needs to improve surveillance as well as access to diagnostic tests and treatment which are influenced by certain factors (Aidoo, 2013; Hill et al., 2013; Noor et al., 2007; Pell et al., 2011). According to the *World Malaria Report 2013* (WHO, 2013), an assessment of trends was not possible in 32 countries in Africa owing to insufficiently consistent data, and the scale-up of diagnostic testing through

rapid diagnostic tests (RDTs) and microscopy remains incomplete in the public sector and to an even greater extent in the private sector. In 17 countries of Western Africa, the proportion of the population with access to an insecticide-treated mosquito net (ITN) within their household was estimated to exceed 50% in 10 countries, the use of indoor residual spraying (IRS) has increased but coverage remains relatively low, and only seven countries reported delivering sufficient antimalarial medicines to treat all patients attending public health facilities. In 10 countries of Central Africa, the recent increase in malaria cases and admissions in Sao Tome and Principe may be related to brief disruptions to spraying activities and supply of artemisinin-based combination therapy (ACTs); the proportion of the population with access to an ITN within their household was estimated to exceed 50% in five countries; and Angola and Burundi reported delivery of sufficient ACTs to treat >50% patients attending the public health facilities. In 11 countries of eastern and southern Africa, the proportion of the population with access to an ITN in their household was estimated to exceed 50% in nine countries; only Mozambique distributed insufficient ACTs to treat all patients attending public health facilities. In five low-transmission southern Africa countries, the number of people with access to an ITN in their household was estimated to exceed 50% in three countries. IRS is the primary vector control measure in South Africa, and South Africa and Swaziland reported inadequate access to antimalarial medicines.

At present, drug resistance has become a priority issue in malaria control in Africa (Sa et al., 2011; Sridaran et al., 2010). Chloroquine-resistance occurs in all of Africa (Frosch et al., 2011), and there is widespread resistance to sulfadoxine-pyrimethamine (Ako et al., 2012). Artemisinin-based drugs in Africa have played a role in malaria treatment and almost all malaria-endemic countries in Africa have changed their policies to adopt ACTs for the treatment of *P. falciparum* malaria (WHO, 2013). Unfortunately, many populations of Africa apply local traditional medicines to meet their primary health care needs with no systematic generation of safety and efficacy data through clinical and pharmacological studies, nor quality control data to support formal registrations and use for treatment and control of malaria (Addae-Mensah et al., 2011). Moreover, countries in sub-Saharan Africa are of significant concern due to the high levels of malaria transmission and widespread reports of insecticide resistance (WHO, 2012a).

From the perceptions and viewpoints on proceedings of the Africa Leaders Malaria Alliance, Africa governments should address the following critical challenges:

1. Securing adequate domestic and external funding for sustained commitment to malaria elimination;
2. Strengthening national malaria control programmes in the context of strengthening the broader health system;
3. Ensuring free access to malaria diagnosis and treatment for vulnerable groups such as children and pregnant women, in addition to universal access to long-lasting insecticide-treated nets;
4. Strengthening human resource capacity at central, district, and community levels; and
5. Establishing strong logistics, information and surveillance systems as well as early detection mechanisms for response to malaria epidemics and other public health threats (Sambo et al., 2011).

On 6–7 May 2013, the Fourth International Roundtable on China–Africa Health Cooperation was held in Gaborone, Botswana to explore new opportunities to strengthen an innovative partnership between China and Africa to cooperate on health issues. The roundtable brought African and Chinese leaders together to share experiences, discuss progress and lessons learned, and to make recommendations on how China–Africa health cooperation could be strengthened. During this roundtable, the major challenges of malaria control and elimination in Africa were identified as follows:

1. Poor infrastructure and substandard health services and coverage;
2. Poor distribution and access to diagnostic services and effective treatment;
3. Limited funding for vector control, diagnostic testing, treatment and surveillance;
4. Cross-border malaria control;
5. Threat of drug and insecticide resistance; and
6. The vicious cycle of poverty and malaria.



4. POTENTIAL OPPORTUNITY AND CONTRIBUTION TO ENHANCE THE PARTNERSHIP

Based on the aforementioned challenges and gaps, the opportunities for scaling-up Chinese involvement in malaria control in Africa may include but not limited to the following:

1. Funding for equipment and essential health commodities;
2. Extending the scope of China medical teams;
3. Training, provided language barriers can be overcome;
4. Collaborative research, also including traditional medicines;

5. Technology transfer for production of pharmaceutical products;
6. Health systems strengthening (laboratory services and IT networks); and
7. Building information system and surveillance systems.

For an accelerated and sustainable impact on malaria control and elimination in Africa, China–Africa cooperation efforts in malaria should be aligned with sound, evidence-based, and costed local strategic plans for malaria control and elimination, with a focus on identifying needs, filling gaps and leveraging all national, bilateral and multilateral as well as private sector opportunities. The P.R. China has accumulated experience, which could be shared with countries in Africa, in developing health policy leading to successful interventions but Chinese contribution should not seek to address every aspect of malaria control. It should start with the Test, Treat, and Track (T3) initiative that was advocated by WHO and all partners, and is also of great demand in Africa. To align with the T3 approach, focussing on scaling up diagnostic testing, treatment and surveillance, T3 and the corresponding surveillance manuals were launched in Namibia by the WHO Director-General in April 2012. Each suspected case of malaria will be confirmed with a rapid diagnostic test, treated with an antimalarial medicine, and tracked using a surveillance system (WHO, 2012b). Joint country efforts could be made on scaling-up access to malaria diagnostic testing, access to treatment at the community level in Africa with quality artemisinin-based antimalarial compound medicines, including lifesaving injectable artesunate, and strengthening the malaria surveillance system. China's strengths at employing these three components are described in the following sections.

4.1 Quality control in diagnosis of malaria cases (test)

During the malaria elimination stage, one of the key components is to further improve the malaria diagnosis system through quality control and assurance. According to the national strategy, to ensure the quality of malaria diagnosis in China, all positive slides or RDTs must be rechecked at the county level. All positive and 10% of randomly-selected negative results have to be verified by microscopy at an upper level, such as the prefecture, provincial or national level, within a month. Unknown species or suspect specimens with clinical symptoms will be diagnosed and confirmed by polymerase chain reaction (PCR) as well.

In line with the WHO T3 initiative launched in 2012, the national malaria diagnosis assurance system is to be updated continuously to guarantee qualified diagnostic testing so that each malaria case can be identified

and traced. The diagnosis system is composed of laboratories at national, provincial and county levels. At present, the national malaria diagnosis laboratory is based in the NIPD under China CDC, and 19 provincial malaria diagnosis laboratories have been set up, all of which were recognised as reference laboratories that are responsible for malaria verification in their own province.

Therefore, P.R. China can provide expert support on the establishment of malaria diagnostic laboratories with quality assurance in local African countries. The specialists can help train the laboratory staff on malaria diagnostic techniques.

4.2 Drug delivery system (treat)

The health system in China has the advantage of a strong network of public health facilities, which is the basis for the delivery of malaria services, such as diagnosis and treatment. The rural health service delivery system is based on facilities at county, township and village levels. To ensure free, prompt, safe and effective treatment, malaria drugs are stocked at the different levels according to the different malaria burden and monthly update of drug stocks.

In China, malaria drugs are administered free of charge to malaria patients after blood tests. G6PD deficiency is tested before giving primaquine to some ethnic minority groups in some areas. To ensure drug compliance and the safety of patients, directly observed therapy is implemented, and patients receive daily follow-up by village doctors or other health staff. To ensure the quality of antimalarial drugs, the State Food and Drug Administration strengthens the implementation of good manufacturing practices, performs routine drug quality testing (including through supporting laboratory quality improvements in rural and remote areas), and improves QA at all levels, from manufacturing to distribution to storage.

Therefore, Africans in endemic malaria areas can access and obtain practical and effective services, including antimalarial medicines, through an improved drug delivery system such as in P.R. China. Moreover, China has accumulated a lot of treatment experience using artemisinin-based therapies and can improve African capabilities toward the cure of severe *P. falciparum* malaria.

4.3 Malaria information reporting system (track)

Timely reporting, effective analyses and rapid distribution of surveillance data can assist in detecting the aberration of disease occurrence and further facilitate a timely response. In the aftermath of the 2003 outbreak

of severe acute respiratory syndrome, the Chinese government strengthened its public health disease surveillance system, taking advantage of modern information technology to build an integrated, effective and reliable disease reporting system, the national Notifiable Infectious Diseases Reporting Information System (NIDRIS). This system gathers real-time epidemiologic information on approximately 40 infectious diseases, including malaria, across every province from every hospital and clinic. Based on NIDRIS, a new nationwide web-based automated system for outbreak detection and rapid response, namely the China Infectious Disease Automated-alert and Response System (CIDARS), was developed in 2008. In CIDARS, three aberration detection methods are used to detect the unusual occurrence of 28 notifiable infectious diseases at the county level and transmit information either in real time or on a daily basis. The Internet, computers and mobile phones are used to accomplish rapid signal generation and dissemination, timely reporting and reviewing of the signal response results, which greatly improved the timeliness of malaria case or epidemic detection and response (Yang et al., 2011). In 2010, when P. R. China started NMEP another web-based reporting system specific to malaria was set up to provide more detailed information on malaria patients and antimalarial interventions.

The information systems have the advantages of real-time data reporting and aggregation, national system structure and protocols to eliminate noncompatibility, enabling local CDCs and other health care organisations to aggregate data in a number of ways at any time and in any region. The systems allow for routine reporting of surveillance data and monitoring of malaria programme, which can help monitor focal malaria prevalence and predict trends due to changing transmission factors as well as to provide strategic guidance on malaria control or elimination activities, including malaria testing and treatment.

Thereafter, in Africa with the selection of pilot countries, China is interested in collaborating on capacity building and health system strengthening, with specific emphasis on monitoring/evaluation and improving health information systems. The core malaria indicators recommended by WHO and demanded in African countries could be designed in such a malaria information system. The combination of advanced technology (e.g. spatial technology) with the reporting system based on Chinese experiences could benefit local malaria detection, treatment and response. Training courses on information techniques and data management could be provided to ensure the system functions appropriately.



5. COLLABORATIVE RESEARCH SCOPES

5.1 Effectiveness evaluation on comprehensive control strategy

There will be three areas of possible research for the collaboration in the field of effectiveness evaluation of comprehensive control strategy as follows:

1. Demographic, epidemiological and environmental impact factors for malaria transmission by a comprehensive comparison in the fields of population prevalence, diagnostic capacity and effects of vector control between demonstration areas and the control areas;
2. Socioeconomic impact factors and health system status involved in a national malaria control/elimination programme, including the local social situation, economy and health services system; and
3. Strategy and measures assessment, including evaluating the control effect of a related policy and strategy applied in the demonstration areas and further exploring the successful models.

5.2 Early warning system for disease surveillance

According to the experiences in establishment of the information management system for malaria control/elimination programmes in P.R. China, a warning system of disease surveillance in Africa countries could be set up to help timely evaluate risks for malaria transmission and control effects (Tambo et al., 2014a; Tambo et al., 2014b).

5.3 Resistance surveillance

Resistance studies on both insecticide and antimalarial drugs are proposed, focussing on the possible mechanisms for resistance occurrence and transmission, which could provide evidence-based strategies for resistance containment in Africa and even worldwide (Liu, 2014).

5.4 Transition of traditional medicines

The African continent bears the greatest burden of types II and III diseases, including the so-called neglected diseases, malaria, tuberculosis, HIV/AIDS, diarrhoea and respiratory diseases. As well, China still suffers from a number of neglected tropical diseases, and emphasis is already being placed in the use of different dosage and administration in combination therapy for control and management of such diseases, including the contribution of traditional medicines (Helmstadter and Staiger, 2013; Odonne et al., 2011;

Pohlit et al., 2013; Zofou et al., 2013), and many experiences can be drawn upon for African countries in treating malaria. In addition, use of and access to available drugs are hindered by resistance, safety and compliance issues as well as cost. As many pharmaceutical companies in China have certain capabilities for developing new antimalarial drugs (Chen, 2014), there is an urgent need for the transformation of current approaches that address these candidate traditional medicines in Africa, in a manner that strengthens South–South collaborations and translates stagnating African discoveries into usable and accessible health tools. This China–Africa partnership presents a real opportunity to advance this area and build relevant capacity (Dawson et al., 2014; Mboya-Okeyo et al., 2009; Nwaka et al., 2010; Thorsteinsdottir et al., 2010; Uwimana et al., 2012).



6. THE WAY FORWARD

Over the past 60 years, P. R. China has made remarkable achievements in malaria control in terms of very limited local transmission and is proceeding with malaria elimination. Although malaria incidence and mortality was reduced by 31% and 49% respectively between 2000 and 2012, sub-Saharan Africa remains currently the highest malaria burden in the world (WHO, 2013). Many international efforts are making contributions, but there is further opportunity to strengthen China–Africa cooperation in Africa on malaria control and elimination, based on Chinese long-term experience in malaria control and China–Africa health cooperation.

Such China–Africa Cooperation efforts should be aligned with sound, evidence-based, and costed strategic plans for local malaria control and elimination, with a focus on identifying needs and filling gaps, and leveraging all national, bilateral and multilateral as well as private sector opportunities. Although a series of challenges and needs were recognized, scaling up and sustaining access to qualified malaria diagnosis, treatment and case-reporting in all public sectors, for-profit and informal health facilities across sub-Saharan Africa is central to current global strategies for malaria control and elimination. Therefore, it is the opportunity for further China–Africa collaboration to apply Chinese strengths into African improvements of quality assurance in malaria diagnosis system, drug delivery system, information reporting system, as well as the related capacity building. To ensure the successful employment of these efforts, the corresponding operation researches with high priority are also indispensable, including control effect

evaluation, early warning, resistance surveillance of antimalarial drugs and insecticides, as well as transformation of traditional medicines. It is encouraged to collaborate on research and development of new products based on technical expertise and support systems from China, and building on Technical Assistance platforms and technical resource networks/Centers in Africa.

According to Chinese experience, the success of large scale campaign must generate from pilot trial. The China–Africa Cooperation efforts in malaria should be directed on an initial group of 6–8 countries, half of which with high burden and maximal potential for saving lives and half with potential to progress towards malaria pre-elimination & elimination. The criteria for selecting countries may include: 1) high level political commitment for malaria control; 2) government resources (financial or human) contributing to the initiative; 3) existing political trade and economic cooperation with Chinese government; and 4) minor language barriers to assure efficient cooperation. Chinese medical team, anti-malaria center and competitive pharmaceutical enterprises in the selected countries as well as malaria experts sent from China would have great contributions.

Simultaneously, these efforts should be in line with malaria resolutions and initiatives of United Nations (UN), WHO, Africa Union (AU) and Regional Economic Communities and in coordination with national and international agencies under bilateral and multilateral partnerships to foster collaboration effect and conformity superiority in the region.



ANNEX 1: ANTIMALARIA CENTERS IN AFRICA ESTABLISHED BY CHINESE GOVERNMENT IN 2007–2009

Year	Country	Location (city or hospital name)
2007	Senegal	Dakar
2007	Liberia	Monrovia
2007	Chad	NDjamena (hospital)
2008	Burundi	Bujumbura
2008	Uganda	Kampala (hospital)
2008	Congo	Brazzaville
2008	Gabon	Libreville (hospital)
2008	Benin	Lokosa
2008	Guinea	Bissau
2008	Ethiopia	Aoluo Mo, Naz.
2009	Togo	Lome

Year	Country	Location (city or hospital name)
2009	Mali	Bamako(hospital)
2009	Cameroon	Yaounde(hospital)
2009	Cote d'Ivoire	Abidjan
2009	Rwanda	Ki Gu Ki Jo
2009	Equatorial Guinea	Bata
2009	Zambia	Lusaka
2009	Comoros	Moheli
2009	Madagascar	Infectious Disease (hospital)
2009	Sudan	Ad Damazin
2009	Central African	Bangui
2009	Garner	Ackner
2009	Angola	Luanda
2009	Guinea	Kona Correa Steen (hospital)
2009	Mozambique	Maputo
2009	Sierra Leone	Friston(Hospital)
2009	Tanzania	Leah Amana hospital

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REFERENCES

- Addae-Mensah, I., Fakorede, F., Holtel, A., Nwaka, S., 2011. Traditional medicines as a mechanism for driving research innovation in Africa. *Malar. J.* 10 (Suppl. 1), S9.
- Agomo, C.O., Oyibo, W.A., 2013. Factors associated with risk of malaria infection among pregnant women in Lagos, Nigeria. *Infect. Dis. Poverty* 2, 19.
- Aidoo, M., 2013. Factoring quality laboratory diagnosis into the malaria control agenda for sub-Saharan Africa. *Am. J. Trop. Med. Hyg.* 89, 403–406.
- Ajayi, I.O., Jegede, A.S., Falade, C.O., Sommerfeld, J., 2013. Assessing resources for implementing a community directed intervention (CDI) strategy in delivering multiple health interventions in urban poor communities in Southwestern Nigeria: a qualitative study. *Infect. Dis. Poverty* 2, 25.
- Ako, B.A., Offianan, A.T., Johansson, M., Penali, L.K., Nguetta, S.P., Sibley, C.H., 2012. Molecular analysis of markers associated with chloroquine and sulfadoxine/pyrimethamine resistance in *Plasmodium falciparum* malaria parasites from southeastern Cote-d'Ivoire by the time of Artemisinin-based Combination Therapy adoption in 2005. *Infect. Drug. Resist* 5, 113–120.
- Bhutta, Z.A., Sommerfeld, J., Lassi, Z.S., Salam, R.A., Das, J.K., 2014. Global burden, distribution, and interventions for infectious diseases of poverty. *Infect. Dis. Poverty* 3, 21.

- Bi, Y., Tong, S., 2014. Poverty and malaria in the Yunnan province, China. *Infect. Dis. Poverty* 3, 32.
- Butler, C.D., 2012. Infectious disease emergence and global change: thinking systemically in a shrinking world. *Infect. Dis. Poverty* 1, 5.
- Chen, C., 2014. Development of antimalarial drugs and their application in China: a historical review. *Infect. Dis. Poverty* 3, 9.
- Chima, R.I., Goodman, C.A., Mills, A., 2003. The economic impact of malaria in Africa: a critical review of the evidence. *Health Policy* 63, 17–36.
- Chinese Medical Cooperation in Africa, 2011. Nordiska Afrikainstitut, Uppsala. <http://nai.diva-portal.org/smash/get/diva2:399727/FULLTEXT02>.
- Dawson, A., Brodie, P., Copeland, F., Rumsey, M., Homer, C., 2014. Collaborative approaches towards building midwifery capacity in low income countries: a review of experiences. *Midwifery* 30 (4), 391–402.
- Frosch, A.E., Venkatesan, P.M., Laufer, M.K., 2011. Patterns of chloroquine use and resistance in sub-Saharan Africa: a systematic review of household survey and molecular data. *Malar. J.* 10, 116.
- Guinovart, C., Navia, M.M., Tanner, M., Alonso, P.L., 2006. Malaria: burden of disease. *Curr. Mol. Med.* 6, 137–140.
- Helmstadter, A., Staiger, C., 2013. Traditional use of medicinal agents: a valid source of evidence. *Drug Discov. Today* 19, 4–7.
- Hill, J., Hoyt, J., van Eijk, A.M., D’Mello-Guyett, L., Ter Kuile, F.O., Steketee, R., Smith, H., Webster, J., 2013. Factors affecting the delivery, access, and use of interventions to prevent malaria in pregnancy in sub-Saharan Africa: a systematic review and meta-analysis. *PLoS Med.* 10, e1001488.
- Liu, D.Q., 2014. Surveillance of antimalarial drug resistance in China in the 1980s–1990s. *Infect. Dis. Poverty* 3, 8.
- Malaria in Africa. http://www.rollbackmalaria.org/cmc_upload/0/000/015/370/RBMInfo-sheet_3.htm.
- Mboya-Okeyo, T., Ridley, R.G., Nwaka, S., 2009. The african network for drugs and diagnostics innovation. *Lancet* 373, 1507–1508.
- Action Plan of China Malaria Elimination (2010–2020). <http://www.nhfpc.gov.cn/cmsresources/mohjbyfkzj/cmsrdocument/doc8571.doc>.
- Noor, A.M., Amin, A.A., Akhwale, W.S., Snow, R.W., 2007. Increasing coverage and decreasing inequity in insecticide-treated bed net use among rural Kenyan children. *PLoS Med.* 4, e255.
- Nwaka, S., Ilunga, T.B., Da Silva, J.S., Rial Verde, E., Hackley, D., De Vre, R., Mboya-Okeyo, T., Ridley, R.G., 2010. Developing ANDI: a novel approach to health product R&D in Africa. *PLoS Med.* 7, e1000293.
- Odonne, G., Berger, F., Stien, D., Grenand, P., Bourdy, G., 2011. Treatment of leishmaniasis in the Oyapock basin (French Guiana): a K.A.P. survey and analysis of the evolution of phytotherapy knowledge amongst Wayapi Indians. *J. Ethnopharmacol.* 137, 1228–1239.
- Pell, C., Straus, L., Andrew, E.V., Menaca, A., Pool, R., 2011. Social and cultural factors affecting uptake of interventions for malaria in pregnancy in Africa: a systematic review of the qualitative research. *PLoS One* 6, e22452.
- Pohlit, A.M., Lima, R.B., Frausin, G., Silva, L.F., Lopes, S.C., Moraes, C.B., Cravo, P., Lacerda, M.V., Siqueira, A.M., Freitas-Junior, L.H., Costa, F.T., 2013. Amazonian plant natural products: perspectives for discovery of new antimalarial drug leads. *Molecules* 18, 9219–9240.
- Sa, J.M., Chong, J.L., Wellems, T.E., 2011. Malaria drug resistance: new observations and developments. *Essays Biochem.* 51, 137–160.
- Sambo, L.G., Ki-Zerbo, G., Kirigia, J.M., 2011. Malaria control in the African Region: perceptions and viewpoints on proceedings of the Africa Leaders Malaria Alliance (ALMA). *BMC Proc.* 5 (Suppl. 5), S3.

- Sridaran, S., McClintock, S.K., Syphard, L.M., Herman, K.M., Barnwell, J.W., Udhayakumar, V., 2010. Anti-folate drug resistance in Africa: meta-analysis of reported dihydrofolate reductase (dhfr) and dihydropteroate synthase (dhps) mutant genotype frequencies in African *Plasmodium falciparum* parasite populations. *Malar. J.* 9, 247.
- Tambo, E., Adediji, A.A., Huang, F., Chen, J.H., Zhou, S.S., Tang, L.H., 2012. Scaling up impact of malaria control programmes: a tale of events in Sub-Saharan Africa and People's Republic of China. *Infect. Dis. Poverty* 1, 7.
- Tambo, E., Ai, L., Zhou, X., Chen, J.H., Hu, W., Bergquist, R., Guo, J.G., Utzinger, J., Tanner, M., Zhou, X.N., 2014a. Surveillance–response systems: the key to elimination of tropical diseases. *Infect. Dis. Poverty* 3, 17.
- Tambo, E., Ugwu, E.C., Ngogang, J.Y., 2014b. Need of surveillance response systems to combat Ebola outbreaks and other emerging infectious diseases in African countries. *Infect. Dis. Poverty* 3, 29.
- Tang, L.H., 1999. Chinese achievements in malaria control and research. *Chin. J. Parasitol. Parastic. Dis.* 17, 3 (in Chinese).
- Tang, L.H., 2009. Malaria in China: from control to elimination. *Int. Med. Parasitic. Dis.* 36, 8 (in Chinese).
- Thorsteinsdottir, H., Melon, C.C., Ray, M., Chakkalackal, S., Li, M., Cooper, J.E., Chadder, J., Saenz, T.W., Paula, M.C., Ke, W., et al., 2010. South–South entrepreneurial collaboration in health biotech. *Nat. Biotechnol.* 28, 407–416.
- Uwimana, J., Zarowsky, C., Hausler, H., Jackson, D., 2012. Engagement of non-government organisations and community care workers in collaborative TB/HIV activities including prevention of mother to child transmission in South Africa: opportunities and challenges. *BMC Health Serv. Res.* 12, 233.
- WHO, 2012a. Global Plan for Insecticide Resistance Management in Malaria Vectors (GPIRM). World Health Organization, Geneva.
- WHO, 2012b. Test, Treat, Track: Scaling up the Fight against Malaria. World Health Organization, Geneva.
- Wang, X.Y., 2013. Chinese achievements and challenges in aid to africa. *Int. Res. Ref.* 7, 6 (in Chinese).
- WHO, 2013. World Malaria Report 2013. World Health Organization, Geneva.
- Yang, W., Li, Z., Lan, Y., Wang, J., Ma, J., Jin, L., Sun, Q., Lv, W., Lai, S., Liao, Y., Hu, W., 2011. A nationwide web-based automated system for outbreak early detection and rapid response in China. *Western Pac. Surveill. Response J* 2, 10–15.
- Yin, J.H., Yang, M.N., Zhou, S.S., Wang, Y., Feng, J., Xia, Z.G., 2013. Changing malaria transmission and implications in China towards National Malaria Elimination Programme between 2010 and 2012. *PLoS One* 8, e74228.
- Zofou, D., Ntie-Kang, F., Sippl, W., Efange, S.M., 2013. Bioactive natural products derived from the Central African flora against neglected tropical diseases and HIV. *Nat. Prod. Rep.* 30, 1098–1120.
- Zofou, D., Nyasa, R.B., Nsagha, D.S., Ntie-Kang, F., Meriki, H.D., Assob, J.C., Kuete, V., 2014. Control of malaria and other vector-borne protozoan diseases in the tropics: enduring challenges despite considerable progress and achievements. *Infect. Dis. Poverty* 3, 1.
- Zuo, Y., 2013. Contributions and challenges of chinese Foreign aid medical team. *Int. Economic Collaboration* 11, 3 (in Chinese).