DR FREDROS OKUMU

# Going after **residual malaria** in Africa

In this insightful and personal interview, **Dr Fredros Okumu** explains his vast and varied experience studying mosquitoes that transmit malaria, and his hopes for the disease's eventual elimination

**Could you provide an insight into your academic background, and describe what first led you to develop a research interest in malaria control?**

I began health research in 2000, a few months after finishing high school. I worked briefly for the International Centre of Insect Physiology and Ecology, assisting resident PhD students as a study volunteer and field technician. In 2001, we began evaluating botanical products for controlling malaria mosquitoes in Western Kenya, resulting in my first scientific manuscript.

I enrolled for undergraduate studies at Moi University's College of Health Sciences in Kenya (2001-05). As an undergraduate, I once again participated in short-term elective research activities, which included field evaluation of mosquito sampling methods in Tanzania in 2004, and an assessment of disease surveillance capabilities in the Kenya/Uganda border areas in 2005. In Tanzania, a colleague and I worked for 24 consecutive 12-hour nights in the mosquito-dense Kilombero Valley, performing a technique called 'human landing catches' where one exposes his legs and collects the mosquitoes that come to bite. This is a risky sampling technique that unfortunately remains the gold standard for measuring human-mosquito contacts. The technique urgently needs replacing for obvious ethical reasons.

**How have your studies on malaria developed to date?**

I joined Ifakara Health Institute (IHI) in late 2007 and in 2008 completed my MSc thesis on olfactory responses of the malaria vector, *Anopheles gambiae*, working within an international consortium and funded through the Grand Challenges in Global Health Programme of the Bill & Melinda Gates Foundation. It was at this time that we also developed synthetic mosquito lures that were four times more attractive than humans. I further completed an in-depth mathematical evaluation of the potential benefits, limitations and target product profiles of odour-baited technologies for malaria prevention in Africa. Because of my strong interest in how geography relates to health, I also completed Master's research in geoinformation and Earth observation sciences and have continued to work on health geographics.

**Your team has recently pioneered innovative crowd-sourcing techniques to improve the surveillance of disease-transmitting mosquitoes in rural Tanzania. What does this involve?**

With the goal of low-cost participatory approaches for targeting vector control interventions, we conducted field trials in three different villages, where we gave community members gridded maps and asked them to rank the grids based on where they expected mosquitoes to be most abundant. Over a period of 12 months, concurrent mosquito trap surveys have consistently verified that these people correctly predicted areas as having high, low or medium mosquito densities. Indeed, preliminary evidence has shown great success and we continue to fine-tune this approach.

**How does the concept of 'integrated innovation' underline IHI's work on malaria?**

As conceptualised by one of our funding partners, Grand Challenges Canada (GCC), integrated innovation is the coordinated application of scientific, technological, social and business innovation to develop solutions to complex health and development challenges. This approach does not discount the singular benefits of each of these types of innovation, but highlights the powerful synergies that can be realised by aligning all three. Integrated innovation recognises that scientific and technological innovations have a greater chance of achieving global impact and sustainability if they are developed in conjunction with appropriate social and business innovations. At IHI, our ultimate goal is to align our research activities and technologies to meet community needs. Going forward, we must therefore ensure that there is real social and economic value to our activities and outputs.

**Looking ahead, what strategies need to be implemented in order to eradicate malaria?**

To achieve zero malaria transmission, we must re-invigorate our efforts for prevention, case finding and treatment; maintain the high coverage of long-lasting insecticide bed nets; and thoughtfully introduce house spraying with effective residual insecticides (indoor residual spraying – IRS). Our studies have shown that while these strategies can be insufficient on their own, decisions to combine them should be based on local evidence, ensuring that selected insecticides are effective against prevailing vector populations; coverage is high enough to achieve the desired impacts; and cost-effectiveness is achieved. Moreover, we must ensure that all people with malaria symptoms get prompt access to proper diagnosis and treatment, and that comprehensive surveillance-response is implemented even in hard-to-reach areas.

Looking ahead, we must also develop effective new tools and strategies to complement these current best practices, reducing transmission beyond the critical thresholds necessary to achieve elimination. The new strategies will fill gaps by, for example, controlling malaria mosquitoes that bite outdoors and would otherwise not be effectively controlled by insecticidal bed nets or spraying. Local and international partnerships, greater financial investment, improvements of health systems and, most importantly, effective surveillance-response efforts remain key.

# Scent imitation:
## innovations for tackling residual malaria mosquitoes in Africa

A group of researchers at **Ifakara Health Institute**, Tanzania, is developing innovative initiatives to lessen the prevalence of humans being bitten by mosquitos and thus reduce the transmission of malaria

**MALARIA HAS LONG** been a major cause of illness and death worldwide, with by far the greatest burden of cases occurring in sub-Saharan Africa. Encouragingly, the past decade has seen a huge scale-up of life-saving prevention and treatment interventions, resulting in sharp decreases in malaria-related deaths. Yet many challenges remain, including the worrying rise in insecticide-resistant mosquito populations across Africa and the lack of available interventions for outdoor- and early-biting mosquitoes.

Dr Fredros Okumu is a prominent research scientist who is taking these challenges seriously. Malaria is something that resonates personally with him; he has seen it affect many people in his community and family. Based in Tanzania at Ifakara Health Institute (IHI) – an independent, non-profit health research organisation – he is currently investigating pioneering new technologies for surveillance and control that will contribute to malaria elimination.

The principle of 'integrated innovation' is fundamental to all the research being carried out at Ifakara. Based on this, Okumu and his team aim to build a practical and community-focused outdoor mosquito control strategy, complementing current indoor-focused interventions such as long-lasting insecticide treated nets (LLINs) and house spraying with residual insecticides. He is also conducting fine-scale surveillance of residual malaria vectors in areas where these existing tools have already significantly reduced the malaria burden but where transmission persists. This strategy will lead to progressive reduction of both indoor and outdoor malaria transmission, thus accelerating elimination of the disease in many low- and middle-income endemic communities.

### ACHIEVEMENTS AND CHALLENGES

The most recent World Health Organization (WHO) *World Malaria Report*, published in 2013, highlights great successes in malaria control over the past 10 years. While Tanzania is still among the most affected, the country has made exemplary progress and is an excellent example of what is achievable, even in apparently difficult situations. According to recent epidemiological profiling – conducted jointly by IHI, the National Malaria Control Program, WHO country office and the Kenya Medical Research Institute (KEMRI) Wellcome Trust – there has been more than a 50 per cent decline in malaria prevalence in children aged between two and 10 since 2000: "Malaria prevalence in mainland Tanzanian children is now just under 10 per cent," Okumu discloses. "In fact, today less than 2 per cent of people in mainland Tanzania live in places that would be classified as having intense high transmission rates, while more than 60 per cent of Tanzanians now live in areas considered as having low transmission."

However, these milestones are tempered with more sobering statistics. A 2012 Tanzania malaria indicator survey suggested that the decline is not uniform, and that progress has been slow in southern and northwestern regions. More than 90 per cent of Tanzania's 45 million inhabitants still live in areas at risk of malaria, representing enormous health and economic concerns. There are currently an estimated eight to 12 million malaria cases, and approximately 21,000 deaths throughout the country annually.

### SYNTHETIC ODOUR BLENDS

Certain malaria-carrying African mosquitoes have adapted to feed almost exclusively on humans, relying on chemicals present in human breath, sweat and skin emanations to select their targets. Many human odorants can be synthesised *in vitro* and formulated into mixtures that mimic humans, subsequently luring mosquitoes. In collaboration with research partners in the US and Europe, Okumu and his colleagues at IHI have used innovative techniques to develop and evaluate odour blends consisting of synthetic mosquito attractants, which effectively mimic and even exceed the lure of humans.

The synthetic attractant has been tested against human volunteers in field experiments conducted in specially designed experimental huts. Interestingly, the scientists found that, at long range, the blend was three to five times more attractive to most mosquitoes than the humans. The odour-blend can be readily

### IFAKARA HEALTH INSTITUTE

Ifakara Health Institute (IHI) is a leading research organisation in Africa with a strong track record of scientific output and policy influence. The Institute conducts research on the entire continuum from basic biomedical and ecological sciences to intervention studies, health-systems research and policy delivery. The Environmental Health and Ecological Sciences thematic group – where most of IHI's malaria research takes place – hosts 20 postdoctoral scientists and 20 PhD or MSc students. The group's scientific findings are regularly published in renowned peer-reviewed journals, and the researchers regularly participate in local and international scientific conferences. There is also strong emphasis on public outreach. Each year IHI hosts a National Malaria Forum, and participates in regular meetings hosted by the Ministry of Health to update stakeholders on new findings and discuss how to improve current practices. The Institute also has a special long-term relationship with rural and urban communities, whose members and local health officials are regularly briefed on the research progress at IHI through formal feedback sessions.

For more information: **www.ihi.or.tz**

## INNOVATIONS FOR TACKLING RESIDUAL MALARIA MOSQUITOES IN AFRICA

### OBJECTIVES

To develop mosquito control and surveillance technologies that could complement current best practices, so as to achieve malaria elimination in affected populations in Tanzania and other low-income endemic countries. To maximise effectiveness, these innovations are being integrated with social innovations, to ensure affordable and sustainable community-driven vector control.

### KEY COLLABORATORS

**Dr Rose Nathan**; **Dr Honorati Masanja**, Ifakara Health Institute, Tanzania • **Dr Sarah J Moore**; **Professor Marcel Tanner**, Swiss Tropical and Public Health Institute • **Dr Gerry Killeen**, Liverpool School of Tropical Medicine, UK • **Professor Jason Mathiopaulos**; **Dr Heather Fergusson,** University of Glasgow, UK • **Professor Alvaro Eiras**, Federal University of Minas Gerais, Brazil • **Professor Willem Takken**, Wageningen University and Research Centre, The Netherlands • **Dr Klaus Schonenberger**, Swiss Federal Institute of Technology Lausanne (EPFL) • **Dr Andreas Rose Maria**, Biogents AG, Germany.

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developed into accurate surveillance tools and perhaps even alternative interventions against mosquitoes that transmit malaria parasites and a variety of other important pathogens.

Okumu and his team aim to build a practical and community-focused outdoor mosquito control strategy, complementing existing indoor-focused interventions

### IFAKARA WELLBEING BOXES

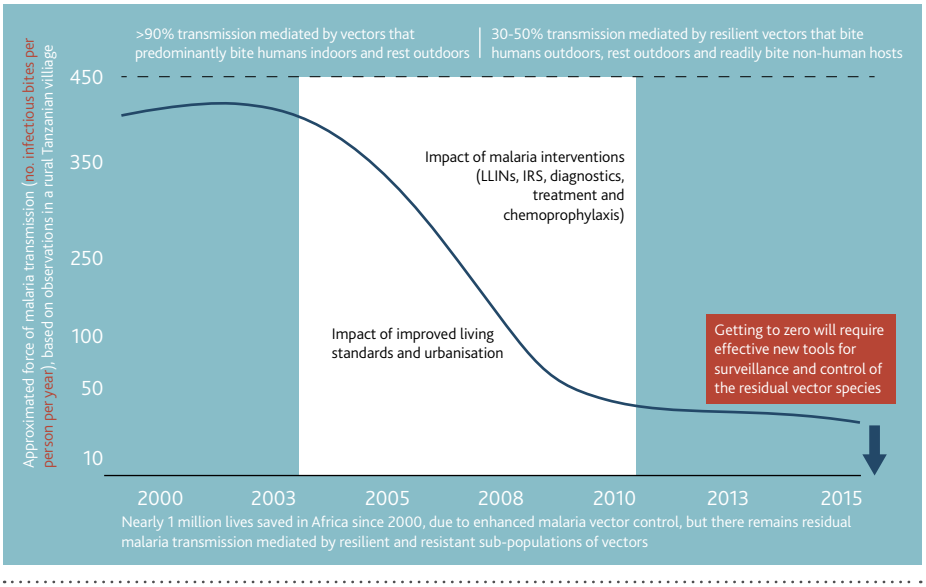
Promisingly, Okumu and his team have developed low-cost methodologies for dispensing these synthetic odour blends; designing outdoor devices dubbed 'Ifakara Wellbeing Boxes', or simply 'Nancy Boxes' (named after the PhD student who led most of the trials on the device). They believe that placing these boxes at optimal sites in malaria-endemic villages where LLINS are also used will kill significant numbers of mosquitoes, thereby disrupting malaria transmission to humans. Mathematical evaluations have corroborated this hypothesis, suggesting that in places with high (80 per cent) bed net coverage, approximately 20 devices per 1000 people are needed to reduce malaria transmission beyond the critical thresholds necessary to achieve elimination.

These innovative wellbeing boxes – which are powered by solar energy – complement existing indoor malaria prevention methods: "They also provide energy for lighting, mobile phone charging and home tuition for school-going kids; and our anthropological studies have shown they would be highly acceptable and effective in rural and remote communities, where mains electricity coverage is often less than 5 per cent," enthuses Okumu. Indeed, lack of electricity access means that many Tanzanians rely on kerosene lights, firewood and moonlight, requiring that significant proportions of evenings are spent outdoors, with an increased risk of being bitten by mosquitoes.

### FUTURE TARGETS FOR SURVEILLANCE AND CONTROL OF RESIDUAL VECTORS

Although the global malaria burden has dropped in recent years, this progress has evidently started to plateau. Along with new interventions, improved malaria surveillance is vital to achieve elimination – yet as malaria declines it is becoming increasingly difficult to detect new infections and measure transmission. Additionally, measuring exposure is still unsafe due to its reliance on human volunteers, and a lack of suitable, affordable and scalable trapping methods provide additional complications.

In view of these challenges, Okumu and his team at IHI are eager to continue developing practical strategies for monitoring densities and transmission activities of residual malaria vector populations. The researchers have begun to translate their experiences with synthetic odours and mosquito trapping technologies into systems that facilitate large-scale mosquito sampling without the need for human volunteers. Working with collaborators in the UK, Switzerland, Tanzania and Brazil, Okumu and his team are also designing quantitative ecology models for the multi-scale targeting of mosquito densities and malaria transmission. These models rely on observable biotic and abiotic environmental variables to target residual transmission at both landscape- (between villages) and fine-scale level (within villages).




**MAIN RESEARCH TEAM:** Fredros Okumu, PhD (Team Leader); Robert Sumaye, PhD; Nancy Matowo, MSc; Arnold Mmbando, BSc; Stephen Mwangungulu; Irene Moshi, MSc; Edith Madumla, BSc; Salum Mapua; Gustave Mkandawile; Joseph Mgando; Sarah Mtali; Godfrey Ligamba; Emmanuel Kaindoa, MSc; Johnson Swai, BSc; Mwajabu Hamis, MSc; Sebard Mteteleka, BSc; Halfan Ngowo, BSc; Alex Limwagu; Elihaika Minja, BSc and Dickson Lwetoijera, PhD.

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