Global **Malaria** Programme

Technical consultation on the use of economics in insecticide resistance management for malaria vector control

Report of a virtual meeting, 14–16 September 2021

World Health Organization

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ABBREVIATIONS

IR	Insecticide resistance
IRM	Insecticide resistance management
NMCP	National Malaria Control Programme
USA	United States of America
WHO	World Health Organization

1. GENERAL BACKGROUND

The problem of mosquito resistance to insecticides is not new. Since the invention and deployment of insecticides, mosquitoes have evolved resistance to them, sometimes within a few generations, and have even been found to be resistant to insecticides never deployed before. Three of the top 16 arthropod species to evolve resistance to pesticides around the world are mosquitoes *(1)*.

Insecticide resistance (IR) is defined in many different ways. The definitions of resistance can be divided into those that are biological and those based on human values *(1)*. Biological definitions focus on genetics and are often based on thresholds for resistance, allele frequency or population mortality when exposed to an insecticide. The presence of a resistance allele in a gene is the basis of biological resistance. According to the World Health Organization (WHO) *(2)*, insecticide resistance is a property of mosquitoes that allows them to survive exposure to a standard dose of insecticide. The emergence of insecticide resistance in a vector population is an evolutionary phenomenon due to either behavioural avoidance (exophily instead of endophily, for example) or physiological factors whereby the insecticide is metabolized, not potentiated, or absorbed less than by susceptible mosquitoes, or is conferred by target site alteration *(2)*.

Note that survival by mosquitoes may or may not be an adequate indicator of even biological resistance, and that ultimately the interest lies in a potential functional loss of insecticidal capacity to reduce transmission. In the context of public health, there is therefore a need to define insecticide resistance as an impact on the effectiveness of an intervention, which implies that while resistance tests (WHO test kits, for example) may indicate a potential problem, they do not necessarily indicate that the effectiveness of an intervention has been lost. Furthermore, mosquitoes categorized as biologically resistant may survive, and therefore be defined by, one dose of insecticide, but killed by a higher dose.

Practical, economic definitions of resistance relevant to public health goes beyond the genetics and the simple bioassay: the economic consequences are also determined by the environment, the abundance of mosquitoes, and all the management interventions deployed. Economic definitions consider the perspective and goals of a stakeholder and the practical consequences of interference with those goals. One example of an economic definition of resistance is the reduction in vector control due to resistance in an *Anopheles* population that causes malaria deaths to exceed a certain number in a country. In this case, it is the control failure which is important, and not the genetics of the mosquito population. It is likely that threshold-based definitions are irrelevant for economic models that account for the evolution of resistance over a time horizon. Note that both biological and economic definitions are subjective.

Integrated vector management is rational decision-making for optimal use of resources for vector control *(2)*. The aim is to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of vector control activities against vector-borne diseases. Insecticide resistance management (IRM) is long-term integrated vector management that helps stakeholders achieve their goals *(1)*. As is the case with Integrated Pest Management in agriculture, the goal is never simply to reduce pest densities or delay evolution of resistance of the pest, but rather to consider wider societal (in this case, public health) benefits. Thus, the evolution of resistance can be delayed by a greater or lesser degree, depending on the economic evaluation. Because economists optimize a benefit to human society when they consider IRM, attempts to limit the evolution of resistance will only be an economically optimal choice if resistance truly and significantly interferes with stakeholders' ability to limit cases of malaria. The speed of evolution is also a major factor. Complete prevention of evolution is rarely attempted: delaying resistance is the usual approach, if determined to be economical.

Typical approaches to IRM include designing the system so that resistant insects do not bite humans or transmit malaria, designing the system so that vector control is easier or less expensive, and reducing the selection pressure (mortality and repellency) experienced by mosquito populations during vector control. In vector control, examples of design options include various insecticide treated nets, such as insecticide-treated nets, window screens, changes to water resources, and possibly the use of non-human hosts ("baits") for the mosquitoes. Some options for control include changes to concentration of insecticide, use of mixtures of insecticides, variation in scheduling use of multiple insecticides, and integration of insecticidal and non-insecticidal vector control.[1] All alternatives should be evaluated not for how they delay evolution of biological resistance, but for how they improve public health and the use of resources.

Unfortunately, solutions and improvements are usually constrained by the limited insecticide pipelines, the problem of repurposing insecticides used now and in the future by agriculture, and limited budgets. Use of the same class of insecticides in agriculture increases the evolution of resistance by mosquitoes targeted in vector control *(3)*, because the mosquito populations can be exposed to the same insecticides inside and outside of houses. However, developing new insecticides that are different from those used in agriculture will likely increase vector control costs.

The specific goals of each national malaria control programme (NMCP) will determine how each evaluates vector control and the mosquito resistance that may reduce the effectiveness of control. Economic evaluations and planning for the future typically require these goals to be based on effective metrics for benefits and costs, a time horizon, a discount rate, a clear description of the spatial scale being considered, and a prediction with a rational basis. When performing an economic analysis involving prediction of the future, two key decisions must be made about the consideration of time. First, the stakeholders must select a time horizon over which decisions will be made and the economics will be evaluated. Consequences for human health are often evaluated over long time horizons (over 30 years). Technologies that are likely to be useful for only 5–10 years are usually evaluated over shorter time horizons, sometimes as short as donor funding cycles (1–3 years). Time after the end of the chosen horizon is considered to be of no importance at the point when funding/procurement decisions are made. The second concern is the choice of time value of costs and benefits. People typically value goods and services provided in the future less than those provided immediately. Thus, future economic values are discounted relative to current values. In many public investment evaluations discount rates vary from 0–3% per year: the higher