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Determining effective spraying periods to control malaria via indoor residual spraying in sub-Saharan Africa

Indoor residual spraying—spraying insecticide inside houses to kill mosquitos—is an important method for controlling malaria vectors in sub-Saharan Africa. While it has been responsible for suppressing at least one of the malaria-carrying mosquito species, in recent years it has received relatively little attention. We propose a mathematical model for both regular and non-fixed spraying, using impulsive differential equations to account for the reduction in the mosquito population. First, we determine the stability properties of the nonimpulsive system. Next, we derive minimal effective spraying intervals and the degree of spraying effectiveness required to control mosquitos when spraying occurs at regular intervals. If spraying is not fixed, then we determine the “next best” spraying times and show that this solution is always sub-optimal. We also consider the effects of an increased mosquito birth rate on the prevalence of mosquitos. We show that, if the mosquito birth rate increased by 25%, then the minimal effective spraying period would be reduced by half, whereas if the mosquito birth rate were doubled, then the minimal effective spraying period would be reduced by three quarters. The results are illustrated with numerical solutions. It follows that, although regular spraying is superior to non-fixed spraying, either will result in a significant reduction in the overall number of mosquitos, as well as the number of malaria cases in humans. We thus recommend that the use of indoor spraying be re-examined for widespread application in malaria-endemic areas.