

Environmental factors and an eco-epidemiological model of malaria in Indonesia

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ABSTRACT

Indonesia is one of the countries in Southeast Asia where malaria is a prominent public health concern with an estimated 15 million malaria cases annually and 42,000 deaths. The study explores the environmental risk factors of malaria guided by an eco epidemiological model of malaria transmission. A longitudinal and cross sectional approach has been employed for data gathering of the environmental variables, spatial and temporal patterns of malaria transmission, malaria vectors behaviour and human risk factors of malaria transmission in Indonesia.

Three different regions in Indonesia were used for the study. The first area is West Timor which has the highest malaria incidence in Indonesia. The second location is Sukabumi District of West Java, which had a malaria outbreak in 2003. The final location is Kebumen District of Central Java, which has one of the highest malaria pocket areas in Java. All areas were divided into three different topographical settings – coastal, hilly and highland areas.

In each study areas, the environmental data were analysed using t-test, ANOVA, Pearson Correlation, and General Linear Model Repeated Measures. Further, LISA (Local Indicators of Spatial Association) analysis using GIS was employed to explore local malaria spatial distribution and generate malaria maps for the malaria transmission areas based on the local spatial association.

Adult mosquito (*Anopheles* spp) surveys were used to explore malaria vectors behaviour in different areas and different topographical settings. Finally, an interview program was used to collect data in order to understand human risk factors in malaria transmission. Human risk factors data were calculated using χ^2 and logistic regression.

The results show that 100% of West Timor's villages are in malaria endemic areas. Villages on the district boundary zones had more malaria than non-boundary villages. The number of rainy days had a significant positive correlation to malaria incidence. Humidity also had a significant positive correlation to malaria incidence. Altitude and maximum temperature had a significant negative correlation with malaria cases.

In Sukabumi, West Java, altitude was not significantly correlated with malaria incidence. The risk of being infected with malaria was similar for respondents in coastal and highland areas. Rainfall, temperature, and wind speed were also not significantly correlated to malaria incidence in Sukabumi.

In Kebumen, Central Java, rainfall patterns did not have a significant correlation with malaria incidence. Altitude, however, showed a significant correlation with malaria incidence, where more cases occurred at an altitude between 60 m and 200 m above sea level.

Malaria incidence was higher in village than urban areas in all West Timor, West Java and Central Java. Number of very high-risk malaria villages was higher in dry than wet seasons in all areas.

Eleven (11) Anopheles mosquito species were recorded during this study: *An. aconitus*, *An. annularis*, *An. barbirostris*, *An. flavirostris*, *An. indefinitus*, *An. kochi*, *An. maculatus*, *An. subpictus*, *An. sundaicus*, *An. tessellatus*, and *An. vagus*. Each species occupied different topographical settings and areas. The species behaved differently for host-seeking and resting. Anopheles species which were very active in host-finding at night included; *An. aconitus*, *An. barbirostris*, *An. subpictus*, and *An. vagus*. Anopheles species with high vectorial capacity were *An. subpictus* and *An. barbirostris*.

This study found that occupation and outdoor activities were correlated with malaria incidence. Farmers and fishermen had a greater risk of being infected by malaria than those in other occupations. Overall, malaria incidence was higher in low socio-economic groups. However, Malaria incidence was not affected by education status: both low and highly educated groups had a similar malaria risk. In all the research areas, respondents who stayed outdoors at night and respondents who slept outside had a higher risk of being infected with malaria. This higher risk may be related to the mosquitoes' habit of seeking hosts more outdoors. Getting access to health facilities is an important aspect of the treatment of diseases, including malaria.

This study concludes that malaria is still a prominent public health problem in Indonesia, in which the level of incidence and transmission vary based on geography and topographical settings. Malaria transmission has local characteristics resulting from the combination of many variables. The eco-epidemiological approach is a useful method for gaining insights into malaria variables in order to improve the understanding of malaria transmission in Indonesia.

This study recommends that more attention be paid to malaria incidence at lower altitudes. This study found mosquitoes were more active outdoors, thus indoor residual spraying (IRS) is not recommended for malaria control in some areas. However, in West Timor Anopheles species predominantly feed and rest indoors. Thus, using insecticide treated nets (ITN) is likely to be effective in this area. Improvement of living conditions and implementing of mosquito-proof house programs would reduce malaria risk.

This study also recommends that the extension of health facilities and health care delivery using local resources such as village midwives and malaria village cadres would provide an accessible malaria service for the villagers. In addition, to have better and more sustained results, integrated malaria intervention is needed. This includes adequate malaria treatment, good malaria surveillance systems and adequate vector control programs. These programs should be based on local conditions such as local weather, human behaviour, topographical and ecological settings, and vector species and their specific ecologies. Geographic information systems such as LISA (Local Indicators of Spatial Association) can be used to predict malaria risk areas and should be incorporated into the malaria surveillance system.