

Effectiveness of Indoor Residual Spraying as A Method of Controlling Dengue Fever in Communities: A systematic review

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ABSTRACT

Background: Dengue remains a significant public health issue in the Western Pacific Region. In the absence of a vaccine, vector control is the mainstay for dengue prevention and control. This study aimed to exploring about the effectiveness of Indoor Residual Spraying as A Method of Controlling Dengue Fever in Communities.

Subjects and Method: A systematic review were conducted by searching articles from PubMed, ResearchGate, Science Direct, Google Scholar, and EBSCO is an article published from 2013 to 2023. The keywords were “dangue haemorrhagic fever” OR “DHF” AND “community” OR “family” AND “disaster” AND “IRS” OR “indoor residual spraying”. The inclusion criteria were cross-sectional study. The articles were selected by PRISMA flow diagram method.

Results: A total of 9 studies was included in this review. All of the study stated that IRS can have both an immediate and sustained effect on reducing adult and immature *A. aegypti* populations and should be considered as an adult mosquito control strategy by dengue vector control programs also IRS led to 86-96% reduction in dengue cases in sprayed premises, compared to unsprayed controls.

Conclusion: IRS significantly reduce malaria burden in high-transmission settings.

Keywords: dangue haemorrhagic fever, DHF, family, community.

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BACKGROUND

Dengue fever remains a significant public health concern, particularly in tropical and subtropical regions where the *Aedes* mosquito thrives. While various strategies have been implemented to combat dengue transmission, the effectiveness of indoor residual spraying (IRS) as a control measure within

communities requires further investigation (Shepard et al., 2016).

Based on data from the Ministry of Health, in 2022, the number of dengue cases will reach 131,265 cases of which around 40% are children aged 0-14 years. Meanwhile, the number of deaths reached 1,135 cases with 73% occurring in children aged 0-14 years.

Dengue fever, caused by the dengue virus transmitted by *Aedes* mosquitoes, poses a substantial health and economic burden globally. Traditional vector control methods, such as larviciding and fogging, have shown limited success in reducing dengue transmission. Indoor residual spraying (IRS) involves the application of insecticides to interior surfaces of houses to target adult mosquitoes. This research seeks to evaluate the effectiveness of IRS as a method of controlling dengue fever within communities (Rothman et al., 2011).

Dengue fever is caused by dengue virus and transmitted to humans through the bite of *Aedes Aegypti* and *Aedes Albopictus*. The risk factors of dengue fever are hanging clothes or clothes free to wear, and trash scattered around the house (Achee et al., 2021).

Indoor residual spraying (IRS) is an example of a well-understood approach with potentially under-exploited promise for *Ae. aegypti* control. Knowledge is the first step to change one's behavior, especially in the health sector. IRS is the treatment of common mosquito resting surfaces inside houses with a long-lasting insecticide. Because *Ae. Aegypti* strongly prefer feeding on humans and rest primarily indoors, they are more likely to be reached by IRS than by space sprays, especially outdoor treatment (Dzul-Manzanilla et al., 2017). Numerous dengue outbreaks have taken place and the number of cases of both classic dengue and its more severe manifestation, dengue haemorrhagic fever (DHF), have increased dramatically. The majority of the cases occur in poor areas of the country.

Abuaku et al. (2018) stated that like other insecticide-based approaches, IRS necessitates specialized training, is time-consuming to deliver, may require a campaign to garner public acceptance, and must be tailored to region-specific factors, such as the insecticide resistance of local mosqui-

toes. Before making these investments, public health officials will likely require information on optimal deployment, scalability, and the long-term effectiveness of IRS. Large scale empirical studies to answer these questions are costly and take many years, but mathematical models—calibrated by real epidemic data and parametrized based on small-scale empirical studies on IRS entomological efficacy (i.e., effect on mosquito mortality) and durability can provide a reasonable basis for action.

IRS appears to have a large impact on *Ae. aegypti* mortality. IRS campaigns to eradicate malaria in the Mediterranean region appear to have led to the elimination of *Ae. aegypti* and IRS either alone, or in combination with larval control, contributed to the elimination of *Ae. aegypti* from Guyana and the Cayman Islands, respectively. All of these results indicate high IRS efficacy. Regarding durability, current IRS insecticides last an estimated three months, but new formulations might last as long as five to eight months (Achee et al., 2021). Based on that background, this study aimed to exploring about the effectiveness of Indoor Residual Spraying as A Method of Controlling Dengue Fever in Communities.

SUBJECTS AND METHOD

1. Study Design

In this article, the method used in systematic review was PRISMA-P (Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol). This research uses systematic review by searching articles in 4 databases namely PubMed, ResearchGate, Science Direct, Google Scholar, and EBSCO, entering the following keywords “dangue haemoragic fever” OR “DHF” AND “community” OR “family” AND “disaster” AND “IRS” OR “indoor residual spraying”.

2. Inclusion Criteria

The inclusion criteria of this study were abstracts and full text article found in the electronic database search. Studies have to be published in a peer-reviewed in Indonesian and English language journal, look at the causal factors of DHF in the community or family published between 2013 to 2023.

3. Exclusion Criteria

Exclusion criteria from this study were study procedures, meta-analyses, editorials, and publications published in non-Indonesian and non-English language journals were all excluded from this review.

4. Study Extraction

Each manuscript was evaluated by looking at the journal in which it was published as well as its main characteristics. Table 1 provides a summary of this information.

5. Data Synthesis

The following element's purpose of study, study design, sample characteristics, and results were used to extract the results of each article's characteristics into a matrix (Table 1).

RESULTS

Location of research. Research locations included nine studies conducted in Africa (Ethiopia, Uganda, Ghana, and Kenya), where the African continent is the continent with the most occurrences of malaria. Below is the process of selecting articles based on a prism flowchart al., 2015) used ANOVA and structural equation modeling.

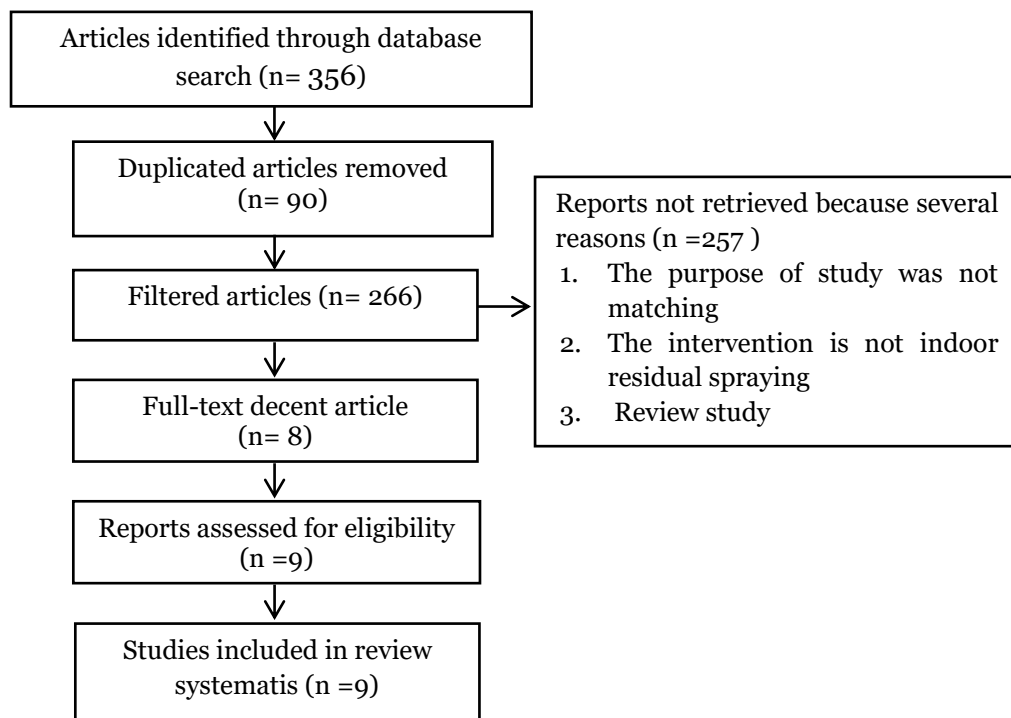


Figure 1. Results of Prisma Flow Diagrams

Table 1. Article Search Results

Author (Year)	Title	Journal	Method	Results	Conclusion
Hamusse et al. (2012)	The impact of indoor residual spraying on malaria incidence in East Shoa Zone, Ethiopia	Global Health Action	Observational study	The incidence of malaria in 2011 and 2002 among the sprayed villages was lower than the respective preceding years for both Plasmodium species (incidence rate ratio 0.60; CI 0.35 to 0.95; $p < 0.001$). After the focal spray, there was significant reduction in malaria incidence in the villages sprayed. Spraying was associated with a 62% reduction in malaria incidence.	This study demonstrated that IRS with DDT was effective in reducing malaria incidence in highland epidemic-prone areas in the East Shoa Zone of Ethiopia.
Steinhardt et al. (2013)	The Effect of Indoor Residual Spraying on Malaria and Anemia in a High-Transmission Area of Northern Uganda	American Journal of Tropical Medicine and Hygiene	Observational study	Parasitemia prevalence among children < 5 years of age was lower in the two IRS districts compared with the non-sprayed district: 37.0% and 16.7% versus 49.8%, $p < 0.001$.	IRS can significantly reduce malaria burden in high-transmission settings.
Fd Paredes-Esquivel et al. (2016)	The impact of indoor residual spraying of deltamethrin on dengue vector populations in the Peruvian Amazon	Acta Tropica	Observational study	The results showed that in an area with moderate levels of <i>A. aegypti</i> infestation, IRS dramatically reduced all immature indices the first week after deltamethrin IRS application and the adult index from 18.5 to 3.1, four weeks after intervention ($p < 0.05$). Even though housing conditions facilitated reinfestation with <i>A. aegypti</i> (100% of the houses have open roof eaves, 31.5% lack sewage systems, and 60.4% collected rain in open containers), indices remained low compared to baseline 16 weeks after insecticide application.	Our results demonstrate that IRS can have both an immediate and sustained effect on reducing adult and immature <i>A. aegypti</i> populations and should be considered as an adult mosquito control strategy by dengue vector control programs.

Author (Year)	Title	Journal	Method	Results	Conclusion
Gimmig et al. (2016)	The Effect of Indoor Residual Spraying on the Prevalence of Malaria Parasite Infection, Clinical Malaria and Anemia in an Area of Perennial Transmission and Moderate Coverage of Insecticide Treated Nets in Western Kenya	PloS One	Observational study	The prevalence of clinical malaria was also lower in the IRS district (1.8% vs. 4.9%, OR = 0.37, 95% CI = 0.20–0.68; p= 0.001).	Both IRS and ITNs are effective tools for reducing malaria burden and when implemented in an area of moderate to high transmission with moderate ITN coverage, there may be an added benefit of IRS.
Vazquez-Prokopec et al. (2017)	Combining contact tracing with targeted indoor residual spraying significantly reduces dengue transmission	Science advance	Observational study	The findings article provides strong evidence for the effectiveness of combining contact tracing with residual spraying within a developed urban center, and should be directly applicable to areas with similar characteristics (for example, southern USA, Europe, or Caribbean countries) that need to control localized Aedes-borne virus transmission or to protect pregnant women's homes in areas with active Zika transmission.	The results highlight that indoor residual spraying significantly reduces dengue transmission.
Toledo et al. (2017)	The additional benefit of residual spraying and insecticide-treated curtains for dengue control over current best practice in Cuba: Evaluation of disease incidence in a cluster randomized trial in a low burden setting with intensive routine control.	PLoS Neglected Tropical Disease	Observational study	There is a significant reduction in Aedes indices (RR= 0.54; 95%CI= 0.32–0.89) in the first month after IRS.	Adding RIT to an intensive routine Aedes control programme has a transient effect on the already moderate low entomological infestation levels, while ITC did not have any effect. evidence impact on disease.

Author (Year)	Title	Journal	Method	Results	Conclusion
Abuaku et al. (2018)	Impact of indoor residual spraying on malaria parasitaemia in the Bunkpurugu-Yunyoo District in northern Ghana	Parasites and Vectors	Observational study	The end of high transmission season prevalence of asexual parasitaemia declined marginally from 52.4% (95% CI: 50.0–54.7%) to 47.7% (95% CI: 45.5–49.9%) following 2 years of IRS with alpha-cypermethrin. Prevalence declined substantially to 20.6% (95% CI: 18.4–22.9%) following one year of IRS with pirimiphos-methyl.	The use of a more efficacious insecticide for IRS can reduce malaria parasitaemia among children less than 5 years-old in northern Ghana.
Abong'o et al. (2020)	Impact of indoor residual spraying with pirimiphos-methyl (Actellic 300CS) on entomological indicators of transmission and malaria case burden in Migori County, western Kenya	Scientifics Reports	Observational study	IRS was associated with reductions in <i>An. funestus</i> numbers in the intervention areas compared to non-intervention areas by 88% with light traps (risk ratio [RR] 0.12, 95% CI 0.07–0.21, $p < 0.001$) and 93% with PSC collections (RR=0.07, 95% CI= 0.03–0.17, $p < 0.001$).	Malaria case counts among febrile patients within IRS areas was lower post-compared to pre-IRS by 44%, 65% and 47% in Rongo, Uriri and Nyatike health facilities respectively.
Gogue et al. (2020)	An observational analysis of the impact of indoor residual spraying in Northern, Upper East, and Upper West Regions of Ghana: 2014 through 2017	Malaria Journal	Observational study	District-level analysis from Northern Region from 2015 to 2017 of the aggregate malaria incidences reported from IRS districts relative to non-IRS comparator districts showed 39%, 26%, and 58% fewer confirmed malaria cases reported from IRS districts in 2015, 2016, and 2017, respectively. In Upper East Region reported malaria cases of withdrawing IRS from the region was striking; after spray operations were suspended in 2015, incidence increased an average of 485% per district (330% to 640%) compared to 2014.	The positive contribution of IRS with a 3GIRS product to malaria control programmes in northern Ghana and the value of using routine surveillance and implementation data to rapidly assess the impact of vector control interventions in operational settings, even in complex implementation environments.

DISCUSSION

This study concludes that IRS can reduce the occurrence of dengue haemorrhagic fever. IRS reduces the likelihood of observing adult mosquitoes by >70% up to 12 weeks post spraying and experimental research in Cairns, Australia indicates IRS led to 86-96% reduction in dengue cases in sprayed premises, compared to unsprayed controls. All of these results indicate high IRS efficacy. Regarding durability, current IRS insecticides last an estimated three months, but new formulations might last as long as five to eight months (Paredes-Esquivel et al., 2016).

Our results indicate that IRS-like interventions are promising approaches to dengue control, but the ideal implementation of these interventions is location-specific. In addition to identifying optimal timing, intervention programs should incorporate a plan for continued monitoring to assess effectiveness and epidemic dynamics. Because of the high level of initial effectiveness in endemic regions, IRS might be combined with other approaches to accomplish local elimination, but new dengue introductions would have to be diligently prevented. The safest and most likely scenario to maintain long-term effectiveness is to combine a wide-spread vector control program with an efficacious vaccine to replace the natural immunization (Hladish et al., 2018).

Sibanda et al. (2011) stated that the knockdown effect of the IRS was consistently higher on brick walls than in unpainted wood walls ($p < 0.05$). This is consistent with results obtained by Etang et al. (2011) in Cameroon, which found that the residual effect of IRS using deltamethrin WG on malaria vectors lasted 26 weeks on brick walls and 15 weeks on wood walls. The presence of open roof eaves to provide ventilation in this tropical environment may negatively affect the residuality of pyrethroid insecticides used in IRS, as insecticide degradation can be tri-

ggered by climatic conditions, such as high temperatures and UV light exposure.

For human dengue infection parameters, there are only two IRS studies. Odds of dengue infection shown by Vazquez-Prokopec et al. (2010), in Australia, were significantly higher at unsprayed than at sprayed premises (OR = 2.8; 95%CI = 1.1-6.9; $p = 0.03$). When 60% of the premises were sprayed around the index case house the odds reduced significantly to zero. Also, the number of dengue cases was strongly and positively correlated to the number of IRS applications ($r > 0.6$). Also, in Taiwan, the number of cases reported over time, dropped with IRS applications from above 3000 to 1000 (no control).

In addition, none of the included studies examined the associated costs of indoor spraying. In Australia however, where IRS is used for dengue control, a cost-analysis shows that the total costs of preparedness through surveillance are far lower than the ones needed to respond to the introduction of vector-borne pathogens (Vazquez-Prokopec et al., 2010). Universal application and re-application are likely beyond the resources of many dengue-affected countries. Therefore, effective use of indoor spraying will require timely surveillance and response mechanisms.

While there is evidence for indoor spraying in the control of dengue, there are a number of challenges with scaling up such interventions. Since, indoor spraying can require high levels of coverage, which requires widespread community acceptance and participation. Few studies included in the review reported qualitative estimates of community acceptance, although IRS is often popular as it has the ancillary benefit of killing many nuisance insects [1,4]. However, Chang et al. (2011) emphasised how communities are still reluctant to take appropriate dengue control measures, psychological cha-

nges involved in the adoption of healthy lifestyle. Furthermore, suggested integrating sustained social participation into IVM activities like source reduction, biological control, and environmental management, in order to overcome such a challenge and to ensure long-term sustainability of dengue prevention and control.

Concluding, evidence obtained from this systematic review showed that the use of IRS and ISS can produce significant reductions of *Aedes* populations (adult and immature forms). IRS can also produce significant reductions in human dengue cases, with very limited available evidence, but no data are available for ISS.

AUTHORS CONTRIBUTION

all authors contributed to this research starting from select research topics, search for articles, process articles, and create publication manuscripts.

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CONFLICT OF INTEREST

There is no conflict of interest in this study.

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