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Twenty Years of Trend in Research on *Aedes sp*. Vector Control: a Bibliometric Analysis

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Abstract

Due to their contribution to over a fifth of all infectious diseases, vector-borne diseases continue to be a health burden. One of the key strategies for tackling the issue of vector-borne disease is limiting vector density. This study intends to identify published research themes, research techniques, and research areas connected to vector control strategies. A bibliometric analysis of 10492 journal articles from Scopus, PubMed, and Wiley Online Library, was done for this study between 2003-2023. The collected articles are used to extract themes using VOSviewer. Insecticide fogging, pet traps, deltacide, eco-friendly control tools, repellant, gravitrap, vectobag, altosid, biological insecticide, and more were among the ten topics of vector control approaches that received the least amount of information. The five research techniques with the lowest frequency are as follows: randomized controlled trial, systematic literature review, longitudinal study, literature review, and intervention study. The majority of study fields originate in Brazil, India, Europe, Mexico, and Thailand. Future studies must therefore focus on mechanical and environmentally responsible vector control techniques, such as gravitrap, eco-friendly control instruments, pet traps, and biological insecticides. Randomized controlled trials and longitudinal studies are indicated as research approaches with a lot of potential for usage in the future. An excellent opportunity exists for Indonesia to conduct study on these topics.

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INTRODUCTION

Health development with currently developed resources and technology gives hope for achieving success as targeted. However, there are still challenges and obstacles; the increasing burden and threat of vector-borne diseases is one example. 80% of the world's human population is at risk from one or more vector-borne diseases. Globally, 17% of the total infectious disease burden is vector-borne. Every year, more than 700,000 deaths are caused by vector-borne diseases. Vectors that play a major role in

transmission include mosquitoes, Triatomine bugs, ticks, snails, sandflies, Mites and Lice, Flies, and Fleas (1).

One of the main mosquito vector-borne diseases is dengue, besides malaria. Dengue fever is the most common viral infection transmitted by *Aedes sp.* mosquitoes besides Zika, Chikungunya and Yellow fever viruses. More than 3.9 billion people in 129 countries are at risk of contracting dengue fever. An estimated 96 million cases with symptoms and around 40,000 deaths each year (2). WHO target in 2030 the case fatality rate (CFR) decreased to 0.0% compared to 2020 0.8%. The number of countries capable of rapid detection and response to dengue outbreaks has increased from 8% in 2020 to 75% in 2030. The next target is to reduce the incidence rate by 25% from 3.1 million in 2020 to 2.35 million in 2030 (3). This target can be achieved through various strategies, one of which is increasing innovation in vector control.

Vector control efforts to reduce the burden of vector-borne diseases, especially dengue, have challenges, including environmental factors, changes in habitat and climate change due to population growth, urbanization and industrialization. In addition to environmental factors, other challenges are policy factors and the movement of people (1). In addition to challenges, vector control efforts also have opportunities, one of which is innovation in Aedes vector control technology. Development of new tools, technologies and approaches such as insecticides with new formulations (4), vector traps and bait (5), biocontrol through Wolbachia spp (6), genetic modification to reduce population density or population replacement (7), sterile vector forms (8), spatial repellents(9) and vapor active insecticides(10), and housing improvements to exclude vectors and reduce favorable harborages(11).

Innovation in *Aedes sp.* vector control methods cannot be separated from studies conducted in various regions. In 2016, Maha Bouzid et all. conducted a meta-review of 13 systematic review articles on Aedes vector control methods. The results show that the success of a control program depends on local conditions, type of intervention, resources, and duration of research. No information shows a picture of the types of technology studied in the last 20 years globally. Therefore, this paper will describe the themes of the types of *Aedes sp* vector control methods, research methods used, and research areas from journals published in 2003-2023.

Methods

Data source

This study used 3 databases: PubMed, Scopus, and Wiley Online Library (WOL). PubMed is a database containing references and abstracts on natural science and biomedical themes. Over 35 million citations to the biomedical literature from Medline and resources from the National Library of Medicine USA. (12) As of 2017, PubMed contained 27.5 million articles from around 7000 journals.(13) Scopus is one of the largest combined curated databases, abstracts and citations from comprehensive literature journals, books, seminar proceedings, etc. Scopus covers more than 240 disciplines. More than 1.8 billion references are cited; each article indexed is 10-15% more than any other database.(14) Scopus indexes 66.07% more journals than the Web of Science and Dimensions, especially in life sciences, physics and technology.(15) WOL is a database service that has the world's largest collection of multidisciplinary sciences between natural sciences, health, physics, and social humanities. More than 1,600 journals, 22,000 ebooks, and more than 250 other types of references.(16) Bibliography related to research on Aedes sp. vector control. Of the three databases will be carried out starting June 2023.

Study design

Bibliometric analysis was used to prepare this paper to find the most favorite journals related to the publication regarding the scope of *Aedes Sp.* vector control. Which includes the number according to the highest order ranking, the country of issue, the indexation quartile category and the impact factor. This refers to the latest related papers; analysis based on search keywords is used to obtain rankings according to the number of words or phrases whose frequency is rarely researched. The searched word or phrase is related to vector control methods, research methods, and research areas. Keyword linkages and networks based on the research period are presented as a mapping chart, resulting from the free tool VOSviewer version 1.6.18. Bibliometric analysis is a statistical method to show an overview of the development of knowledge and information from studies or research and other information such as journal identity and frequency of keyword similarities.(17)

Search strategy

Search for keywords for paper themes using "vector control" and the MeSH term "Pest Control" OR "Pest Management" AND "Aedes." MeSH (Medical Subject Headings) is the NLM-controlled vocabulary thesaurus used for indexing articles for PubMed.(18) The Scopus and WOL databases use "Aedes" AND "Vector Control." Search restrictions on 3 databases were carried out covering the year of publication 2003-2023; keywords were obtained from titles, abstracts, and documents in the form of journals. Management to eliminate duplication used free software, namely Endnote version 21 free trial; 10492 documents were obtained.

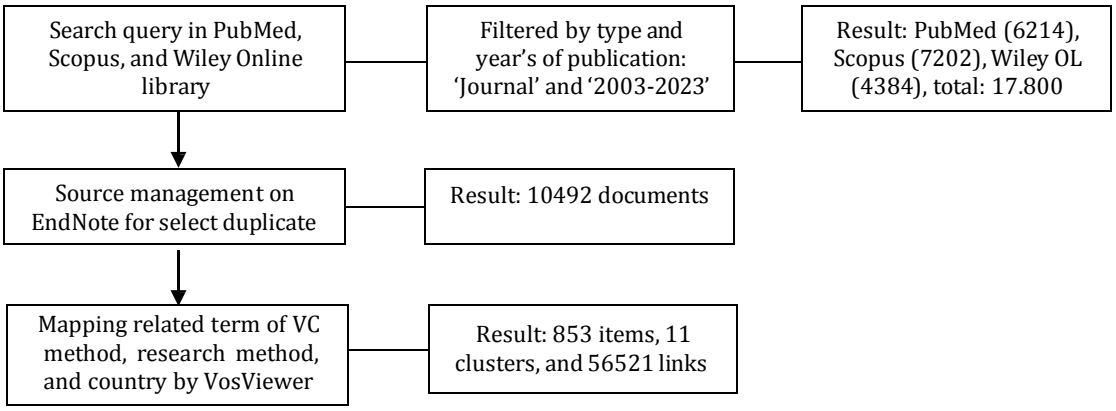

Figure 1. Bibliometric study strategy

Data Analysis

All documents compiled from EndNote were transferred to VOSviewer, then extracted words or phrases based on the similarity of events in the title and abstract. The full counting method and a minimum number of occurrences of 10 were used. Then, a selection was carried out, and words unrelated to *Aedes sp* vector control were not selected (verify selected terms), resulting in 853 items with 11 clusters and 56521 links. VOSviewer is a useful program in bibliometric network analysis. Publication mapping can be based on citations, link networks, or keyword mapping can also be made based on shared occurrence networks(19) This paper will describe the distribution according to the keyword groups of vector control methods, research methods, and location countries.

Results

The reputation of a scientific paper is influenced by many factors, one of which is the quality of the journal where the article is published. The more people who cite written works, the higher the h-index and impact factor will be indicators of recognition by the academic world for their existence and quality. The following are the journals obtained from the three databases that have published the most research results on *Aedes sp.* vector control.

Table 1.
20 Top Journals Based on the Number of Published Articles on *Aedes sp* vector control

No	Journal Name	Publisher Country	Publication			
			N	%	Quartile Category(Q)	IF
1	PLoS Neglected Tropical Diseases	United States	555	5.28	1	1.30
2	Parasit Vectors	United Kingdom	435	4.14	1	0.96
3	Journal of Medical Entomology	USA oxford	442	4.2	1	0.69
4	Journal of the American Mosquito Control Association	United States	400	3.81	3	0.39

5	PLoS One	United States	310	2.95	1	0.89
6	Journal of Vector Ecology	United States	254	2.42	2	0.46
7	Medical and Veterinary Entomology	United Kingdom	246	2.34	1	0.64
8	Acta Tropica	Netherland	234	2.23	1	0.75
9	Insect Molecular Biology	United Kingdom	171	1.63	1	0.79
10	Pest Management Science	United Kingdom	169	1.61	1	1.02
11	Parasitology Research	Germany	160	1.52	1	0.6
12	Insects	Switzerland	125	1.19	1	0.79
13	American Journal of Tropical Medicine and Hygiene	US	124	1.18	1	1.04
14	Scientific Reports	United Kingdom	124	1.18	1	0.97
15	Tropical Medicine & International Health	United Kingdom	109	1.03	2	0.79
16	Parasites and Vectors	United Kingdom	79	0.75	1	0.96
17	Entomological Research	United Kingdom	72	0.68	3	0.33
18	Tropical Biomedicine	Malaysia	70	0.67	3	0.27
19	Viruses	Switzerland	69	0.66	1	1.29
20	Journal of the American Mosquito Control Association	US	66	0.63	3	0.39
	Total		**4214**	**40.1**	**Rerata**	**0,77**

Table 1 shows that 70.0% of journals are included in the 1st quartile category; this means that most of the Aedes sp vector control research themes have been published in highly reputable journals. The most favorite journal for publication is PLoS Neglected Tropical Diseases (PNTD) (5.28%) with an impact factor of 1.3. Journals in quartile 3 include the Journal of the American Mosquito Control Association, Entomological Research, and Journal of the American Mosquito Control Association. Most of the published Q1 journals come from America; there is only 1 from the Netherlands, namely Acta Tropica and from Switzerland, namely Viruses. There is only 1 journal from Southeast Asia out of the top 20 journals, namely Tropical Biomedicine from Malaysia. Journals with more than 1 impact factor come from America, only 1 outside America, namely from Switzerland. The smallest impact factor is 0.27 (Tropical Biomedicine Journal).

Table 2.
Frequency Distribution of The 10 Smallest Species and The 5 Largest Items Relevant to *Aedes sp*. Vector Control. Includes the Vector Control Methode, Research Methode, and Field Study

No	Vector Control Methode	F	%	Research Methode	F	%	Field	F	%
1	Insecticide fogging	10	0.09	Systematic literature review	10	0.09	Armenia	10	0.09
2	Pet trap	10	0.09	Longitudinal study	13	0.12	East Mediterranean	10	0.09
3	Deltacide	11	0.10	Randomized controlled trial	14	0.13	Guangzhou	10	0.09
4	Eco friendly control tool	11	0.10	Literature review	17	0.16	Kosovo	10	0.09
5	Reppelent	11	0.10	Intervention study	18	0.17	Oceania	10	0.09
6	Gravitrap	11	0.10	Field survey	21	0.20	Rio de jeaneiro	10	0.09
7	Vectobac g	11	0.10	Epidemiological study	23	0.22	South Asia	10	0.09
8	Altosid	12	0.11	Case control study	23	0.22	South Korea	10	0.09

9	Biological insecticide	12	0.11	Collection method	29	0.27	Tunisia	10	0.09
10	Clove oil	12	0.11	Laboratory experiment	45	0.43	Barcelona	11	0.10
1	*Bacillus thuringiensis*	510	4.86	Cross Sectional study/survey	71	0.67	Thailand	352	3.35
2	Essential oil	811	7.72	Meta Analysis	82	0.78	Mexico	427	4.07
3	Trap	1275	12.15	Cohort	105	1.00	Europe	428	4.08
4	*Wolbachia*	1350	12.87	Systematic review	115	1.09	India	477	4.54
5	Insecticide	1661	15.83	Trial	581	5.54	Brazil	863	8.22
	Ovitrap	546	5.2				Indonesia	169	1.6
	Oviposition trap	62	0.59				Yogyakarta	32	0.3
	Lethal Ovitrap	52	0.49						

The recapitulation results of keyword items related to vector control methods found that Insecticide fogging and pet traps were the smallest research themes (0.09%). Related to the research theme of tools or traps, which are still considered rarely disclosed are eco-friendly control tools and gravitrap (0.10% each). Most studies of *Aedes sp* vector control methods over the last 20 years were regarding the application of Insecticide (15.83%), *Wolbachia* (12.87%), and traps (12.5%). Research on traps, specifically the ovitrap as much as 5.2%, oviposition trap (0.59%), and lethal ovitrap as much as 0.49%. .

Most of the research methods used were trials (5.54%), especially randomized controlled trials, only 0.13%. Systematic literature review is the smallest writing method (0.09%), but it was found that the use of the term systematic review was 1.09%—experimental laboratory of 0.43%, more than the field survey (0.20%). In the longitudinal study, it is known that the primary research method is the smallest, namely 0.12%; it is also known that the observational cohort is 1.00%. At the same time, the case-control (0.22%) is smaller than the cross-sectional method (0.67%).

Based on the research location, it is known that the smallest are Armenia, East Mediterranean, Guangzhou, Kosovo, Oceania, Rio de Janeiro, South Asia, and Tunisia (0.09% each). The highest research contribution came from Brazil (8.22%), followed by India (4.54%), Europe (4.08%), and Mexico (4.07%). Thailand is a Southeast Asian country, which is also a large country (4.07%, the 5th largest after Mexico) as a research location related to Aedes sp. vector control. Especially Indonesia found in 1.6% of the paper and the city of Yogyakarta by 0.3%. So Indonesia, in the 3 databases in Scopus, PubMed, and Wiley online library, contributed 1.9%.

Figure 2. Social Network Analysis of Vector Control Method, Research Method, and Field of Study at *Aedes sp* Vector Control (2003-2023)

Research trends in *Aedes sp* vector control, around the end of 2017 until now, have studied a lot about autocidal gravid ovitrap, ago traps, bacterial species, clove oil, and *Aedes sp* presence. Apart from that, the application of bendiocarb, pyrethroid resistance, and adult bioassays are among the most recent studies. The research locations are in Mexico, Tunisia, Ecuador, Congo, Makkah, Lahore, Punjab and South Texas. From early 2014 to late 2016, research studies were dominated by issues of insecticides and their resistance, genes and activity, trap and oviposition, attractant, and repellent. Larvacidal bioassay and spraying were also research topics at that time. Around 2012, most of the research themes included mosquito traps, control traps, adult traps, vectors, oviposition response, gravid traps, and BTi resistance. Research locations at that time included Sao Paolo, Haiti, Korea, France and America. Trials and reviews have been seen starting around 2015 to be used more as a research method.

Discussion

This study is based on searching the same words from different journals; in this case, from 3 databases, the system (VOSviewer) will show all the results. However, they are shared according to the criteria, namely those still within the scope of *Aedes sp.* vector control. This approach will make it easier to find information from large databases. The research themes that have been carried out previously will form the basis for the development of further research materials that are up-to-date and as needed to contribute to problem-solving, in this case, the problem of disease transmission by the *Aedes sp*. vector. The principle of this approach is to extract important information and textual patterns from paper documents or journals so that scientists can process and explore previously researched methods and technologies.(17)

From the 3 databases of Scopus, PubMed, and Wiley Online, it was found that 20 journals serve as publications on Aedes vector control, almost three-fourths of which fall into the Q1 category. This shows that the three databases are worthy of being a reference for research results on Aedes sp. vector control. The Scopus platform provides data access through search, find, and analysis options. The find option facilitates users to identify collaborators, organization of research results and published data regarding various metrics such as keywords and mutual references.(15) In addition to the metadata records, Scopus provides comprehensive author and institutional profiles derived from manual profiling and curation algorithms and ensures precision. The credibility of Scopus lends to its use as a source of bibliometric data for large-scale analyses in research assessments, research landscape studies and science policy evaluation.(20) The latest version of the PubMed website, introduced in 2020, can collect and service research results in the health sector with high-quality and freely accessible information.(21) The advantage of the Wiley online library is that it provides free or low-cost online access to research in developing countries and helps strengthen publishing and authorship in developing countries.(16) Publishing journals from Asia, especially Southeast Asia, have yet to contribute much to publishing articles on *Aedes sp* vector control. This has proven to be the only journal in the top 20 journals with the most publications for this issue, and even then, only Q3.

The theme of research in the field of *Aedes sp* vector control over the last 20 years is still dominated by the theme of insecticides (more than 15.0%). This shows that chemical vector control of *Aedes sp* is still a favorite research theme. Chemical control is the application of both natural and synthetic compounds that have insecticidal properties to reduce mosquito populations in the environment.(22) Plant-based insecticides are an alternative to chemical ones because they are more easily degraded and less harmful to the environment, as well as lower toxicity to non-target insects.(23) The study of plant-based insecticides is a study that still needs to be developed because research on "eco-friendly" is still relatively small (0.1%). An environmentally friendly vector control method, namely mechanically with the application of traps and research themes which are still relatively small in biology and chemistry (0.09% pet trap, 0.59% oviposition, 0.49% lethal ovitrap, and 5.2% ovitrap). Ovitrap can be used to detect *Aedes sp* vectors at an early stage and can function as an alarm indicator for outbreak predictions. Ovitrap is sensitive for detecting the presence of *Aedes* mosquitoes, providing efficient and precise data for outbreak prediction.(24)

The research method used in research on *Aedes sp* vector control is Trial, but randomized controlled trials are still small. This shows that only some still carry out research with high accuracy and validity compared to other research methods, for example, observational. The RCT method for *Aedes sp* vector control still needs to be developed to provide evidence of the real impact of complex interventions, including biological control, on life.(25) Longitudinal study is also an approach that is rarely used. Longitudinal studies are suitable for research on the surveillance of vector densities and the impact of intervention programs.(26)

The research results on *Aedes sp* vector control are mostly from tropical countries such as Brazil and India. This is due to the large burden of dengue cases suffered by countries in tropical regions such as Bangladesh, Philippines, Vietnam, India, Maldives, Indonesia, Singapore, Colombia, Paraguay, Peru, Kenya, Fiji, Cook Islands, Reunion Islands, Sri Lanka, Thailand, Sudan, Mauritania, Timor-Leste, Yemen, Nepal, Mayotte, Ecuador and Brazil.(1) Indonesia is still a country that contributes to the dengue problem in the world. Therefore, it is still possible for Indonesia to conduct more research on both the scope of the impact and the control program.

Insecticides are still the most research theme from 2023 to 2023 for the control of the *Aedes sp.* vector. Most of its control still depends on insecticides in the larval phase and adult mosquitoes indoors and outdoors. However, insecticide resistance has developed in *Aedes sp.* populations worldwide, and it is evident that this resistance interferes with the success of interventions.(27)(28)(29) Therefore, starting at the end of 2017 until now, research on mechanical vector control, namely traps, has begun to attract researchers in the field of vector control along with studies of natural insecticides that are more environmentally friendly (autocidal gravid trap, clove oil) followed by studies of insecticide resistance. Plant-based insecticides are an alternative to chemical ones because they are more easily degraded and less harmful to the environment. In particular, essential oils containing terpenoids, phenylpropanoids, thiophenes, amides and alkaloids also have larvicidal activity.(23) In the future, research on vector control, especially *Aedes sp.*, needs to be developed to find more effective and environmentally friendly controls to anticipate the spread of resistance to existing chemical insecticides.

Conclusions

As long as the dengue problem remains a public health burden, developing vector control technology remains a priority before a high-effectiveness dengue vaccine is found. The research theme on Aedes vector control that has dominated for the last 20 years (always every time) is about insecticides. But lately, research on vector control mechanically (trapping) with a combination of natural insecticides has become quite an interesting research topic to follow up. RCT is an approach that can also be a focus for the development of vector control research so that it can produce more accurate and valid evidence despite the many challenges in its implementation. Indonesia, as one of the tropical countries with a high burden of dengue disease in terms of public health, has become a location for research on vector control topics that are quite large after Thailand, Brazil and India.

Author Contributions

Suharyo contributed to the design and writing of the manuscript; Mursid R, Martini, and Muh. Fauzi supervised and critically revised the final version of the manuscript; All authors have read and agreed to the published version of the manuscript.

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