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A REVIEW OF BED NETS USAGE AND SEWERAGE CONDITIONS AS RISK FACTORS FOR LYMPHATIC FILARIASIS IN DEVELOPING COUNTRIES

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Abstract

Introduction: *Lymphatic filariasis is a neglected tropical disease (NTD) caused by microscopic worms that live only in the human lymphatic system. Physical environmental factors play a role in preventing filariasis, especially the presence of breeding places and contact with mosquitoes. The aim of this study was to describe agent, vector, and physical environment risk factors such as bed net usage and sewerage conditions for lymphatic filariasis in developing countries.* ***Discussion:*** *This study was conducted using the narrative literature review method. The main sources for this study were articles from Google Scholar, Research Gate, PubMed, Springer, Scopus, and DOAJ databases with the criteria published between 2012 and 2022, observational studies including cross-sectional, case-control, and cohort designs, open access, and articles were organized according to STROBE guidelines. Out of the 100 articles identified, only 14 articles fulfilled the predetermined criteria after undergoing screening and removal of duplicate articles. The study was carried out in a group of developing country, including India, Myanmar, Indonesia, Nigeria, Ethiopia, Democratic Republic of Congo, Republic of Congo, Zambia, and United Republic of Tanzania. Wuchereria bancrofti is the most common agent of lymphatic filariasis. Culex and Anopheles are the vectors. The presence of bed nets and sewerage conditions were physical environment risk factors for lymphatic filariasis in developing countries.* ***Conclusion:*** *The use of mosquito nets or insect repellent at night can prevent lymphatic filariasis. In addition, open drains should be cleaned regularly to prevent them from becoming breeding sites for mosquito as vectors.*

INTRODUCTION

Public health issues related to infectious illnesses persist, with lymphatic filariasis remaining a challenge in Indonesia and globally (1). This disease threatens up to 863 million people in 47 countries worldwide (2). Lymphatic filariasis is a neglected tropical disease (NTD) caused by filarial parasites, including *Wuchereria bancrofti*, *Brugia malayi*, and *Brugia timori*, transmitted through mosquito bites. This disease can occur worldwide, both in tropical and subtropical areas. The infection that ensues could cause lymphedema, elephantiasis, and hydrocele–all of which are chronic conditions that can be severely disabling (3).

Lymphatic filariasis rarely has fatal consequences, but its clinical manifestations bring serious, debilitating individual and socioeconomic consequences for those infected and those affected (4). Lymphatic filariasis can lead to permanent disability by enlarging the legs, arms, breasts, and genitals in both women and men (5). Irreversible disabilities can impede employment, reduce access to services and lead to social stigmatization of the person and their family. Furthermore, the clinical symptoms associated with this disease have considerable effects on the mental health of the person affected, especially if the morbidity and disability associated with the disease are not adequately managed (6).

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Thus, lymphatic filariasis is the second leading cause of disability worldwide after mental illness, estimated to cause 5,549 million disability-adjusted life years (DALYs) (7).

The World Health Organization (WHO) launched the Global Program to Eliminate Lymphatic Filariasis (GPELF) with two main strategies: preventive chemotherapy to disrupt the transmission of lymphatic filariasis and managing the morbidity associated with the disease (8). The number of lymphatic filariasis cases has reduced by 74% since the initiative to eradicate the disease began in 2000, affecting approximately 51 million individuals in 2018 (9). In 2020, the World Health Organization reported a total of 186,036,248 cases of treated lymphatic filariasis globally. The most affected nation was India, followed by Nigeria, Mozambique and Myanmar. Indonesia ranked fifth worldwide, with a population count of 13,565,163 (10). All five countries were considered as developing countries, denoting a weak health system. In developing countries, nearly 8 million individuals die each year from avoidable illnesses. A robust healthcare system, facilitated by the government and healthcare providers, can help to prevent these deaths (11). Furthermore, the absence of clean water supply, insufficient sanitation facilities, low income, and inhabitable housing conditions facilitate the breeding of filarial mosquito vectors. This is also the reason for the increasing prevalence of lymphatic filariasis cases in developing countries (12).

Environmental factors have a significant impact on the spread of lymphatic filariasis. These include the physical, biological, social, economic, and cultural environment. Environmental factors and conditions such as urbanization, insufficient waste disposal management, and poor sanitation conditions can lead to increase the number of breeding sites for malaria vectors. This will affect the transmission of parasitic agents of lymphatic filariasis, especially in endemic areas (13). Compared to the biological environment, such as the presence of water hyacinth or other factors, the physical environment, such as the presence of a sewerage system, is commonly found in the surrounding environment and near communities, particularly in residential areas. Furthermore, open and unmarked sewers have a greater probability of turning into mosquito breeding grounds. The use of mosquito nets is also one of the government's continuing filariasis prevention programs (12).

In terms of physical environmental factors, research conducted in India shows that the presence of open drainage systems, such as U-ditches, and other mosquito breeding sites could amplify the risk of lymphatic filariasis by 24.6 times and 2.1 times, respectively (14). In addition, a study in Indonesia found that people who did not use bed nets at night were seven times more likely to develop lymphatic filariasis than those who did (15). Therefore, we further examine to understand the relationship between the sewerage conditions and the frequent use of mosquito nets and the incidence of filariasis in the community, especially in developing countries where filariasis remains endemic in some areas. This study aimed to describe agent, vector, and physical environmental risk factors such as bed net usage and sewerage conditions for lymphatic filariasis in developing countries through a comprehensive literature review, using narrative review method.

DISCUSSION

This literature review explores scientific articles that study the agent, vector, and physical environment risk factors associated with lymphatic filariasis, a neglected disease. The keywords used were "filariasis" OR "lymphatic filariasis" OR "elephantiasis" AND "environmental" OR "physical environment" AND "risk factors". The PRISMA methodology for systematic reviews and meta-analyses was used to collect the articles. The inclusion and exclusion criteria in the STROBE guidelines were used as a basis for adapting the flowchart method.

The inclusion criteria include articles published in national journals between 2012 and 2022, ranked at least Sinta indexed 3, or Scopus for international journals. The articles should be full-text articles and open access, discussing lymphatic filariasis's agent, vector, and physical environmental risk factors. Cross-sectional, case-control, and cohort research designs were acceptable. The language of the articles should be either Indonesian or English. The literature search utilized online databases including Google Scholar, ResearchGate, PubMed, Springer, Scopus, and the Directory of Open Access Journals (DOAJ).

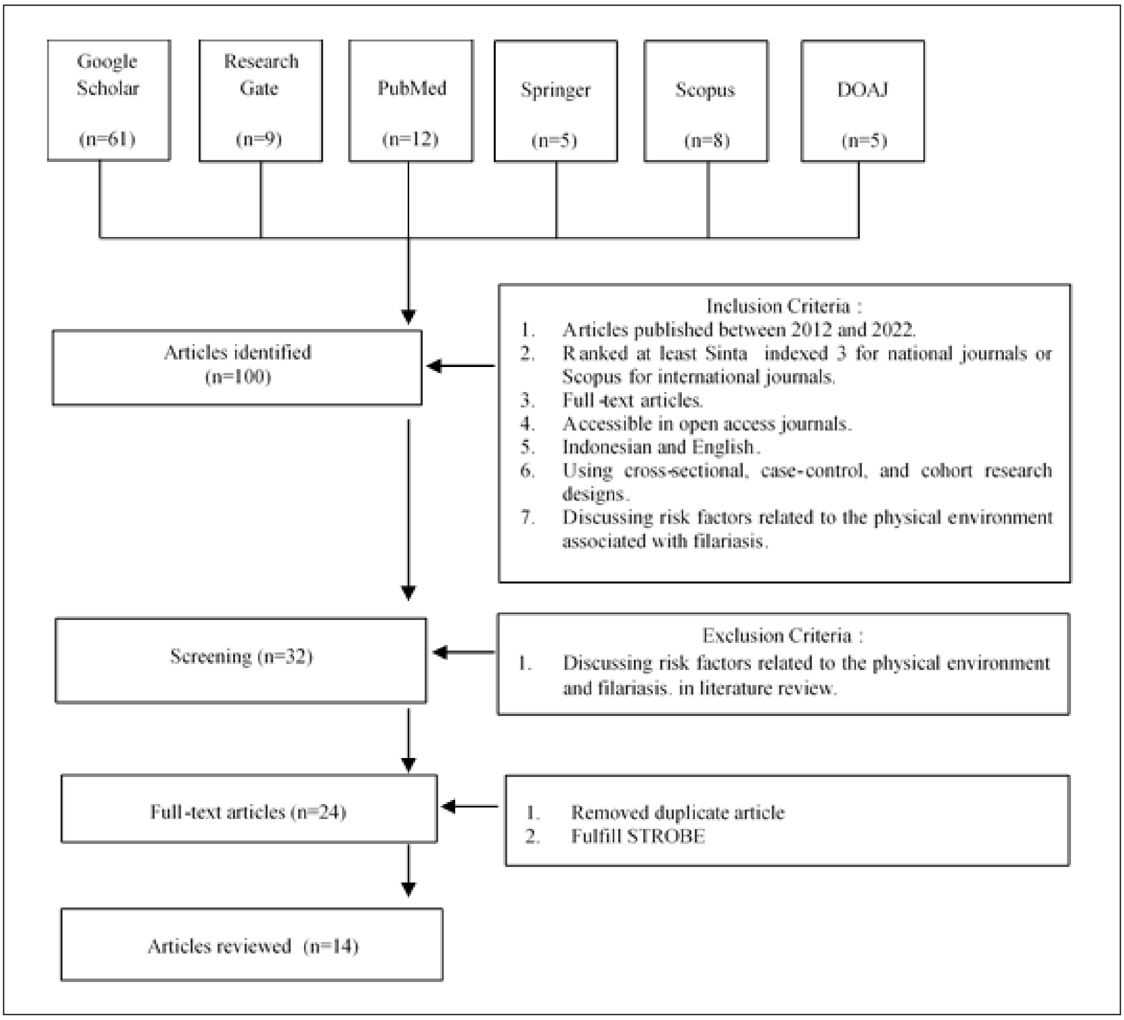

Figure 1. PRISMA Flowchart

This study found that, out of 100 articles identified, 14 articles aligned with the predetermined criteria and following the STROBE guidelines. The study criteria encompassed eight developing countries, namely India, Myanmar, Indonesia, Nigeria, Ethiopia, the Democratic Republic of the Congo, the Republic of the Congo, and the United Republic of Tanzania, which were featured in the 14 chosen articles. These countries are categorized as developing countries according to the Gross National Income (GNI) statistics of the World Bank.

Agent of Lymphatic filariasis

The countries most commonly studied for lymphatic filariasis are India and Indonesia. Lymphatic filariasis is a tropical disease caused by parasitic nematode infection. This investigation revealed that eight out of 14 studies identified *Wucheria bancrofti* as the causative agent for lymphatic filariasis (12,16–22), while the remaining six articles did not specify the species of agent. Each study had a different method of parasite identification, some used patient blood examination, while others preferred molecular analysis of PCR techniques or examined the mosquitoes under a microscope (18, 22-23).

Reports from both the Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO) indicate that *Wuchereria bancrofti* is responsible for the majority (90%) of all global lymphatic filariasis cases. The remaining cases are mainly caused by *Brugia malayi*, with supplementary causation by *Brugia timori* (16-17). Therefore, given the fact of that statement, the species of Wuchereria bancrofti demands the highest level of vigilance.

Wuchereria bancrofti is endemic in 78 countries and impacts 128 million people globally. This nematode is widely found in the humid and tropical zones of Asia, Africa, America, and the Pacific Islands and is common in areas with low socioeconomic levels. The disease is usually transmitted through bites from infected mosquitoes. Overall, six genera and 70 species of mosquitoes are associated with the spread of *Wuchereria bancrofti* (24). The incubation period of these agents is highly variable and sometimes difficult to determine for both microfilariae and adult worms, which have been observed in patients six months to 12 months after infection (25).

Wuchereria bancrofti has different characteristics between females and males. Female worms range from 80 to 100 mm in length and 0.24 to 0.30 mm in diameter.

In comparison, the male worm has a length of about 40 mm with a diameter of 1 mm. Adult-worms can produce microfilariae with a length of 244 to 296 µm and a 7.5 to 10 µm diameter. These worms are nocturnal or active at night, except for microfilariae from the South Pacific, which do not have a clear periodicity. Adult parasites are generally found in lymphatic vessels and rarely in blood vessels. Microfilariae can live as hosts for up to 12 months. Meanwhile, adult worms take six to 12 months to develop and can live from four to six years in the human body (26).

Research conducted in Masasi, Tanzania, detected *Wuchereria bancrofti* infection in *Culex quinquefasciatus* mosquitoes. Of the 365 groups of containing *Culex quinquefasciatus*, 33 mosquitoes were found to be infected with *Wuchereria bancrofti*. This research found that the probability that each mosquito in each groups was likely to be infected with any stage of *Wuchereria bancrofti* parasite was around 0.5% (22). Another study conducted in two villages in the Democratic Republic of the Congo detected the presence of *Wuchereria bancrofti* through the blood smears method on respondents aged ≥ 5 years. The results showed that the prevalence of *Wuchereria bancrofti* microfilariae (mf) was 11.8% of 820 respondents. The highest prevalence was found in male respondents compared to women (14.4 vs 9.6%) (12). A study in Pekalongan, Central Java, Indonesia, also detected the presence of *Wuchereria bancrofti* antigen in 13 respondents (0.72%) from a total of 1,804 samples aged ≥ 13 years who were examined using the Filarial Test Strip (FTS) method (27).

Apart from *Wuchereria bancrofti* agents, 9-10% of lymphatic filariasis cases are caused by *Brugia spp*. consisting of *Brugia malayi* and *Brugia timori*. *Brugia malayi* is spread throughout South and Southeast Asia, while *Brugia timori* is limited to eastern Indonesia (especially in East Nusa Tenggara Islands) (28). *Brugia malayi* is also endemic to India and can only be found on the western coast of Kerala, India, and in isolated geographical areas in six other states (29).

Microfilariae in *Brugia spp*. has a sheath, 260 µm in length in *Brugia malayi* and 310 µm in *Brugia timori* (30). *Brugia timori* and *Wuchereria bancrofti* have the common color of the body sheath, which is colorless, while *Brugia malayi* is pink. The microfilariae in *Brugia timori* have a longer headroom width and length (1:3) than *Wuchereria bancrofti*. The body nuclei of *Brugia timori* are rough, grouped, and not neatly arranged, whereas, in *Wuchereria bancrofti*, the body nuclei are smooth and neatly arranged and do not overlap. The end of the tail of *Brugia timori* is rather blunt, with two nuclei, whereas in *Wuchereria bancrofti*, the tail end is like a ribbon towards the end and has no core (28).

The previous research in Gampaha, Sri Lanka found two positive cases of microfilariae, giving an overall microfilariae rate of 0.2%. One male case aged 14 years was found to be infected with *Brugia spp* (31). Another study in Belitung, Indonesia, detected 24 positive cases of microfilariae identified as *Brugia malayi*. The highest prevalence of microfilaria was found in males (4.6%) compared to females (2.7%) (32). A study in Sambi Rampas, East Manggarai, East Nusa Tenggara, Indonesia, also found microfilariae identified as *Brugia malayi* as many as 38% of a total of 154 respondents who were identified as positive for lymphatic filariasis (33).

Vector of Lymphatic filariasis

Mosquitoes are vectors for lymphatic filariasis and are generally present in certain geographical locations. Acute symptoms of lymphatic filariasis infection include recurrent fever accompanied by indications of lymph node or duct inflammation. In advanced stages, the disease can cause limb disability by enlarging the legs, arms, breasts, and scrotum (34).

This study reviewed 14 articles and found three articles that looked at mosquito vectors. They found *Aedes spp, Culex spp, Anopheles spp, Mansonia spp*, and *Coquilettidia sp* to be vectors of lymphatic filariasis (19,22,35). Table 1 demonstrates that the selected vector species varied greatly. The most common mosquito vector species were observed in Tanzania, with a total of six species, namely *Anopheles gambiae, Anopheles funestus, Culex quinquefasciatus, Culex sinilius, Coquilettidia spp.,* and *Aedes spp.* Whereas Nigeria's research revealed the least species with four, including *Anopheles gambiae, Anopheles arabiensis, Culex,* and *Aedes* (19,22). Only those articles which mentioned the vector species responsible for lymphatic filariasis analyzed *Culex* and *Anopheles* species. At least 43 *Anopheles* species are responsible for lymphatic filariasis infections in rural Southeast Asia, some parts of the South Pacific, and West Africa (24).

Table 1. Filariasis Vectors Researched in Developing Countries

Country	References	Filariasis Vectors
Indonesia	(Wary Purnama, Nurjazuli, and Mursid Rahardjo) (35)	*Anopheles letifer, Culex vishnui, Culex tritaeniorhyncus, Mansonia uniformis, Mansonia annulifer*
Nigeria	(Tara A. Brant, Patricia N. Okorie, Olushola Ogunmola, Nureni Bolaji Ojeyode, S.B. Fatunade, Emmanuel Davies, Yisa Saka, Michelle C. Stanton, David H. Molyneux, J. Russel Stothard, Louise A. Kelly-Hope) (19)	*Anopheles gambiae, Anopheles arabiensis, Culex, Aedes*

Country	References	Filariasis Vectors
United Republic of Tanzania	(Eliza Lupenza, Dinah B. Gasarasi, and Omary M. Minzi) (22)	*Anopheles gambiae, Anopheles funestus, Culex quinquefasciatus, Culex sinilius, Coquilettidia spp., Aedes spp.*

Table 2. Physical Environmental Factors and Their Relation to the Incidence of Filariasis in Developing Countries

Research Sites	Physical Environmental Factors	
	The Existence of Mosquito Nets	Sewer Conditions
Indonesia	(Zainul Ikhwan, Lucky Herawati and Suharti) (55); (Agus Rahmat, Devi Rahmayanti, Kurnia Rachmawati) (46); (Masrizal, Fivi Melva Diana, Rosifa Rasyid) (44)	(Zainul Ikhwan, Lucky Herawati dan Suharti) (55); (Wary Purnama, Nurjazuli, and Mursid Raharjo) (35)
Myanmar	(Benjamin F.R. Dickson, Patricia M. Graves, Ni Ni Aye, Thet Wai Nwe, Tint Wai, San San Win, Myint Shwe, Janet Douglass, Peter Wood, Kinley Wangdi, William J. McBride) (17)	-
Nigeria	(Obiora A. Eneanya, Tini Garske, Christi A. Donelly) (59); (Tara A. Brant, Patricia N. Okorie, Olushola Ogunmola, Nureni Bolaji Ojeyode, S.B. Fatunade, Emmanuel Davies, Yisa Saka, Michelle C. Stanton, David H. Molyneux, J. Russel Stothard, Louise A. Kelly-Hope) (19)	-
Ethiopia	(Ararsa Negasa, Mebrate Dufera) (18)	-
India	(Sobha George, Teena Mary Joy, Anil Kumar, K.N. Panicker, Leyanna Susan George, Manu Raj, K. Leelamoni, Prem Nair) (20)	(Suryanaryana Murty Upadhyayula, Srinivasa Rao Mutheneni, Madhusudhan Rao Kadiri, Sriram Kumaraswamy, Balakrishna Nagalla) (16)
		(Srinivasa Rao Mutheneni, Suryanaryana Murty Upadhyayula, Sriram Kumaraswamy, Madhusudhan Rao Kadiri, Balakrishna Nagalla) (58)
The Republic of Congo	(Cèdric B. Chesnais, François Missamou, Sébastien D. Pion, Jean Bopda, Frédéric Louya, Andrew C. Majewski, Peter U. Fischer, Gary J. Weil, Michel Boussinesq) (21)	-
United Republic of Tanzania	(Eliza Lupenza, Dinah B. Gasarasi, Omary M. Minzi) (22)	-
Democratic Republic of the Congo	(Cédric B. Chesnais, Naomi-Pitchouna Awaca-Uvon, Johnny Vlaminck, Jean-Paul Tambwe, Gary J. Weil, Sébastien D. Pion, Michel Boussinesq) (12)	-

The genus *Anopheles* and *Culex spp* can transmit nocturnal periodic agents of *Wuchereria bancrofti* to individuals in East Africa, the Middle East, urban Southeast Asia, and Latin America (24).

The species *Anopheles gambiae*, *Anopheles funestus,* and *Culex quinquefasciatus* are the most dominant types of mosquitoes in Tanzania and appear most often during the rainy season, from April to September and December to January (36). In areas with a distinct rainy season, mosquitoes' population densities reach its peak during or immediately after the season and is followed by an increase in infections transmitted by mosquitoes (37). Meanwhile, in subtropical and warm temperate regions, population density peaks in the warmest month of the year (13).

Briefly, mosquitoes can be identified by their structural features, such as head, mouth parts, wings, thorax, abdomen, legs, and scales, to determine their species. Once identified, mosquitoes are counted and sorted into filarial and non-filarial vectors (22). Methods for detecting lymphatic filariasis agents in mosquito vectors can use the Polymerase Chain Reaction (PCR) method and/or dissecting mosquitoes through microscopy. Molecular xeno-monitoring (MX) is a test that detects the presence of microfilariae or larvae in mosquitoes, which reflect transmission at that time; this technique involves collecting and testing hematophagous mosquitoes to detect the DNA or RNA of the lymphatic filariasis parasite. PCR is a diagnostic tool that can detect microfilariae DNA in human blood and mosquitoes through laboratory methods (38). The PCR technique targets the repeated amino acid sequences of *W. bancrofti* DNA (22). Research conducted in Banyuasin, South Sumatra, Indonesia, by analyzing lymphatic filariasis vectors through PCR tests confirmed that only *Mansonia annulifera* was detected as positive as a lymphatic filariasis vector. In that study, *Brugia malayi* was detected as captured *Mansonia annulifera* (39). This corresponds to the data provided by the Indonesian Ministry of Health, indicating that *Brugia malayi* is responsible for 70% of lymphatic filariasis cases in Indonesia (40).

The research in the Masasi, Tanzania, collected 1,822 females *Culex quinquefasciatus* mosquitoes and 37 species of *Anopheles* using light and gravid traps. Light traps are more efficient in capturing *Anopheles* species, whereas gravid traps are more successful in capturing *Culex quinquefasciatus* species. The results of mosquito dissection found that 33 species of *Culex quinquefasciatus* infected *Wuchereria bancrofti*, and all *Anopheles* species tested negative (22).

Further research conducted in areas endemic with lymphatic filariasis in Bogor, West Java, Indonesia, has indicated that the species of *Culex quinquefasciatus* possess significant potential as the primary vector for spreading lymphatic filariasis in both rural and urban area. The high dominance of the species *Culex* *quinquefasciatus* is due to the high density of this mosquito and the habitat conditions that support the development of this species (41). Research in Brebes, Central Java, Indonesia, shows that the *Culex quinquefasciatus* mosquito is the most dominant species (85.25%) and has the highest frequency (0.88%) compared to others. Calculating the average mosquito density showed that the *Culex quinquefasciatus* species had the highest Man Hour Density (MHD). High MHD indicates a high chance of lymphatic filariasis transmission (42). Another research conducted in urban areas in Yaonde, Cameroon, Central Africa, which found that the species *Culex quinquefasciatus* was the most abundant, representing 79.4% of the total mosquitoes identified and was the most dominant species throughout the year due to its high adaptability (43).

Several types of mosquitoes, such as *Anopheles spp*, *Culex sp*, and *Mansonia spp*, have biting activity in the evening, after sunset until sunrise (44). Therefore, bed nets are an effective and useful step to prevent contact with mosquito vectors when sleeping, especially at night, reducing the risk of contracting lymphatic filariasis (45). The mosquito species *Culex sp.* is an anthropophilic mosquito, which has the habit of sucking the blood of its host only at night. The *Culex quinquefasciatus* species was found biting throughout the night from 18.00 to 06.00 Western Indonesia Time, with peak biting activity at 01.00 to 02.00 Western Indonesia Time. The pattern of biting behavior in mosquitoes is critical to know because it is closely related to the spread of diseases such as lymphatic filariasis. This biting behavior can be seen as related to the time of biting and biting behavior patterns in mosquitoes. This provides important information regarding further policy decisions to be taken to eradicate the disease (42).

Table 3. Journal Review

Author	Title	Method	Sample	Result	Summary
Zainul Ikhwan, Lucky Herawati and Suharti (55)	Environmental, Behavioral Factors, and Filariasis Incidence in Bintan District, Riau Islands Province	Case-control study	33 individuals with cases of filariasis and 65 individuals as group originating control from Bintan	- As many as 34.8% of respondents who had a gutter/ ditch and 32.7% of respondents who did not have a gutter/ ditch experienced positive filariasis. - The proportion of people using mosquito nets was 68.4% or 67 respondents. - Respondents who do not have the habit of using a mosquito net have a 1.417 times higher risk of contracting filariasis.	Factors most related to filariasis incidence in Bintan are knowledge, mosquito net use, and the distance between the residence and the swamp. No significant relation was found between the existence of gutters/ditches and filariasis incidence in Bintan.
Agus Rahmat, Devi Rahmayanti, Kurnia Rachmawati (46)	Faktor-Faktor yang Berhubungan dengan Kejadian Filariasis di Kabupaten Barito Kuala	Case-control study	45 individuals from Barito Kuala, consisting of 15 individuals as the case group and 30 individuals as control group	Respondents who did not use a mosquito net had a 6.91 times risk of getting filariasis.	There is a relationship between the habit of using mosquito nets and the incidence of filariasis in Bariton Kuala.
Masrizal, Fivi Melva Diana, Rosifa Rasyid (44)	Spatial Analysis of Determinants of Filariasis-Endemic Areas in West Sumatra	Case-control study	148 individuals from West Pasaman and Agam, consisting of 74 individuals as the case group and 74 individuals as the control group.	- The results of the study in Agam showed that 58.33% of respondents from the cases group and 52.78% of the control group did not use a mosquito net. While the results in West Pasaman showed that 41.67% of respondents from the case group and 47.22% of the control group used a mosquito net. - The results of the study in West Pasaman showed that the use of a mosquito -net was related to the incidence of filariasis (p-value – 0.033).	Education regarding filariasis vector control program and integrated environment needs to be implemented and improved.
Wary Purnama, Nurjazuli, **and** Mursid Raharjo (35)	Faktor Lingkungan dan Perilaku Masyarakat yang Berhubungan dengan Kejadian Filariasis di Kecamatan Muara Pawan Kabupaten Ketapang Provinsi Kalimatan Barat	Case-control study	64 individuals from Muara Pawan, Ketapang Regency, consisting of 32 individuals as the case group and 32 individuals as the control group	Respondent whose homes have breeding places have a 9,345 times higher risk of contracting filariasis. The results of the observation found that there were many breeding places around the respondent's house, including ditches, swamps, rice fields, and ponds that had not been taken care of.	Breeding places are one of the environmental factors that support the occurrence of filariasis around the house.

The Presence of Bed Nets

From this review, it appears that 11 out of 14 studies analyzed the use of bed nets in cases of lymphatic filariasis. However, only six of this study discuss a direct relationship between the two variables. In Tanzania, the highest percentage of respondents who owned bed nets was 80.8%. In Indonesia, the highest percentage of respondents who did not use bed nets and were part of the lymphatic filariasis case group was 80%. There was a significant correlation between bed nets and lymphatic filariasis cases. The finding was corroborated by research that explored the correlation between bed net usage and lymphatic filariasis incidence in Barito Kuala, South Kalimantan, Indonesia. The odds ratio (OR) results showed that someone who did not use bed nets was 6.91 times more likely to be infected with lymphatic filariasis than someone who used bed nets (46).

Research conducted in South West Nigeria also found that respondents who had bed nets had a lower prevalence of lymphatic filariasis (1.3%) compared to those who did not have (4.0%). Among respondents, those who used bed nets while sleeping at night also had a lower prevalence of lymphatic filariasis (1.0%) compared to respondents who did not use them (2.1%) (19). Another study conducted in two villages of the Democratic Republic of the Congo showed an increased risk for *Wuchereria bancrofti* infection in people who did not use bed nets (*p-value* = 0.023) (12).

Other studies in endemic area in West Sumatra, Indonesia, found a relationship between the use of bed nets and the incidence of lymphatic filariasis (*p-value* = 0.033) (44). People who do not use bed nets while sleeping at night have a 5.82 times greater risk of transmitting lymphatic filariasis than those who use bed nets. Mosquitoes generally have the highest biting activity at night. Therefore, using bed nets while sleeping prevents the transmission of lymphatic filariasis (45). In another study, conducted in Southwest Sumba on Sumba Island, East Nusa Tenggara, Indonesia, it was reported that as many as 77% of respondents did not utilize bed nets (47). The respondents' awareness of the use of bed nets needs to be improved. Those who use mosquito nets but use them incorrectly, make them ineffective in preventing mosquito bites. People don't use mosquito nets for sleeping because they're uncomfortable in hot weather.

Research conducted in Ghana rural area also found that the most frequent reason respondents did not own a net was related to mass distribution. As many as 66% of respondents reported not having been given a net, not coming during distribution, or being unable to afford it. Another reason was that 24% of respondents felt they did not need it or did not like sleeping using bed nets, or that the net was damaged (6.6%) (48). Other research conducted in West Sumatra, Indonesia, also states that the behavior of using bed nets is related to economic conditions, where people with low incomes cannot afford to buy them (44).

The most commonly used types of nets are ordinary and insecticide-treated mosquito nets (ITN). ITN is a mosquito net that has been coated with anti-mosquito netting by the manufacturer. Using bed nets sprayed with pyrethroid or permethrin insecticides that can repel mosquitoes, is the way of avoiding mosquito bites. ITN are originally intended for the prevention of malaria, severe illness, and malaria-related deaths in endemic areas. ITNs have been shown to decrease child mortality under the age of five by 20% from all causes in testing sites in African countries (49). For instance, bed nets with permethrin residue are highly recommended for the reduction of lymphatic filariasis (15). Since insect repellents in mosquito bed nets do not harm humans, they are not hazardous to health (7). ITNs aim to protect the public, especially infants, toddlers, and pregnant women who are very vulnerable to diseases caused by the transmission of mosquito bites (44).

One of the physical environmental factors that affect lymphatic filariasis prevalence is the accessibility and use of mosquito bed nets. To minimize the risk of mosquito bites, mosquito bed nets can be implemented as a preventative measure. According to the CDC, preventing mosquito bites is the most effective method to avoid contracting lymphatic filariasis. Mosquitoes that are carriers of microscopic worms typically bite primarily during nighttime, between dusk and dawn (50). Preventive measures to avoid mosquito bites include wearing long sleeves and trousers and using mosquito repellent on exposed skin. Therefore, using bed nets while sleeping is also preventive measure too. Respondents' use of any type of bed nets while sleeping remains an important effort to prevent lymphatic filariasis transmission. However, the use of bed nets will only be helpful when they are used regularly (44).

The environment, the agent (filarial worms), and the host (human) are the risk factors for the occurrence of filariasis. Outdoor activities during the night are one of the triggers caused by host-related factors (44). Nighttime outdoor activities can occur as a result of sociocultural conditions, wherein individuals frequently go out of their homes to chat, watch television together outside, or engage in activities such as sitting in stalls throughout the night (23,42). The habit of staying out late at night has been linked to an increased risk of filariasis in multiple studies (7,12,23,35,42). This is generally caused by job-related activities that extend into the late hours or the habit of gathering outside the home at night. Frequently going outdoors until late at night, when mosquitoes are actively searching for hosts, increases the risk of getting mosquito bites. Therefore, it's crucial for those who frequently go out at night to protect themselves by wearing clothing that covers their bodies, sleeping under a mosquito net, and applying insect repellent. By accomplishing this, the chance of mosquito bites and the spread of filariasis can both be decreased (7).

Research conducted in the Democratic Republic of the Congo found that spending the entire night outdoors is a significant risk factor for microfilariae (mf) (*p-value* = 0.010). This activity increases exposure to mosquitoes (12). A study carried out in Western Indonesia revealed significant correlations between the individuals' habit of going out outside at night and the prevalence of filariasis (p-value = 0.008) (44). Furthermore, additional research carried out in Pekalongan, Central Java, Indonesia, has also shown a strong correlation between the habit of being outdoors at night and the prevalence of filariasis (*p-value* = 0.010) (23).

Work that demands time away from home till late at night can potentially be a factor in the incidence of filariasis. A study conducted in Brebes, Central Java, Indonesia, found that the majority of respondents, before being infected with filariasis, worked as agricultural laborers on onion farms (51). Their jobs primarily involved activities performed in waterlogged fields and during nighttime hours. Other job fields that typically include working late during the night are farmers, oil palm plantation workers, and fishermen (44). Another investigation carried out in Asahan, North Sumatra, Indonesia, revealed a correlation between nighttime work habits and the transmission of filariasis (*p-value* = 0.002). The risk of transmitting filariasis is 4.1 times higher in those who work at night regularly than in people who don't (7).

Those who often go out during the night are 9.345 times more likely to become infected with filariasis than people who do not engage in this behavior (35). Since mosquitoes are actively looking for hosts at night, the individuals' habit of going out during the night increases the prevalence of the risk of filariasis (44). According to previous research, the highest density of *Culex quinquifasciatus* mosquitoes biting occurs between 8:00 pm and 9:00 pm. As a result, the habit of going out at night while mosquitoes are actively seeking hosts increases the possibility of interaction with mosquitoes, raising the risk of filariasis incidence (23).

Sewerage Conditions

Mosquito vector habitats can be natural or artificial. Research conducted in Western Seram, Maluku, Indonesia, collected 200 *Anopheles sundaicus* and *Anopheles aconitus* larvae in rice fields, water ponds where animals trample, water storage outside the house, rainwater in boats, and coconuts filled with water. Some places generally have open spaces (52). Mosquitoes have a preference for stagnant water, both temporary and permanent sites. Common habitats or breeding places for mosquitoes include swamps, lakes, rice fields, puddles, irrigation ditches in rice fields, and sewerage systems (53). Research conducted in Andhra Pradesh, India, revealed that the sewerage systems frequently remain exposed (16). However, the state of the community's sewers and their potential relationship to lymphatic filariasis are rarely addressed in the study findings of related research. This is because limited research has been conducted on sewers, given the variance in environmental conditions and infrastructure across different countries.

Based on the reviewed articles, only three out of 14 assessed sewerage conditions and lymphatic filariasis, with only 4 showed significant correlation. Sewerage encompasses gutters or ditches, swamps, paddy fields, cesspools, cesspits, and drainage. Research conducted in Kuningan, West Java, Indonesia, showed that respondents with poor sewerage were significantly associated with lymphatic filariasis (*p-value* = 0.041; OR = 3.667). In this study, 68.8% of respondents with lymphatic filariasis had poor sewerage systems (54). In another study in Bintan, Riau, Indonesia, respondents who had gutters or ditches around their homes were more likely to be positive for lymphatic filariasis (34.8%) compared to respondents who did not have gutters or ditches around their homes (32.7%) (55).

The prevalence of lymphatic filariasis was most prominent in habitats conducive to breeding such as ditches, swamps, and other locations associated with sewerage, reaching 93.8%. A study conducted in Ketapang, West Kalimantan, Indonesia, observed a 9.345-fold higher likelihood of lymphatic filariasis among respondents residing in homes with breeding sites, compared with those without (35). Environmental observations in Pekalongan, Central Java, Indonesia, found that as many as 90% of houses had mosquito breeding places. Three types of mosquito habitats that are commonly found, namely sewerage, pools and gutter of wastewater. Mosquito breeding sites are most commonly found in wastewater disposal facilities (WWDF) and drainage, with a proportion of 24.4%. This study also found that patients with lymphatic filariasis had more than one mosquito habitat in their homes, such as a combination of gutter, river and under bridges, or the combination of gutter, river, and rice fields (56).

Another research conducted in Semarang, Central Java, Indonesia, also found that the percentage of breeding places around the respondent's house was 64.4%. Mosquito breeding sites were found in open drainage systems, bird drinking bowls, dispensers, bathtubs, stagnant water on the ground and calm rivers (57). In another study in Brebes, Central Java, Indonesia, the distance between breeding places and houses with lymphatic filariasis was 151.15 meters (42). Closer distances between breeding places and houses will increase the chances of contact between humans and lymphatic filariasis vectors through mosquito bites (49).

Two out of four reviewed publications omitted the specification of sewerage closure. According to Upadhyayula's study in Andhra Pradesh, India, respondents living in homes with open drainage systems had a higher proportion of positive test results for microfilaria parasites (4.9%) (16). Research in Andhra Pradesh, India, in 2016 found that mosquito breeding habitats such as cesspits, cesspools, and open drainages lead to a higher vector density and increased risk of lymphatic filariasis transmission. These findings highlight the negative impact of certain breeding grounds on mosquito populations and the potential for disease transmission. It is important to consider these factors when implementing measures to control mosquito populations and prevent disease outbreaks (58). Houses that do not have drainage systems or have ones but are in an open condition have the potential to cause stagnation of wastewater. These puddles of wastewater are very popular as breeding grounds for vectors, causing a high risk of lymphatic filariasis transmission (54).

Research conducted in Brebes, Central Java, Indonesia, found that 33.3% of puddles contained mosquito larvae. In the puddles, 44.44% of the waste was found. Apart from that, sewers were also found to have a 16.05% risk of mosquito larvae. As many as 97.26% of the total drains contain rubbish, and as much as 89.04% do not flow because the rubbish blocks water flow. Such a place is a favorite for mosquitoes as their breeding site. Mosquito larvae are still found in puddles of water, making it a potential place to transmit lymphatic filariasis. Lymphatic filariasis vectors such as the *Culex sp.* mosquito like to breed in dirty stagnant water (42).

Most mosquitoes choose habitats containing domestic wastewater, such as ditches (55.5%). Such places are suitable for the *Culex quinquefaciastus* mosquito species, which usually lay their eggs in water contaminated with organic material such as garbage, human waste, and branches of trees. Apart from drains, used containers such as open boxes or buckets can also be used as breeding places for mosquitoes. Therefore, cleaning up rubbish and closing used containers must also be done to prevent mosquitoes from laying eggs in these places (42).

Mosquitoes, especially the *Culex sp.* species, like polluted water as a breeding site (56). Therefore, sewers within the community must always be cleaned and maintained to reduce the presence of breeding sites for mosquito vectors. Improving the physical environmental conditions, particularly the elimination of stagnant water, is a crucial measure for controlling lymphatic filariasis. One approach is to cover, fill, or drain stagnant water around breeding sites of mosquitos. Traditionally, wastewater was collected through the use of combined storm and sanitary sewers. Nevertheless, the aforementioned strategy can lead to severe overflow and overload of the existing wastewater systems due to heavy rainfall, increased runoff volume and pollutant loads. In other side, during dry seasons, stagnant and polluted sewers can become breeding sites for mosquito vectors. The implementation of effective sewerage systems will prevent the formation of stagnant and polluted pools of water that serve as breeding places for mosquito vectors (54). Another evaluation study of filariasis elimination program, conducted in the villages of Malando and Kahale in the Kodi Balaghar, Southwest Sumba, Indonesia, found that the living environment of the community, while not officially classified as a slum, still requires maintenance. Grass was left uncut and discarded coconut shells trap rainwater, creating mosquito breeding grounds. Public knowledge regarding cleaning the environment as a measure against mosquito breeding was limited and recommended that the local government take prompt and suitable action to address environmental concerns. There were concerns that the incidence of filariasis may increase as a result of inadequate adherence and a lack of behavioral changes and environmental modification to prevent filariasis. Environmental factors have a significant impact on the density of the filariasis vector (57).

CONCLUSION

The most common agent of lymphatic filariasis cases, according to this review, was *Wuchereria bancrofti* found in India and Indonesia. The vectors in relation to lymphatic filariasis were *Culex spp, Anopheles spp, Aedes spp, Mansonia spp, and Coquilettidia sp,* with the first two species being the most common. In developing countries, lymphatic filariasis was associated with physical environmental factors such as bed net usage and sewerage conditions. People residing in areas endemic to lymphatic filariasis, can prevent lymphatic filariasis-transmitting vectors by sleeping inside bed nets, wearing covered-up clothes and using insect repellents to minimize mosquito bites in their outdoor activity during night. Moreover, it is crucial to raise public awareness about the importance of maintaining clean and unclogged sewerage. Regular cleaning of sewerage is necessary to prevent them from becoming breeding sites for mosquitoes that transmit filariasis. The implementation of an effective system for sewerage will also help to prevent the accumulation of dirty water, which can also serve as a breeding place for mosquito vectors. Local governments should prioritize the provision of sanitation infrastructure to address this issue.

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