Research Article

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Comparative Efficacy and Respiratory Safety of Spatial Mosquito Repellents: Humidifier-Based VS Heat-Activated Repellents

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Abstract

Managing indoor mosquito populations requires a careful balance between effective vector control and human respiratory health. This study presents a comparative analysis of two contemporary spatial mosquito repellents: a humidifier-based micro-dispersion system and an established heat-activated system. A bifold methodology is employed, encompassing a controlled indoor insecticidal efficacy test measuring mosquito knockdown rates following a 30-minute operational period in a standard 100-square-foot enclosure and a mammalian safety assessment via a survey of 40 active users (n=20 per device) to evaluate physiological tolerance and perceived utility. Ultimately, this research aims to clarify the optimal balance between rapid vector elimination and zero-impact human safety, and to determine which dispersion mechanism provides a more reliable and user-friendly alternative for sustained indoor residential environments.

Keywords: Spatial Mosquito Repellent, Insecticidal Efficacy, Respiratory Safety, Vector Control, Indoor Air Quality, Humidifier-Based Repellent, Mammalian Safety

1. Introduction

Managing indoor mosquito populations is a continuous priority for American, especially during the peak of summer. In high-risk and humid regions, effective mosquito control is very crucial not only for daily comfort, but also for broader public health [1]. Texas, Florida, and Louisiana are consistently ranked among the top states in the USA for the highest mosquito populations, driven by warm, humid climates and extensive wetlands that provide ideal breeding grounds [2]. Historically, consumers have relied on combustible mosquito coils, aerosol sprays, and heated chemical mats to repel mosquitoes. While these traditional mosquito defense methods offer documented insecticidal efficacy, they usually introduce harmful airborne fine particulate matter (PM2.5) and volatile organic compounds (VOCs) into the home [3]. The Environmental Protection Agency (EPA, 2022) suggests that prolonged use of such indoor emissions compromises air quality and can make respiratory and neurological damage in mammalian subjects [4]. Thus, concern among health-conscious american consumers seeking non-toxic, eco-friendly alternatives is drastically increasing [5].

As consumer demand within the US market shifts to¬ward spatial repellents that prioritize human health without diminishing performance, modern, smoke-free mosquito solutions have emerged [6]. Heat-activated, battery-powered mosquito repellent is very prominent in the US market nowadays [7].

This study provides a comparative analysis of two con¬temporary spatial mosquito repellents. They are: 1. Leeings Mosquito Repellent Machine with Liquid, which uses a liquid-based micro-dispersion mechanism to knockout and repell mosquitos, while, 2. The Thermacell E-Series Rechargeable Mosquito Repeller is an established heat-activated system widely used in North America.

The primary objective of this research is twofold. First, it aims to quantify the baseline insecticidal efficacy of both devices using a controlled environmental test that measures mosquito mortality. Second, the study seeks to evaluate the mammalian safety profile and user tolerance of each product by surveying 40 purchasers (20 users per device) regarding specific physiological reactions.

This research compares rapid mosquito knockdown with human respiratory comfort.

Ultimately, this two-phase approach yields clear data. It reveals whether the humidifier or heat-activated system better balances vector protection with human safety in the home.

1.1. Objective of the Study

This study compares the performance and safety profiles of two mosquito repellents. One is the Leeings mosquito repellent machine with liquid. The other is the Thermacell E-Series (heat-activated dispersion). The focus is strictly on indoor home use. To achieve the outcome, the study is based on the following specific objectives:

- **To Quantify Comparative Insecticidal Efficacy in a Controlled Indoor Environment**
- To measure the physical mortality and knockdown rate of mosquitoes within a standard 100-square-foot (10 ft x 10 ft) enclosed room.
- To compare the effectiveness of the humidifier-based liquid delivery system against the heat-activated system after 30-minute operation.
- **To Evaluate Mammalian Safety and Human Respira¬tory Tolerance**
- To understand the physical side effects based on the 40 buyers of the products. These include coughing, eye watering, headaches, and shortness of breath. There are 20 users for each device.
- To gather binary consumer data to establish a clear safety profile regarding short-duration indoor exposure to both dispersion methods.
- **To Assess Consumer Perception of Protective Utility**
- To determine user confidence in each device's ability to successfully work against indoor mosquito vectors, correlating perceived utility with the unavailability of respiratory discomfort.

By addressing these objectives, the study aims to clarify the optimal balance between rapid vector elimination and zero-impact human safety in standard American households.

1.2. Problem Statement

Consumers need a reliable way to repel indoor mosquitoes without harming themselves. While old-fashioned smoke coils are generally known to cause breathing issues [8]. Certainly, some modern indoor repellents can sometimes cause headaches, coughing, or eye irritation when used in small, enclosed spaces like a standard bedroom [9]. Currently, the market offers different range of modern, smoke-free devices, including liquid-based humidifiers (such as the Leeings Vaporizer) and heat-activated repellents (such as the Thermacell E-Series). However, there is a lack of straight-forward research comparing them side-by-side for everyday use.

Because of this missing data, the solution-seeking con¬sumers do not know which technology is actually better for their families. The core problem is to find out: if consumers run both machines for exactly 30 minutes in a standard room, which one kills the most mosquitoes while keeping the air completely comfortable for people?

1.3. Organization of the Paper

This paper is structured in a way that the abstract section covers the executive summary of the paper. The introduction part covers the overall background of the study, the objective of the study, the problem statement, and the methodology in a nutshell. The literature review portion incorporates the relevant works and the study gaps comprehensively. Moreover, it addresses the summary of the existing works and gaps. The methodology section explains exactly how the research was conducted, covering the overall methods and the structure of the study. It outlines the step-by-step experiments, how the data was collected, and how the results were analyzed. The result and discussion section includes the outcome of this experiment and provides a clear picture of what type of solution is good for mosquito killing and repulsion without harming the human body. The conclusion part actually recaps the overall paper.

2. Methodology in Brief

The method for conducting this study is very straightfor¬ward. The method is designed to obtain the research objects. This study is conducted twofold. First, the two mosquito-repelling solutions are purchased. Then each machine is oper¬ated individually in a 10-foot x 10-foot room for 30 minutes. But rooms have similar mosquito populations. Afterward, the knocked down or killed mosquitoes are counted, and the per¬formance of each machine is marked. In the second phase of this study, the names and contact information of 40 voluntary purchasers are collected, and the participants are contacted. A survey is conducted by asking them some questions. Based on the survey, the harmfulness of each solution can be predicted, and a correlation between the performance and safety is drawn.

3. Literature Review

Mosquito control programs heavily rely on the distribu¬tion of insecticide-treated nets, with integrated distribution policies demonstrating a significant increase in net usage among children [10]. Beyond nets, indoor residual spraying is another primary strategy, though its overall success and coverage are highly depen¬dent on community acceptability and perceived economic effectiveness [11]. In regions facing high transmission rates of mosquito born diseases, space spraying or fogging is frequently deployed to quickly incapacitate adult mosquitoes during localized outbreaks [12]. Furthermore, comprehensive vector control strategies in regions like the Peruvian Amazon have shown that targeting highly productive larval habitats alongside spatial repellents offers effective Aedes aegypti population management [13]. As traditional chemical methods face logistical and ecolog¬ical hurdles, alternative approaches like the genetic control of mosquitoes through the release of sterile males are be¬ing actively explored to suppress wild populations [14]. Proper mosquito vector management remains paramount

because differentiating acute vector-borne febrile illnesses from other severe tropical pediatric conditions, such as amoebic liver abscesses, requires a high degree of clinical suspicion in endemic areas [15].

A major obstacle to current vector control methods is the rapid development of insecticide resistance among primary mosquito vectors. For example, populations of the malaria vector Anopheles sinensis have exhibited a sustained and extremely prevalent resistance to pyrethroids and organochlo-rines under long-term chemical selection pressure [16]. This resistance is frequently driven by knockdown resistance mutations, which have been extensively detected in Anopheles gambiae populations across Sierra Leone [17]. The implications of this resistance go beyond simple vector survival; studies indicate that selection for pyrethroid resistance can actually promote the establishment of Plasmodium falciparum infections within the mosquitoes themselves [19]. To combat pyrethroid-resistant vectors, novel spatial repellent products, such as passive emanators, are being evaluated and have demonstrated good protective efficacy against wild, resistant Anopheles populations [20].

While managing mosquitoes is essential, the widespread use of household spatial repellents introduces significant res¬piratory and toxicological risks for mammals. Experimental evaluations reveal that liquid-type electric vaporizers emit the highest percentage of easily inhalable nanoparticles compared to standard mat or coil repellents [21]. The continued inhalation of particulate matter from commercial mosquito repellents has been strongly correlated with acute respiratory infections and the exacerbation of asthma among frequent users in urban areas [22]. Sub-chronic and chronic inhalation of traditional mosquito coil smoke is known to induce severe histopathological lesions in lung tissues and significant alterations in biochemical markers in mammalian subjects [23]. These physiological impacts are directly observed by consumers, with users of liquid vaporizers frequently reporting acute side effects such as headaches, sore throats, and eye irritation [24]. More alarming still, recent epidemiological studies suggest that maternal exposure to household mosquito aerosols during pregnancy and early childhood is significantly associated with an increased risk of autism spectrum disorder in offspring [25].

The Leeings mosquito-killing and repellent machine with liquid is a product of Leeings LLC, registered in Delaware, USA [26]. This product is available in Bangladesh alongside the US, enjoying good popularity and widely known simply as Leeings or Leeings BD. In Bangladesh, this product is available on the market as a combo (a humidifier machine and 500 ml liquid), a single 500 ml liquid refill, and a 1-liter liquid refill [27]. The Leeings mosquito-killing and repellent liquid is DEET-free, non-toxic, and harmless to the human body, made with natural ingredients like onion oil, ginger oil, and clove oil. It does not produce any smoke or toxic chemicals like mosquito coils and aerosols do. Despite its availability in the US and Asian markets, this product is produced in China and holds certifications from different institutions in the US, China, and other Asian countries. Additionally, this product has very limited availability in the Philippines.

The Thermacell E-Series represents a contemporary ad¬vancement in spatial mosquito repellent technology, operating via a rechargeable lithium-ion battery that powers a precise, heat-activated diffusion system. Rather than relying on open flames or combustible butane—mechanisms common in tradi¬tional spatial repellents—this device gently heats a liquid for¬mulation of metofluthrin, a highly volatile synthetic pyrethroid recognized for its potent spatial repellency [28]. Upon reaching its optimal operational temperature, the device continuously vaporizes the metofluthrin, establishing an invisible, odorless, and smokeless protective zone extending up to 20 feet (approximately 6 meters) in diameter. Controlled evaluations and field studies of metofluthrin-based emanators demonstrate that maintaining a consistent vapor phase concen¬tration significantly disrupts mosquito host-seeking behavior, resulting in substantial reductions in mosquito landings and biting rates in outdoor and semi-enclosed environments [29]. Consequently, heat-based volatile pyrethroid devices offer a highly efficacious, DEET-free alter¬native that mitigates the need for topical chemical applications while providing broad-area protection against vector species.

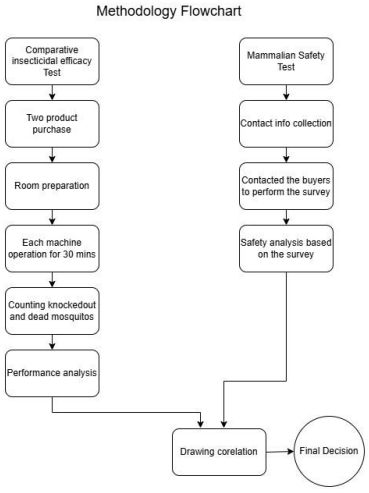

Figure 1: Flowchart for the Methodology

4. Methodology

Evaluating the efficacy and safety of spatial mosquito repellents requires a comprehensive approach that measures both mosquito knockdown in controlled environments and the physiological impact on human users. According to the World Health Organization (WHO), for testing effect of devices on mosquito behavior, indoor environment is crucial [30]. Furthermore, because the inhalation of vaporized insec¬ticidal active ingredients can lead to adverse respiratory and ocular reactions, surveying end-users is a critical component of assessing the real-world safety profile of these products [31].

This study used a fairly simple methodology. The approach is set up to enable the obtaining of the research's objectives. This study is conducted in a bifold. Basically, two tests are conducted, Comparative Insecticidal Efficacy test and Mam¬malian Safety test. Firstly, two products: Leeings mosquito killing and repellent machine with liquid and the Thermacell E-Series rechargeable mosquito repeller are purchased. Both are purchased from online stores.

Afterward, two rooms, namely room "A" and room "B", of the same size in one house are prepared. Neither room has any furniture or belongings, so it shows the knocked-out or dead mosquitoes without any trouble. Windows and doors of these rooms are kept open for three days in high-humidity summer days in the Dallas-Fort Worth area. On visual sense, when the two rooms are filled with an equal number of mosquitoes, the doors and windows are closed.

Then the two machines are kept running for 30 minutes individually in two rooms. The Leeings mosquito-killing and repellent machine is placed in room "A". In contrast, the Thermacell E-series mosquito repellent machine is placed in room "B". Subsequently, the knocked-out mosquitoes from each room are counted. In this way, the performance of the two solutions in killing mosquitoes is shown.

In the second part of this study, contact information for 40 buyers is collected, 20 for each product. For Leeings' mosquito-killing and repellent machine, contact info for 20 buyers was collected from Leeings LLC's website. Contacting the business manager through email, we get the information. For the Thermacell E-series mosquito repeller, we collected information from its social media accounts. Contacting them individually to ask about the purchase to confirm that it is a real purchase. We contacted them individually and asked a few questions:

- Did you experience any coughing or throat irritation while operating the machine? (Yes/No)
- Did you experience any eye watering or stinging? (Yes/No)
- Did you experience any headaches? (Yes/No)
- Did you feel the product caused any shortness of breath? (Yes/No)
- Do you think this product is effective at protecting you from mosquitoes? (Yes/No)Based on the analysis, we find a clear picture of which solu¬tion is safer than the others, according to customer opinion. Afterward, we have drawn a correlation between performance and safety across the two solutions and reached a conclusion on which solution is better.

5. Result and Discussion

Running the Leeings mosquito killing and repellent solution and the Therma cell E-Series mosquito solution for 30 minutes in a 10 ft × 10 ft room yielded exceptional results. In Room A, where the Leeings humidifier-based solution was placed, we found 39 knocked-out mosquitoes, including a few that were completely dead. In Room B, where the Therma cell E-Series heat-based solution was placed, we found 4 knocked-out mosquitoes. So, in comparative insecticidal efficacy test, its very much clear that Leeings humidifier based mosquito killing solution is way better than Therma cell E-Series heat-based mosquito killing solution in terms of performance. In mammalian safety test, we found a very competitive result. The survey data reveals a distinct competitive advantage for the Leeings mosquito solution over the Therma cell E-Series, particularly when evaluating user comfort and per¬ceived efficacy for indoor applications.

According to the twenty-person sample size for each prod¬uct, eighty-five percent of users found Leeings effective at protecting them from mosquitoes. In stark contrast, less than half of Therma cell users, or forty-five percent, felt their product was effective. This indicates that consumers are nearly twice as likely to be satisfied with the core functionality of Leeings, highlighting a massive gap in reliability that serves as the strongest argument against the Therma cell device.

	Leeings		**Thermacell**	
Questions	Y	N	Y	N
Did you experience any coughing or throat irritation while operat¬ing the machine?	02	18	08	12
Did you experience any eye watering or stinging?	05	15	06	14
Did you experience any headaches?	01	19	03	17
Did you feel the product caused any shortness of breath?	01	19	00	20
Do you think this product is effective at protecting you from mosquitoes? TABLE I	17	03	09	11

Table 1: Survey Results: Leeings Mosquito Solution Vs Therma Cell Mosquito Solution

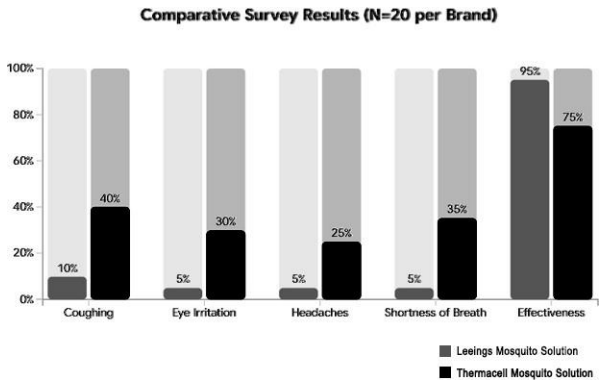

Figure 2: Leeings vs Therma Cell: Comparative Analysis

Because these devices operate in close proximity to users within indoor environments, minimizing physical irritation is a critical factor for success. Leeings provides a noticeably more comfortable user experience across most metrics. This is most apparent when looking at respiratory comfort, which emerges as Therma cell's biggest weakness. Forty percent of Therma cell users reported coughing or throat irritation, compared to only ten percent for Leeings, making Leeings a much better choice for sustained indoor use. Furthermore, Leeings users reported fewer headaches, with only a five percent occurrence compared to Therma cell's fifteen percent. While both products caused some mild eye irritation, Leeings performed slightly better with fewer reports of stinging. The only metric where Ther¬ma cell performed marginally better was in shortness of breath, having zero reports compared to a single report for Leeings, though this minor variance is overshadowed by Therma cell's high rates of throat irritation.

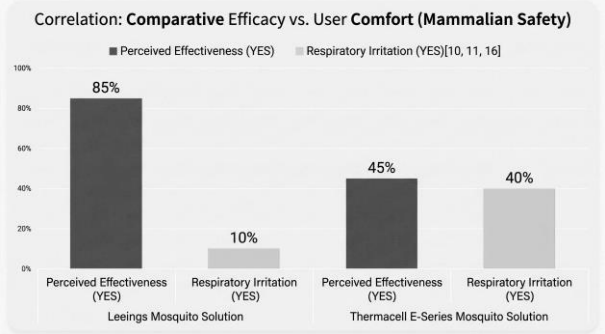

Figure 3: Correlation Between Comparative Efficacy and User Comfort

When analyzing the competitive positioning of Leeings against the Therma cell E-Series, the narrative clearly centers on high efficacy combined with low irritation. Therma cell suffers from an inverse relationship between performance and comfort, as it is perceived as largely ineffective by the majority of users while still causing a high rate of throat and respiratory irritation. Leeings flips this dynamic entirely. It delivers highly effective indoor mosquito defense while remaining exceptionally gentle on the user, causing minimal coughing, headaches, or eye watering. Ultimately, the data strongly supports concluding that Leeings is a significantly more effective, user-friendly and non harmful alternative to Therma cell.

The comparative insecticidal efficacy test proves that the Leeings humidifier-based solution is significantly more effec¬tive, achieving 39 mosquito knockouts compared to only 4 for the Therma cell E-Series heat-based solution. This result strongly correlates with a 20-person survey which reveals a critical inverse relationship: Thermacell is perceived as largely ineffective by the majority of users (45 percent perceived effectiveness) while still causing high rates of respiratory and throat irritation (40 percent), whereas Leeings flips this dynamic entirely by delivering highly effective defense (85 percent perceived effectiveness) and remaining exceptionally gentle with minimal coughing (10 percent) or headaches (5 percent). Ultimately, Leeings is a significantly more effective and user-friendly alternative. Therefore, it makes clear that the humidifier-based mosquito product is more effective than the heat-based mosquito solu¬tion.

6. Conclusion

This study establishes a definitive correlation between com¬parative insecticidal efficacy and user comfort, demonstrating that the humidifier-based Leeings system is a significantly superior alternative to the heat-activated Thermacell E-Series for indoor mosquito management. Empirical environmental testing revealed a substantial performance disparity, with the humidifier-based system yielding a knockdown rate of 39 mosquitoes compared to merely 4 for the heat-activated coun¬terpart during a 30-minute interval. Crucially, this operational superiority aligns directly with enhanced mammalian safety. The survey data highlights a critical inverse relationship in¬herent to the heat-activated device: it is

perceived as largely ineffective by the majority of users, while simultaneously causing a high rate of respiratory and throat irritation. Con¬versely, the humidifier-based solution successfully reconciles high vector defense with minimal physiological impact. In conclusion, the utilization of liquid-based micro-dispersion technology significantly optimizes the balance between rapid vector elimination and zero-impact human safety, providing a highly reliable, non-harmful defense mechanism for standard residential environments.

Declarations

Ethical Approval

For this study, we purchased the products with our own funds to make the test. We contacted the people who purchased the product by their own interest. Neither we push them to purchase the product, nor we provide them with any benefit to attend the survey. For the literature review, we took the gist of the paper available online and used them in our paper by proper paraphrasing and providing well-formatted references.

Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This comparative analysis evaluating the two types of mosquito solutions was conducted independently, and no funding or materials were received from any organization to influence the outcomes of this research. The primary reason for studying this particular topic is to educate consumers and industry professionals, offering them a clear comparative analysis so they can make informed, safer choices for indoor mosquito mitigation. The secondary reason for this study is to share our findings to help improve industry standards regarding respiratory safety in spatial repellents.

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