Review Article

ULTRASONIC MOSQUITO REPELLERS AS A GREEN ALTERNATIVE TO CHEMICAL PROTECTION : A Review

Abstract

Ultrasonic mosquito repellers have emerged as an eco-friendly solution for preventing mosquito bites instead of using chemical mosquito repellents. These devices produce high frequency sound waves which repel mosquitoes that post serious threat to public health by transmitting diseases like Malaria, Dengue and Zika. Moreover, these devices are non-toxic energy efficient physical tool to deter mosquitoes by irritating them with Ultrasonic sound waves. However some scientific studies highlight the Limited efficacy of these devices by stating that mosquitoes are largely unaffected by the designed higher sound frequencies. Despite this, they have very less environmental impact compared to other chemical repellents which always cause water contamination and harm other non-targeted species. In addition, the low energy footprint making these devices a good option for Indoor and outdoor environment. In contrast, potential concerns include, this device probably negatively interfere with the species that rely on sound for communication and navigation. Apart from this, the wide spread use could contribute to the accumulation of electronic waste if the devices are discarded after limited use. This review critically examines the potential of ultrasonic repellers as eco-friendly mosquito repelling tool based on available scientific evidence.

Keywords: Mosquito, Ultra sonic mosquito repellers, Repellents, Environmental impact

1. Introduction

Mosquitoes pause severe threat to humans since they spread diseases such as Zika, dengue, Malaria which have serious global health impacts, resulting in millions of cases and thousands of death annually. Traditional mosquito control depends mainly on chemical repellents like Perthrin , DEET and insecticide treated nets which are effective but cause severe environmental and health problems .Chemical repellents can make negative impact on non-targeted species, pollute environment and contribute to mosquito resistance over time. In response to these concerns ,interest has shifted toward more sustainable and ecofriendly alternative options. Ultra sonic repellents represent one such alternative method since they use high frequency sound waves instead of chemical agents. This review evaluates and examines the scientific supports on the effectiveness and environmental impact of ultrasonic mosquito repellents, compares their advantages and limitations with traditional methods as they are marketed as an environmentally safe and energy-efficient solution.

2. Mechanism of Ultrasonic Mosquito Repellents

Ultrasonic mosquito repellents emit sound waves of ultrasonic frequency range, typically above 20 kHz. Human ,auditory apparatus is unable to support and detect such frequencies, but they are audible to mosquitoes and other insects. The underlying principle of ultrasonic mosquito repellent is that specific frequencies may irritate or disorient mosquitoes, leading the repulsion of mosquito from the area where the ultrasonic device is active (Tiwari et al.,(2016)[1]).

a) Sensory Reception in Mosquitoes:

- Mosquitoes depends on various sensory cues, such as sound, to locate hosts and communicate. They have a specialized organ named the Johnston's organ, situated in their antennae, which detects various sound frequencies(Lapshin et al.,(2017)[2]). Studies indicate that this organ is very much sensitive to frequencies associated with wing beat sound waves from other mosquitoes and potential predators like bats(Fradin and M.S.(2018)[3]).
- Research by Dou et al.,(2021) [4] suggests that male mosquitoes, that possess much sensitive sensory structures, may show higher response to specific frequencies than females.

b) Theoretical Repellent Mechanism and Challenges in Frequency Calibration:

Ultrasonic devices are often marketed as mimicking the sounds of mosquito predators or males, which females are thought to avoid post-mating. The goal is to exploit mosquitoes' auditory sensitivity to create a hostile sound environment that repels them. However, the actual response varies widely across mosquito species and individual devices(Cabrini et al.,(2026)[5], Klimuthu et al(2020)[20] and Muhammad et al., 2020[24]. Moreover, studies reveal that not all ultrasonic frequencies affect mosquitoes equally. For example, research by Kim et al.(2021) [6]found that only high-intensity ultrasound (90-110 dB) at 100 kHz had any measurable impact on *Aedes aegypti* host-seeking behaviour, while other frequencies were greatly ineffective. Hence, this variability underscores the necessity for precise calibration, as various frequencies may affect mosquito behaviour differently. So, without standardized frequencies, ultrasonic repellents may provide inconsistent protection.

3. Overview of Major Studies and Findings

A significant number of researches have tested the efficacy of ultrasonic mosquito repellents under various conditions. Even though the findings reveal limitations in their effectiveness they also indicates their possibilities as eco-friendly physical tool which will be helpful in future to reduce the population density of various mosquito species and to repel mosquitoes from the area where it is in activated mode.

a) Solar-Powered Autonomous Systems:

- Singh et al.(2016)[7]in his research, developed a solar-powered ultrasonic mosquito repeller, which claimed to cover an area of 255 square meters. Operating at frequencies between 38-44 kHz, the device aimed to provide a sustainable, off-grid mosquito control solution. While promising as an energy-efficient choice , its effectiveness across different environments remains unproven, indicating the necessity for further field trials to verify these primary level findings

b)Controlled Trials and Species-Specific Responses:

- Multiple controlled studies have found no significant repellent effect on various mosquito species. In laboratory flight chamber tests, ultrasonic devices operating at 20-70 kHz failed to repel four mosquito species (Foster et al.,(1985) [8]). Similarly, a field trial in Gabon using devices emitting 3-11 kHz frequencies showed no significant difference in mosquito landing rates between houses with active devices and places(Lell et al.,(2000)[9]. Furthermore, experiments with a random ultrasonic generating device (20-100 kHz) demonstrated limited repellent effect on mosquitoes or German cockroaches Ahamad et al.,(2007) [10]. These findings consistently suggest that ultrasonic devices are not much effective as mosquito repellents.

c) Behavioral Responses and Biting Rates:

- Andrade et al.(2010) [11] spotted an increase in rate of biting of *Aedes aegypti* mosquitoes when exposed to specific ultrasonic frequencies, showing that these devices may sometimes have the opposite of their intended effect. This surprising result emphasising the need for more nuanced research into how ultrasonic waves interact with mosquito behavior.
- Kim et al.(2021) [6] also found that high-frequency ultrasound at 100 kHz could disrupt *Aedes aegypti*'s CO_2-oriented olfactory behavior, albeit only at high sound intensities. This raises potential for high-powered ultrasound in specific applications .

2. Combined Devices and Practical Efficacy:

- Okorie et al.,(2015) [12] tested an ultrasonic-enabled air conditioner, which, when combined with active airflow, displayed significant expulsion rates for *Anopheles gambiae*. This indicates that ultrasonic technology may be more effective when integrated into devices that leverage additional mosquito control mechanisms.

4. Ultrasonic Repellents as an Eco-Friendly Solution

Ultrasonic mosquito repellents are often commercialised as an eco-friendly alternative which is very much appealing to consumers concerned with environmental sustainability. Several features support their environmental benefits:

(a) Low Environmental Impact:

- Ultrasonic devices elude the use of chemicals, which can contaminate soil and waterways, impacting ecosystems. This makes them significantly suitable for environmentally sensitive areas, such as near water bodies or in urban parks (Tiwari et al.,(2016)[1].

(b) Non-Toxic to Non-Target Species and Low Energy Footprint

- Conventional insecticide treatments can harm a wide range of organisms, including pollinators. On the other hand, ultrasonic devices target specific auditory sensitivities and generally cause no harm to non-target species, preserving biodiversity (Yusuf et al.,(2021) [13]).
- Devices like the solar-powered repellent structured by Singh et al.(2016) [7] offer an energy-efficient solution, particularly in rural settings where sustainable pest control

options are limited (Yusuf et al.,(2021)[13]) .Most ultrasonic devices operate on low energy, making them a viable option for reducing carbon footprints (Andrade et al.,(2010)[11]).

(c) Reduced Risk of Resistance Development:

- Unlike chemical repellents, which may induce resistance in mosquito populations, ultrasonic devices work through non-biochemical means, thus can avoid resistance development. This could increase the possibilities of ultrasonic devices a more sustainable long-term choice within integrated pest management(Ikeri et al.,(2017)[14], Toma et al.,(2024) [21]and Nasir et al.,(2012)[22]).

5. Comparative Analysis with Other Mosquito Repellents

The comparison of ultrasonic mosquito repellents with other mosquito repulsion methods helps to understand their efficacy, sustainability, and practical applications. This section evaluates the merits and demerits of ultrasonic repellents relative to chemical, natural, and other physical methods.

- **Chemical repellents**, such as DEET and permethrin, have been widely tested and shown to provide long term protection against mosquitoes. Specifically ,DEET is a significant repellent pointed out by various studies , showing effectiveness rates above 90% when used correctly(Fradin et al.,(1998)[3],Norris et al.,(2017)[39], Sahu et al.,(1998)[41]). In addition, Permethrin-treated bed nets have also been found to significantly reduce mosquito bites (Lapshin et al.,(2017)[2]). On the other hand, ultrasonic devices have displayed different results . While some studies indicate their partial ability for repulsion under controlled conditions, others suggest their efficacy is varying and can even cause increased mosquito attraction at certain frequencies due to acoustotactic responses (the tendency of mosquitoes to be attracted or repelled by certain sound frequencies)(coro et al.,(1998) [15],Ghorse et al.,(2022)[19],Saini et al.,(2016)[23],Ozkurt et al.,(2021) [27]). Thus, ultrasonic repellents can be considered less reliable in terms of efficacy compared to chemical options. In contrast, the chemical repellents show significant environmental impact . For instance, DEET is known to continuously persist in the environment, polluting0 water sources and soil, with deteriorating effects on aquatic life (Mapossa et al.,(2020)[33]). Additionally, the production of chemicals like permethrin include the use of highly toxic substances that can negatively alter the ecosystems (Fradin and M.S.(1998)[3],Arias et al.,(2020)[25] , Afolabi et.al.,(2022)[28] and Wang et al.,(2018)[42]. However, ultrasonic repellents, offer a noticeable advantage in this regard. They are non-toxic and do not contaminate water or soil, making them a good eco-friendly alternative (Muhumuza and N.(2023)[17]) and Nik Abdull Halim et.al.,(2025)[26]. The primary environmental concern lies in the production and disposal of electronic components, which can result in the accumulation of electronic waste if not managed properly. In terms of Energy and Sustainability, since chemical repellents require continuous manufacturing, packaging, and distribution, it often results in substantial environmental costs. The production of DEET, for example, involves petrochemicals, contributing to its carbon footprint (Brown et al.,(1997) [16]) . In addition, synthetic chemicals often lead to resistance in mosquito populations, which in turn result in the use of higher concentrations or alternative chemicals over time. In contrary, Ultrasonic devices generally have a reduced energy footprint (Karunaratne et al.,(2022)[30]). Solar-powered ultrasonic repellents, such as those tested by Singh et al.(2026) [7], are particularly energy-efficient.

- **Natural and Plant-Based Repellents (e.g., Citronella, Lemon Eucalyptus)** including citronella and lemon eucalyptus oil, are often commercialised as safer alternative options to chemical repellents (Kalita et al.,(2013)[35]). However, they often provide shorter-lasting repulsion effect and require frequent reapplication. Citronella, for example, has very short effective duration, requiring reapplication at short intervals, which can be impractical in areas having high mosquito activity (Brown et al.,(1997)[16]). But, ultrasonic devices could theoretically have longer effective duration without the need for reapplication, offering convenience However, as mentioned, their effectiveness can vary based on frequency, intensity, and environmental factors (Tiwari et al.,(2016)[1]). While they may be more reliable than plant-based repellents in terms of duration, their lower efficacy in some studies means they should not be solely relied upon. Environmental and Health Impact of Plant-based repellents are generally considered safe for both humans and the environment, with minimal toxicity to non-target species(Huang et al.,(2017)[36] ,Tisgratog et al.,(2016)[37], Shooshtari et al(2013)[43] and Gillij et al.,(2008)[46]. However, these natural repellents are often derived from large-scale agricultural production, which may carry environmental costs such as land use and pesticide use (Brown et al.,(1997)[16]). Ultrasonic devices, in contrast, eliminate the need for such agricultural inputs and are non-toxic to humans and wildlife when used correctly (Amuyunzu and M.A.P(2021)[31]). They do not require constant reapplication or additional resources like plant extracts, but as electronic devices, they contribute to e-waste, which poses its own environmental challenge. Both ultrasonic devices and natural repellents are relatively environmentally friendly in their immediate use, but ultrasonic devices present the unique concern of e-waste(Tiwari et al.,(2016)[1]. On the other hand, natural repellents require regular harvesting, processing, and transport, which can involve significant carbon emissions if produced on a large scale (Benelli et al.,(2016)[32]).
- **Physical Barriers (e.g., Bed Nets, Window Screens)** offer effective protection when used correctly. They are significantly important in areas with high mosquito population density and known disease transmission. However, their effectiveness relies on accurate use, and they often fail to address the larger outdoor mosquito population(Fradin and M.S. (1998) [3]). In larger outdoor spaces having huge mosquito population, ultrasonic repellents can complement physical barriers because there might have shortage of screens and nets . They do not provide a physical barrier but could enhance protection when used in combination with nets and screens (Rutledge et al.,(1999)[44]) . Bed nets, particularly those treated with insecticides like permethrin, create a moderate environmental impact due to chemical usage (Curtis et al.,(1990)[50] and Paluch et al.,(2010)[45]). Physical barriers also require materials, manufacturing, and transportation, contributing to resource consumption (Kampango et al.,(2013)[51]). Ultrasonic devices, especially solar-powered ones, reduce the need for material resources and offer low-maintenance solutions. However, as with other electronic products, their production and disposal contribute to e-waste, which must be managed carefully.

6. Environmental Considerations and Draw backs

Even though ultrasonic mosquito repellents present an appealing alternative to chemical solutions, they also come with practical and ecological considerations that must be carefully evaluated and handled.

- **Low Environmental Impact and Energy Footprint**

Many ultrasonic devices are powered by low-energy sources like small batteries or solar panels, making them very much suitable for use in off-grid areas. Solar-powered ultrasonic repellents, such as those showed by Singh et al.(2016) [7], offer an energy-efficient alternative, especially in regions where electricity supply is inconsistent.

- **Interference with Non-Target Species**: Ultrasonic repellents have a clear advantage over chemical alternatives in terms of safety owing to its non-toxicity(Ahamad et al.,(2007) [10] ,Zahraei Ramazani et al.,(2023)[29]). However, there is evidence to suggest they may affect other animals sensitive to sound frequencies. Small mammals, birds, and other insects, especially those that rely on echolocation or similar sound-based navigation systems, may be inadvertently disturbed by these devices.

- **Accumulation of E-Waste**: One of the significant environmental concerns with ultrasonic devices is the growing issue of e-waste. As these devices are used over time, they can contribute to the mounting problem of discarded electronics, which require proper recycling to avoid environmental contamination from heavy metals and other toxic components (Norris et al.,(2017)[38]).

- **Limited Range and Efficacy**: Ultrasonic devices lose intensity over distance, reducing their effective range. This limitation may require multiple devices to cover larger areas, which could increase energy consumption and e-waste (Halidu et al., (2022)[40]). Additionally, the inconsistent efficacy of these devices means that they may not offer reliable protection in all situations, requiring supplementary control measures like chemical repellents or physical barriers (Fradin et al.,(2002)[41]).

Conclusion

Ultrasonic mosquito repellents displays an innovative approach to mosquito control that prioritizes eco-friendliness and sustainability. Even though, they offer several advantages over conventional chemical repellents, including decreased ecological impact and non-toxicity to non-target species, their effectiveness remains in varying mode . Further research into optimizing frequency calibration, enhancing device range, and improving practical efficacy in field settings is mandatory. As supplementary tools within integrated pest management strategies, ultrasonic repellents have much efficacy to complement more traditional methods, but they should not be consider as the core remedy to mosquito control.

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