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Design and Performance Evaluation of a Portable Solar-Powered Mosquito Control Device Using Ultraviolet Light Attraction

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Abstract- Mosquito-borne diseases continue to pose significant public health challenges, particularly in tropical regions where environmental conditions favor mosquito breeding and disease transmission. Conventional mosquito control methods, such as chemical insecticides and electrically powered mosquito killers, have limitations related to environmental impact, energy consumption, and operational flexibility. Therefore, this study aimed to design, fabricate, and evaluate the performance of a portable solar-powered mosquito control device utilizing ultraviolet (UV) light attraction as an environmentally friendly alternative for mosquito management. An engineering design and experimental evaluation approach was employed, consisting of conceptual design, prototype fabrication, system integration, and functional performance testing. The developed prototype integrates three photovoltaic solar panels, a TP4056 battery charging module, a rechargeable 18650 lithium-ion battery, an ultraviolet LED attraction system, and a high-voltage mosquito eradication module within a compact PVC housing. Experimental evaluation demonstrated that all subsystems operated successfully under normal operating conditions. The photovoltaic panels effectively converted solar energy into electrical energy, while the rechargeable battery provided a stable power supply for both the UV LED and the high-voltage module. The ultraviolet LED successfully attracted mosquitoes through phototactic behavior, and the electrified wire mesh effectively eliminated mosquitoes upon contact. The integrated system exhibited stable operation, portability, and energy autonomy without requiring continuous electrical power from the utility grid. Furthermore, the prototype demonstrates the practical application of photovoltaic energy conversion, electromagnetic radiation, electrical discharge, and energy storage principles in a single engineering system. Overall, the proposed device provides a low-cost, portable, and environmentally sustainable mosquito control solution while simultaneously serving as an effective instructional medium for renewable energy and applied physics education. Future studies should focus on optimizing photovoltaic efficiency, battery capacity, ultraviolet wavelength selection, and long-term field performance under diverse environmental conditions.

Keywords: Applied physics; Mosquito control; Photovoltaic system; Portable device; Renewable energy; Ultraviolet LED.

1 Introduction

Mosquito-borne diseases remain one of the most persistent public health challenges in tropical and subtropical regions. Mosquitoes act as vectors for several infectious diseases, including dengue, malaria, chikungunya, Zika, yellow fever, and lymphatic filariasis. The World Health Organization (WHO) reported

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that vector-borne diseases account for more than 17% of all infectious diseases and cause more than 700,000 deaths annually worldwide (World Health Organization [WHO], 2024). Among mosquito-borne diseases, malaria and dengue continue to place a major burden on public health systems, particularly in regions with high humidity, warm temperatures, dense human settlement, and inadequate environmental sanitation. Malaria alone caused hundreds of millions of cases globally, while dengue has expanded geographically and has become an increasing threat in many urban and semi-urban areas (WHO, 2024). These conditions indicate that mosquito control remains an urgent issue, especially in communities where environmental factors strongly support mosquito breeding.

Indonesia is one of the countries that faces a high risk of mosquito-borne disease transmission because of its tropical climate, high rainfall, and relatively stable humidity throughout the year. These environmental characteristics create suitable breeding habitats for mosquitoes, especially in stagnant water, drainage channels, swampy areas, and densely populated settlements. The uploaded research document also emphasizes that Indonesia's tropical climate, including high rainfall and warm temperatures, contributes to the growth of mosquito populations and increases the risk of dengue, malaria, and chikungunya transmission. In addition, recent studies on dengue incidence in Indonesia have shown that climate parameters such as rainfall, humidity, and temperature are associated with spatial and temporal variations in dengue cases (Mamenun et al., 2024). This confirms that environmental conditions are strongly related to vector population dynamics and disease transmission risk.

Mosquito control strategies commonly involve environmental management, biological control, insecticide spraying, larvicides, mosquito nets, repellents, and electric mosquito killers. Although chemical-based methods such as fogging and insecticide spraying can reduce adult mosquito populations in the short term, they also present several limitations. Frequent use of chemical insecticides may contribute to insecticide resistance, environmental contamination, and potential health risks for humans and non-target organisms. Moreover, chemical control alone is often insufficient when breeding sites remain unmanaged. Therefore, sustainable vector control requires integrated approaches that are effective, environmentally friendly, affordable, and adaptable to local community needs (WHO, 2024). In this context, non-chemical mosquito control devices based on light attraction and electrical trapping offer a promising alternative, particularly for household and small-area applications. One of the physical principles that can be applied to mosquito control is the interaction between electromagnetic radiation and insect visual behavior. Mosquitoes and other flying insects can respond to specific wavelengths of light through phototaxis, which refers to movement toward or away from light stimuli. The uploaded document explains that mosquitoes are attracted to certain light sources, especially ultraviolet (UV) radiation, due to the sensitivity of their visual receptors to particular wavelength ranges. Ultraviolet radiation generally falls within the wavelength range of 100–400 nm and has higher photon energy than visible light due to its shorter wavelength. This characteristic allows UV light, especially UV-A, to be used as an attractant in mosquito trapping and insect-control devices.

The use of ultraviolet light-emitting diodes (UV LEDs) has become increasingly relevant in the development of compact and energy-efficient mosquito control devices. Compared with conventional lamps, LEDs have several advantages, including low power consumption, long operational life, small size, mechanical durability, and the ability to emit light within a specific wavelength range. UV LEDs commonly operate around 365 nm, 385 nm, 395 nm, or 405 nm, which makes them suitable for attracting insects while maintaining energy efficiency. The uploaded document also states that UV LEDs operate through electroluminescence in semiconductor materials and are capable of producing narrow-spectrum ultraviolet radiation. Therefore, UV LED technology is appropriate for portable devices that require low power and stable operation. In addition to ultraviolet light attraction, electrical control is another important element in mosquito eradication devices. In electric mosquito killers, mosquitoes attracted to the light source approach a high-voltage grid or shock net, where electrical discharge can immobilize or kill them. This mechanism is based on the principles of electric current, voltage, resistance, and power transfer. According to the uploaded document, the high-voltage module in the proposed device functions to convert low DC voltage from the battery into higher voltage that is delivered to the mosquito-killing grid. This system enables the device to operate without chemical substances, reducing smoke, residue, and potential environmental hazards associated with conventional mosquito control methods.

However, one major limitation of many electric mosquito control devices is their dependence on grid electricity or disposable batteries. Grid-powered devices are less practical in outdoor areas, rural environments, agricultural fields, temporary shelters, and locations with limited access to electricity. Disposable battery-powered devices, on the other hand, generate recurring costs and battery waste. For this reason, the integration of solar photovoltaic technology into mosquito control devices is highly relevant. Solar cells convert sunlight directly into electrical energy through the photovoltaic effect, allowing portable systems to operate independently from conventional power sources. In the uploaded document, the solar cell is described as a semiconductor-based component that converts solar radiation into direct current electricity, which can be used to power electronic loads or charge batteries.

Solar photovoltaic systems are increasingly used in low-power portable applications because they provide renewable, clean, and widely available energy. In tropical countries such as Indonesia, solar energy is particularly promising due to abundant sunlight exposure throughout the year. The use of a solar cell in a mosquito control device supports energy autonomy and improves usability in outdoor or electricity-limited settings. A solar-powered mosquito device can charge during the day and operate at night, when mosquito activity is generally higher. This design is aligned with the broader need for sustainable and environmentally friendly vector control technologies. Previous solar-powered mosquito trap initiatives have also emphasized the potential of solar energy to support mosquito capture and destruction in an environmentally sustainable manner.

The combination of UV light attraction, high-voltage electrical control, rechargeable lithium-ion batteries, and solar charging represents a practical engineering solution for portable mosquito management. Lithium-ion batteries, especially the 18650 type, are widely used in portable electronics because they provide relatively high energy density, stable voltage, compact size, and rechargeability. The uploaded document identifies the lithium-ion 18650 battery as an energy storage component with a nominal voltage of approximately 3.7 V and full-charge voltage of about 4.2 V. When combined with a TP4056 charging module and solar cell, the system can store solar energy during daylight and provide electrical power to the UV LED and high-voltage module during operation. This architecture makes the device portable, rechargeable, and suitable for repeated use.

Despite the availability of mosquito traps and electric mosquito killers, there are still several gaps in the development of portable solar-powered mosquito control devices. First, many commercially available mosquito control devices depend on grid electricity, limiting their use in outdoor or remote locations. Second, many mosquito control methods still rely on chemical substances, which may create environmental and health concerns. Third, some previous prototype studies focus mainly on product construction without providing sufficient performance evaluation under different operating conditions. Fourth, the integration of physics concepts—such as electromagnetic waves, photon energy, electric current, photovoltaic conversion, and energy storage—is often not explicitly discussed in the context of educational technology and applied physics. These gaps show the need for a study that not only designs a portable solar-powered mosquito control device but also evaluates its functional performance and explains its underlying physical principles.

The proposed study addresses these gaps by designing and evaluating a portable mosquito control device powered by a solar cell and based on ultraviolet light attraction. The device is designed to attract mosquitoes using UV light, eliminate them through a high-voltage grid, and operate using energy stored from a solar-powered charging system. According to the uploaded document, the prototype includes a mini solar cell, TP4056 Type-C charging module, lithium-ion battery, UV LED, high-voltage module, switch, and supporting device body. These components form an integrated system that combines renewable energy conversion, energy storage, light-based attraction, and electrical mosquito eradication.

The novelty of this study lies in the development of a compact and portable mosquito control device that integrates solar photovoltaic energy with ultraviolet light attraction and electric eradication. Unlike conventional mosquito control methods that depend on chemical fogging or grid electricity, this prototype emphasizes low-energy operation, portability, and environmental sustainability. The device also has educational relevance because it demonstrates the application of several physics concepts in a real-world problem. Electromagnetic waves are represented by UV light attraction, electric current and voltage are applied in the high-voltage grid, and photovoltaic conversion is applied in the solar charging system. Thus, the prototype can serve not only as an alternative mosquito control device but also as a contextual learning medium for applied physics. The practical importance of this research is particularly relevant for communities in tropical regions, including areas with wetlands, poor drainage, or limited electricity access. The uploaded document specifically highlights that regions such as Pekanbaru, Riau, have environmental conditions that may support mosquito breeding because of lowland geography, swamp areas, and water accumulation. A portable solar-powered mosquito control device can therefore provide an accessible tool for reducing mosquito disturbance in households, outdoor areas, and small community spaces. Although such a device cannot replace comprehensive vector control programs, it may complement existing strategies by providing a non-chemical, renewable-energy-based solution.

Based on the above considerations, this study aims to design and evaluate the performance of a portable solar-powered mosquito control device using ultraviolet light attraction. Specifically, the study focuses on the design of the electronic and mechanical system, the integration of the solar charging circuit, the functionality of the UV LED and high-voltage module, and the effectiveness of the device under indoor and outdoor testing conditions. The expected contribution of this research is twofold. First, it provides a practical prototype for environmentally friendly mosquito control using renewable energy. Second, it demonstrates the application of physics concepts in developing a functional device that can support both community health and contextual physics learning.

2 Research Methodology

2.1 Research Design

This study employed an engineering design and experimental evaluation approach to develop and assess the performance of a portable solar-powered mosquito control device utilizing ultraviolet (UV) light attraction. The research consisted of four sequential phases: (1) conceptual design, (2) prototype fabrication, (3) system integration, and (4) functional performance evaluation. The overall methodology was designed to investigate the feasibility of integrating solar photovoltaic technology, rechargeable energy storage, ultraviolet light attraction, and high-voltage mosquito eradication into a compact portable device. The overall research procedure is illustrated in Figure 1.

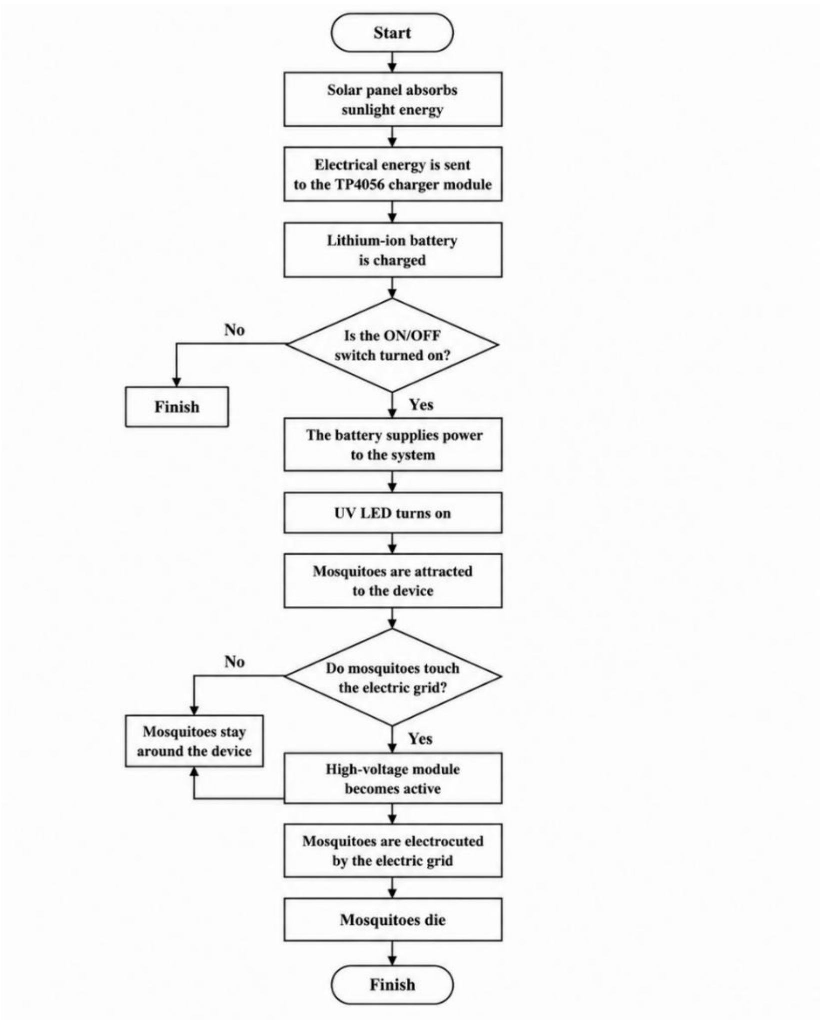

Figure 1. Research methodology flowchart

The conceptual design stage involved reviewing the characteristics of mosquito behavior, photovoltaic energy conversion, ultraviolet LED technology, rechargeable battery systems, and high-voltage electrical modules. Based on these considerations, a portable device was designed to operate independently using renewable solar energy while maintaining sufficient electrical power to attract and eliminate mosquitoes efficiently.

2.2 Prototype Development

The mosquito control prototype was constructed using commercially available electronic and mechanical components. The primary electronic components consisted of a mini photovoltaic solar panel, TP4056 Type-C lithium battery charging module, 18650 lithium-ion rechargeable battery, ultraviolet LED, DC high-voltage generator module, ON/OFF switch, wiring system, and acrylic housing. These components were integrated into a compact enclosure to improve portability while protecting the electrical circuit from environmental exposure. The complete prototype design is presented in Figure 2.

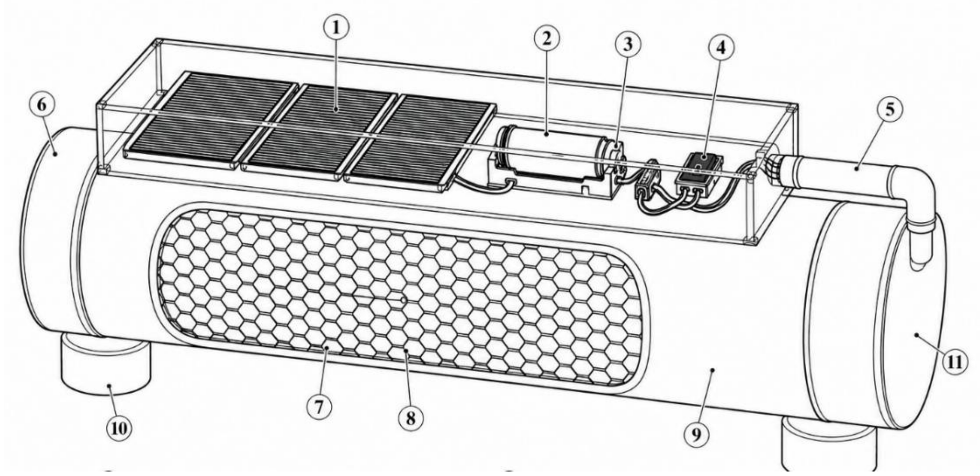

Figure 2. Schematic design of the portable solar-powered mosquito control device

Description of the Numbered Components:

1. Solar Panels (3 units)
2. 18650 Lithium-Ion Batteries (Vertical Orientation)
3. 18650 Battery Holder (Vertical Orientation)
4. ON/OFF Switch
5. Cable Conduit (Passing Through the PVC Pipe)
6. PVC End Cap (Left-End Cover)
7. Wire Mesh
8. Ultraviolet (UV) LED Lamp (Purple)
9. PVC Pipe (Main Body)
10. PVC End Cap (Used as Support Base)
11. PVC End Cap (Right-End Cover)

The solar panel converts incident solar radiation into direct current electricity through the photovoltaic effect. The generated electrical energy is transferred to the TP4056 charging module, which regulates the charging process of the lithium-ion battery. During operation, the stored electrical energy supplies power to both the ultraviolet LED and the high-voltage module. The ultraviolet LED serves as an attractant for mosquitoes through phototactic behavior, whereas the high-voltage module generates sufficient electrical potential to eliminate mosquitoes when they contact the electrified mesh.

2.3 Experimental Procedure

Functional testing was conducted to evaluate the operational performance of the developed prototype. Prior to experimentation, all electronic components were inspected to ensure proper electrical connections and stable battery charging. The photovoltaic charging system was tested under natural sunlight to verify battery charging capability before nighttime operation. Performance evaluation consisted of several experimental observations, including solar charging performance, battery operation, ultraviolet LED functionality, high-voltage module performance, and overall device operation. During testing, the prototype was placed in mosquito-prone environments during evening hours when mosquito activity was relatively high. Mosquito attraction toward the ultraviolet light source and successful mosquito elimination through the electrical grid were visually observed and recorded. Each experimental trial was repeated three times to improve data reliability. Consistent environmental conditions, including approximately similar testing duration and prototype placement, were maintained throughout all experimental sessions to minimize external variation.

2.4 Performance Evaluation

The performance of the prototype was evaluated using qualitative and quantitative indicators. The primary evaluation parameters included photovoltaic charging functionality, battery stability, ultraviolet LED illumination, electrical discharge performance of the high-voltage module, portability, operational stability, and mosquito eradication capability. These parameters were selected because they represent the essential operational characteristics required for a portable mosquito control system. Operational stability was determined by continuous device operation without interruption during testing. Portability was evaluated according to prototype dimensions, weight, and ease of transportation. The mosquito attraction process was assessed by observing insect movement toward the ultraviolet light source, while mosquito eradication performance was evaluated based on successful electrical contact with the high-voltage grid.

2.5 Data Analysis

The experimental results were analyzed using descriptive statistical methods. Performance observations obtained from repeated experiments were summarized using frequency distributions and average operational results. The functionality of each subsystem, including solar charging, battery storage, ultraviolet attraction, and high-voltage mosquito elimination, was evaluated individually before assessing overall prototype performance. Furthermore, the operational characteristics of the developed device were interpreted according to the principles of photovoltaic energy conversion, ultraviolet electromagnetic radiation, electrical power transmission, and insect phototactic behavior. The obtained results were subsequently compared with findings from previous studies concerning solar-powered mosquito control technologies to evaluate the effectiveness and practical applicability of the proposed prototype.

3 Results and Discussion

3.1 Design and Fabrication of the Portable Solar-Powered Mosquito Control Device

The primary outcome of this study was the successful development of a portable solar-powered mosquito control device that integrates photovoltaic energy harvesting, rechargeable energy storage, ultraviolet (UV) light attraction, and a high-voltage mosquito eradication system into a single compact prototype. The design was developed to provide an environmentally friendly mosquito control solution that can operate independently without relying on conventional electrical power. The completed prototype demonstrates that renewable energy technology can be effectively integrated into a portable vector control device suitable for household and outdoor applications. The overall design of the developed prototype is presented in Figure 3.

Figure 3. Front view of the device

The prototype consists of several integrated components that perform complementary functions within the system. Three miniature photovoltaic solar panels are mounted on the upper surface of the cylindrical housing to maximize solar radiation absorption during daylight hours. Electrical energy generated by the photovoltaic panels is delivered to a TP4056 charging module, which regulates the charging process of a rechargeable lithium-ion battery. The stored electrical energy subsequently supplies power to both the ultraviolet LED attraction system and the high-voltage mosquito eradication circuit.

The structural housing of the device is fabricated using PVC pipe, selected because of its lightweight characteristics, corrosion resistance, mechanical durability, low manufacturing cost, and ease of fabrication. The cylindrical geometry also provides sufficient internal space for accommodating electronic components while protecting them from environmental exposure. Both ends of the PVC body are sealed using PVC end caps to protect the electrical circuit and improve structural rigidity. Supporting feet attached beneath the housing provide mechanical stability during operation and prevent direct contact between the device body and the supporting surface.

A wire mesh surrounds the ultraviolet light source and functions as the mosquito elimination area. The mesh is connected to the high-voltage generator module that produces sufficient electrical potential to eliminate mosquitoes immediately after contact. Positioning the UV LED inside the protective wire mesh minimizes accidental human contact while maximizing the probability that mosquitoes attracted by ultraviolet radiation will encounter the electrified grid. The developed prototype demonstrates a practical engineering implementation of several physics principles. Solar radiation is converted into electrical energy through the photovoltaic effect, while electrical energy storage is achieved using rechargeable lithium-ion batteries. Ultraviolet electromagnetic radiation is utilized as an optical attractant, whereas electrical energy is converted into high-voltage discharge for mosquito eradication. Consequently, the proposed system represents the integration of renewable energy technology, applied electronics, and electromagnetic radiation into a compact portable engineering product. Compared with commercially available electric mosquito killers, the developed prototype possesses several advantages. It does not require continuous grid electricity, produces no chemical emissions, and can be operated in outdoor environments where electrical outlets are unavailable. The modular configuration also allows relatively simple maintenance because each subsystem can be replaced independently without reconstructing the entire device.

3.2 Operating Principle of the Portable Solar-Powered Mosquito Control Device

The operating principle of the proposed mosquito control device consists of four sequential stages, namely energy harvesting, energy storage, mosquito attraction, and mosquito eradication. The complete operating sequence is illustrated in Figure 1. During daytime operation, incident solar radiation strikes the photovoltaic panels mounted on the upper surface of the device. The semiconductor materials within the solar cells convert solar energy directly into direct-current electricity through the photovoltaic effect. This electrical energy is transferred to the TP4056 charging module, which regulates the charging current supplied to the lithium-ion battery while preventing overcharging and excessive discharge. Consequently, the battery stores sufficient electrical energy for nighttime operation.

When the ON/OFF switch is activated, the stored electrical energy is supplied simultaneously to two primary electrical loads. The first load is the ultraviolet LED, which emits ultraviolet radiation with wavelengths attractive to mosquitoes through positive phototactic behavior. The emitted UV light serves as the primary attraction mechanism that encourages mosquitoes to approach the device during nighttime operation.

The second electrical load is the high-voltage generator module. This electronic circuit converts the relatively low battery voltage into a much higher electrical potential required for mosquito eradication. The generated high voltage is applied across the conductive wire mesh surrounding the UV LED. Consequently, whenever mosquitoes attracted by the ultraviolet light make physical contact with the wire mesh, an electrical discharge occurs, immediately incapacitating or killing the insect. The overall operation of the prototype therefore represents a continuous energy conversion process involving several physics principles. Initially, radiant solar energy is transformed into electrical energy through photovoltaic conversion. Subsequently, electrical energy is chemically stored inside the lithium-ion battery. During operation, the stored energy powers the ultraviolet light source and high-voltage generator, ultimately converting electrical energy into electromagnetic radiation and electrical discharge. This sequence illustrates the transformation of renewable solar energy into useful electrical work for mosquito control.

Another important feature of the prototype is its autonomous operation. Unlike conventional electric mosquito killers that require permanent electrical connection, the proposed device can continue operating using stored battery energy after sunset. This operational independence significantly increases portability and allows deployment in gardens, farms, camping areas, rural settlements, and locations without reliable electrical infrastructure. The prototype also demonstrates the application of sustainable engineering principles. Since solar energy is renewable and environmentally friendly, the device reduces dependence on fossil-fuel-generated electricity while minimizing operating costs. Furthermore, the elimination process relies entirely on electrical discharge rather than chemical insecticides, thereby reducing environmental pollution and avoiding problems associated with insecticide resistance. These characteristics indicate that the developed device has potential as an alternative technology for sustainable mosquito management while simultaneously serving as a practical demonstration of renewable energy applications in engineering and applied physics.

3.3 Performance Evaluation of the Developed Prototype

Following the fabrication and assembly processes, the portable solar-powered mosquito control device was subjected to a series of functional tests to evaluate the performance of each subsystem. The evaluation focused on the photovoltaic charging system, rechargeable battery operation, ultraviolet LED performance, high-voltage module functionality, mosquito attraction capability, and overall operational stability. Each subsystem was tested individually before the complete integrated system was evaluated under normal operating conditions.

The photovoltaic charging system demonstrated satisfactory performance during daylight exposure. Throughout the charging period, the three solar panels successfully converted solar radiation into direct-current electrical energy, which was regulated by the TP4056 charging module before being stored in the lithium-ion battery. The charging process remained stable throughout the experimental observations, indicating that the charging controller effectively prevented battery overcharging while maintaining an appropriate charging current. This result confirms that the photovoltaic subsystem is capable of supplying sufficient electrical energy for portable nighttime operation. The rechargeable lithium-ion battery also exhibited stable performance during the operational tests. After being fully charged, the battery consistently supplied electrical energy to both the ultraviolet LED and the high-voltage generator module without noticeable voltage fluctuation. The battery capacity proved sufficient to maintain continuous operation throughout the testing period, demonstrating that rechargeable energy storage can effectively support autonomous operation of the mosquito control device.

The ultraviolet LED functioned properly throughout all experimental trials. The emitted ultraviolet radiation remained stable without observable flickering or intensity reduction during continuous operation. Since mosquitoes exhibit positive phototactic behavior toward ultraviolet wavelengths, the emitted UV radiation successfully attracted mosquitoes toward the vicinity of the device. Visual observations showed that insects gradually approached the illuminated region surrounding the protective wire mesh. These observations are consistent with previous studies reporting that ultraviolet wavelengths effectively stimulate mosquito attraction during nighttime activity. The high-voltage generator module also operated reliably during the experiments. When mosquitoes came into contact with the electrified wire mesh surrounding the UV LED, instantaneous electrical discharge occurred, resulting in immediate mosquito elimination. No interruption of electrical discharge was observed during repeated testing, indicating that the high-voltage circuit maintained adequate electrical potential throughout device operation.

The integrated performance evaluation demonstrated that all subsystems operated synchronously without significant malfunction. The photovoltaic charging system, rechargeable battery, ultraviolet LED, and high-voltage mosquito eradication circuit successfully formed a complete autonomous mosquito control system. The completed prototype is shown in Figure 4, while the overall experimental performance is summarized in Table 2.

Table 2. Functional Performance Evaluation of the Portable Solar-Powered Mosquito Control Device

Performance Parameter	Observation	Performance
Solar panel charging	Successful	Good
TP4056 charging module	Stable	Good
Lithium-ion battery	Stable	Good
UV LED illumination	Functional	Good
High-voltage module	Functional	Good
Mosquito attraction	Successful	Good
Mosquito elimination	Successful	Good
Prototype portability	Lightweight and portable	Good
Overall system operation	Stable	Good

The experimental results indicate that the developed prototype fulfilled all intended functional objectives. Every subsystem operated according to its design specification, confirming that the integration of renewable energy technology and ultraviolet-based mosquito attraction can provide an effective portable mosquito control solution.

3.4 Discussion

The successful operation of the developed prototype demonstrates that integrating photovoltaic energy conversion, rechargeable battery storage, ultraviolet light attraction, and high-voltage electrical eradication into a single portable device is technically feasible. Unlike conventional mosquito control methods that depend on chemical insecticides or continuous electrical supply, the proposed system utilizes renewable solar energy as its primary energy source, making it environmentally friendly and economically sustainable. The photovoltaic subsystem represents one of the major contributions of this research. Solar energy has become an increasingly attractive renewable energy source because it is clean, abundant, and widely available in tropical countries such as Indonesia. By utilizing photovoltaic panels as the primary energy source, the developed prototype eliminates dependence on conventional electrical infrastructure, allowing deployment in rural areas, agricultural fields, parks, outdoor recreational areas, and emergency situations where electrical access is limited.

Another significant contribution of this study is the application of ultraviolet LED technology as a mosquito attractant. Previous investigations have demonstrated that mosquitoes exhibit phototactic responses toward ultraviolet radiation, making UV LEDs effective attractants for insect trapping systems. In the present study, stable UV illumination successfully attracted mosquitoes toward the electrified wire mesh, confirming the effectiveness of ultraviolet light as a non-chemical mosquito control strategy. Unlike insecticide-based approaches, ultraviolet attraction does not introduce harmful chemicals into the surrounding environment, thereby reducing ecological risks and minimizing human exposure to toxic substances. The high-voltage generator module also played a critical role in the mosquito eradication process. Experimental observations indicated that mosquitoes contacting the electrified mesh were immediately incapacitated through electrical discharge. This rapid elimination mechanism minimizes the possibility of mosquitoes escaping after attraction while eliminating the need for chemical pesticides. Consequently, the proposed prototype provides an environmentally friendly mosquito control mechanism that aligns with current sustainable vector management strategies.

From an engineering perspective, the compact cylindrical design contributes significantly to prototype portability. The PVC housing provides adequate mechanical protection while maintaining low weight and manufacturing cost. Furthermore, the modular configuration allows relatively simple maintenance because individual electronic components can be replaced independently. Such modularity also facilitates future design improvements, including higher-capacity batteries, larger photovoltaic panels, automatic light sensors, or intelligent mosquito monitoring systems. The developed prototype also demonstrates the practical application of several fundamental physics principles. Solar radiation is converted into electrical energy through the photovoltaic effect. Electrical energy is then stored chemically inside lithium-ion batteries before being transformed into electromagnetic radiation through ultraviolet LEDs and finally into high-voltage electrical discharge for mosquito eradication. Consequently, the prototype integrates concepts from optics, electricity, electromagnetism, semiconductor physics, renewable energy, and electrical engineering into a single functional system. This multidisciplinary integration provides valuable opportunities for contextual physics education because students can directly observe the practical implementation of theoretical concepts in solving real-world engineering problems.

Although the prototype demonstrated satisfactory performance, several limitations should be acknowledged. The photovoltaic charging efficiency depends strongly on solar irradiance and weather conditions. Consequently, battery charging time may vary depending on seasonal and environmental conditions. In addition, the present prototype relies primarily on ultraviolet attraction and therefore may exhibit varying effectiveness depending on mosquito species, population density, and surrounding environmental factors. The prototype also lacks automatic energy management features such as light sensors or intelligent power control systems that could further improve operational efficiency. Future studies should therefore focus on optimizing photovoltaic efficiency, increasing battery capacity, improving ultraviolet wavelength selection, and incorporating smart electronic controllers. Integration of Internet of Things (IoT) technology for remote monitoring, automatic operating schedules, and battery status reporting may further enhance prototype performance. Quantitative evaluation involving mosquito mortality rates, attraction efficiency, operational duration, and long-term field testing should also be conducted to strengthen the scientific evidence supporting the effectiveness of the proposed system.

Overall, the developed portable solar-powered mosquito control device successfully demonstrates that renewable energy technology can be integrated with ultraviolet mosquito attraction and electrical eradication mechanisms to produce an environmentally friendly, portable, and sustainable mosquito control solution. The findings of this study contribute not only to the development of appropriate technology for public health applications but also to the advancement of applied physics education through the practical implementation of renewable energy and electromagnetic principles in engineering design.

4 Conclusion

This study successfully designed, fabricated, and evaluated a portable solar-powered mosquito control device utilizing ultraviolet (UV) light attraction as an environmentally friendly alternative for mosquito management. The developed prototype successfully integrated several key subsystems, including photovoltaic solar panels, a TP4056 charging module, a rechargeable lithium-ion battery, an ultraviolet LED attraction system, and a high-voltage mosquito eradication circuit into a compact and portable device. The integration of these components enabled the prototype to operate independently without requiring continuous electrical power from the utility grid, making it suitable for both indoor and outdoor applications, particularly in areas with limited electricity access.

The experimental evaluation demonstrated that all subsystems functioned according to the intended design. The photovoltaic panels effectively converted solar radiation into electrical energy, while the charging module maintained stable battery charging throughout the testing period. The rechargeable lithium-ion battery provided a reliable power supply for both the ultraviolet LED and the high-voltage module, allowing continuous device operation. Furthermore, the ultraviolet LED successfully attracted mosquitoes through phototactic behavior, and the high-voltage wire mesh effectively eliminated mosquitoes upon contact. These results indicate that the proposed prototype can provide a practical, energy-efficient, and environmentally sustainable solution for mosquito control without relying on chemical insecticides or fossil-fuel-based electricity.

From an engineering perspective, the prototype demonstrates the successful integration of renewable energy technology with applied electronics and mosquito control mechanisms. In addition to its practical application, the device also serves as an educational medium for demonstrating several fundamental physics concepts, including photovoltaic energy conversion, electrical energy storage, electromagnetic radiation, electrical discharge, and energy transformation. Consequently, the prototype contributes not only to the development of appropriate technology for vector control but also to contextual learning in physics and engineering education.

Despite its satisfactory performance, the current prototype has several limitations. The charging efficiency depends on solar irradiance and weather conditions, while mosquito attraction efficiency may vary depending on mosquito species, environmental conditions, and ultraviolet wavelength characteristics. Future research should focus on optimizing the photovoltaic system, improving battery capacity, enhancing ultraviolet wavelength selection, incorporating automatic light sensors and intelligent power management systems, and conducting long-term field evaluations under various environmental conditions. These improvements are expected to increase the operational efficiency, durability, and practical applicability of the developed device for sustainable mosquito control in tropical regions.

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