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A Comprehensive Review of Mosquitoes: Their Significant Impact on Human Health Throughout History and Prospects for Future Control

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Abstract

Mosquitoes are among humanity's most deadly enemies. As vectors for infections, they have tormented societies for millennia and continue to cause great pain. This review presents an in-depth assessment of mosquito biology, history, and public health implications. It studies important diseases transmitted from past to the present, their attendant morbidity and death costs, and modern control options and obstacles. Given their severe risk to global wellness, constant innovation will be important to reducing mosquito-borne illnesses and supporting eradication aims.

Keywords: Mosquitoes; Diseases; Innovations; Wrigglers; Transmission of diseases

Introduction

Mosquitoes, small flying insects, are part of the Diptera order, which also includes flies. Within this order, mosquitoes belong to the Culicidae family [1]. There are over 3,500 known species of mosquitoes that can be divided into two subfamilies: Anophelinae and Culicinae. The Anophelinae subfamily consists solely of one genus called Anopheles. These mosquitoes are well-known carriers of malaria parasites [2]. On the other hand, the Culicinae subfamily contains most mosquito species across various genera. Notable genera within the Culicinae with medical importance include Aedes, Culex, Culiseta, and Psorophora. Aedes mosquitoes spread illnesses like yellow fever, dengue fever, chikungunya, and Zika. Meanwhile, Culex mosquitoes transmit encephalitis viruses and filariasis. Among all mosquito types, females need blood to lay eggs, but their feeding habits vary by group. For instance, Aedes prefers daytime bites, whereas Culex is more active at twilight and dawn. Despite ongoing discoveries about various species and a deeper understanding of this area, mosquito classification is a task still in development [3-5].

Life cycle

The life cycle of mosquitoes consists of four distinct stages: egg, larva, pupa, and adult. Female mosquitoes lay their eggs rapidly in or near sources of stagnant water. These eggs then hatch into larvae commonly referred to as "wrigglers," which reside in the water and feed on bacteria. To obtain oxygen, the larvae breathe through syphon tubes and must regularly come to the surface. Within a span of 4-7 days, the larvae reach maturity and transform into pupae, or "tumblers." During this stage, the larval form dissolves as an adult mosquito develops within a protective pupal coat. This non-feeding phase lasts for about 1-2 days. Once fully transformed, the adult mosquito emerges from its pupal case and rests on the water's surface while its exoskeleton hardens, and its wings grow. Once they have reached adulthood, mosquitoes typically live for approximately 2-4 weeks, depending on various factors such as species type and environmental conditions. While male mosquitoes primarily consume nectar and other plant carbohydrates for sustenance, female mosquitoes require a diet rich in protein derived from blood to produce their first batch of eggs. After mating has occurred, females actively seek out a blood meal, which is crucial for successful egg development. They rely on chemoreceptors located on their antennae to identify suitable hosts. After feeding on blood, female mosquitoes fly back to still-water areas and lay clusters of 50-200 eggs [6-7]. These eggs can remain viable for several months, patiently awaiting favourable conditions such as floods or intense rainfall to hatch. This cycle enables mosquito populations to experience a surge during certain seasons. Throughout their lifetime, females can deposit multiple sets of eggs, ensuring a continuous rhythm from egg to adult and vice versa. A comprehensive comprehension of the mosquito life cycle plays a vital role in controlling population numbers and reducing the transmission of diseases.

Historic diseases and plagues

Mosquitoes have played a significant role in some of the most devastating pandemics throughout human history. One such example is malaria, which has ancient roots and has been linked to the decline of the Roman Empire by draining the vitality and productivity of its population and military forces. The American colonial era also witnessed major epidemics caused by mosquitoes, with yellow fever being particularly impactful. Coastal towns like Philadelphia and New Orleans experienced severe outbreaks during the 17th and 18th centuries, resulting in tens of thousands of deaths that influenced urban development in North America. In fact, a massive outbreak in 1793 even forced Philadelphia to temporarily relinquish its status as the capital of the United States. The construction of the Panama Canal encountered significant challenges due to frequent yellow fever epidemics from 1881 to 1914 [8-9]. French attempts resulted in approximately 5,600 fatalities before American engineers led by Walter Reed discovered that mosquitoes were carriers of this disease. As a result, targeted control measures were implemented to successfully complete the canal project. Another mosquito-borne illness with a history marked by large-scale outbreaks is dengue fever. Throughout time, these diseases transmitted by mosquitoes have had far-reaching consequences for societies worldwide, from shaping historical events to influencing public health policies and infrastructure development efforts. In 1780, Philadelphia experienced a significant outbreak that resulted in the deaths of approximately 3,000 individuals. Similarly, Asia and Africa were hit by another epidemic during the 19th century. The presence of dengue fever greatly impacted the combat readiness of both Allied and Japanese forces during World War II in the Pacific region. Throughout history, mosquito-borne diseases have played a role in various notable events. For instance, malaria caused the downfall of the Inca Empire and hindered European colonization efforts in tropical areas for many centuries. Additionally, yellow fever epidemics caused substantial delays in constructing the Panama Canal over several decades. Military operations have also been impeded by dengue fever during numerous conflicts. The transfer of infections across different time periods by mosquitoes has had far-reaching effects on civilization's development and decline, as well as urban planning and colonial pursuits. Despite their small size, these insects have exerted immense influence on human society through their ability to transmit diseases [10-12].

Current disease burdens

Mosquito-borne infections have been a significant concern for global health in recent years. Malaria, for instance, continues to be a problem, with approximately half of the world's population at risk of contracting the disease. Despite efforts to control it, drug and pesticide resistance have hindered progress, resulting in over 400,000 deaths annually. Sadly, most of these fatalities occur among young children in sub-Saharan Africa. Another mosquito-borne virus that has gained global prominence is dengue fever. Since the 1970s, it has spread extensively and is now prevalent in more than 100 countries across Asia and Latin America. The World Health Organization (WHO) estimates that there could be as many as 400 million cases each year; however, many go undiagnosed. Severe dengue can lead to approximately 20,000 deaths per year, predominantly affecting children. The emergence of the Zika virus in the Americas between 2015 and 2016 highlighted how quickly a new mosquito-borne illness can spread and cause pandemics. Due to its association with birth defects such as microcephaly in newborns, the transmission of Zika has been declared a public health emergency by international authorities [13-14]. Preventing mosquito bites remains crucial for avoiding both Zika virus infection and its associated consequences. While no vaccine provides complete protection against all four circulating serotypes, controlling Aedes mosquitoes, which transmit Zika, is currently our best defence against this disease. The West Nile virus was first detected in New York in 1999 and has since spread throughout the entire United States. While most human cases are mild, some can lead to severe neuroinvasive disorders.

The ongoing transmission of the virus by birds and mosquitoes makes it challenging to control. The combination of warmer temperatures and climate change may contribute to the increased dissemination of the virus. The chikungunya virus has caused repeated outbreaks in Africa, Asia, Europe, and the Americas since 2004. Its arrival in the Western Hemisphere in 2013 resulted in epidemics affecting over a million people across the Caribbean, South America, and Central America. Currently, there is no vaccine or specific treatment available for this virus. Yellow fever remains a concern in tropical parts of Africa and South America despite successful immunization programs. Outbreaks still occur frequently among individuals who have not been vaccinated or where vaccination coverage is limited, and mosquito control measures are inadequate. With modern globalization and climate change as contributing factors, there is an increasing risk of mosquito-borne diseases worldwide. It is crucial for public health authorities to prioritize developing new strategies for controlling these illnesses globally, with the aim of reducing their impact on populations [15].

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Control strategies: from ancient to modern

Presently, the management of pest control primarily relies on pesticides for indoor residual spraying or larvicide. However, the effectiveness of these methods is limited due to the development of resistance. To protect populations at risk, long-lasting insecticidal bed nets are considered the most scalable solution. Unfortunately, there is still a lack of sufficient distribution coverage for these nets. Attempts to reduce pests by modifying their habitats have produced varied results. Developing vaccines also faces significant challenges such as dealing with antigenic diversity, ensuring multivalent coverage, and achieving complete sterilizing immunity [16-18].

Ancient/historic methods

i. Source reduction: draining standing water sources near dwellings and larval habitat modification to reduce breeding places Practiced for millennia.

ii. Environmental management: removing vegetation and keeping yards clean to deny mosquitoes resting or hiding places.

iii. Smoking or burning plants: Using plant smoke or ashes like neem or citronella is claimed to repel insects.

iv. Repellents: Natural oils like coconut and lemon eucalyptus are utilized as protective sprays or lotions.

20th century innovations

i. Insecticidal chemicals: larvicides like Paris Green and pyrethroids in the 1900s; DDT indoor residual spraying contributed to malaria decreases in the 1950s and 1960s.

ii. Herbicides and vegetation removal: eliminating weeds and shrubs that hide adult mosquitoes.

iii. Bed nets: use of untreated or later insecticide-treated nets to protect sleepers against night biting vectors.

iv. Contemporary Methods: Insecticides: synthetic larvicides and adulticides such as malathion and pyrethroids through indoor residual spraying.

v. Genetic control: Sterile Insect Technique releases transgenic modification like Wolbachia symbionts.

vi. Larviciding: applying bacterial pesticides like BTI and insect growth inhibitors to water sources.

vii. Repellents: DEET, picaridin, IR3535, and oil of lemon eucalyptus are efficient repellents.

viii. Source reduction: drainage, garbage disposal, emptying flowerpots, or tires retaining water.

ix. Integrated vector management: layered utilization of numerous techniques like those above in coordinated campaigns.

New technology

Effective insect control: Bug zappers prove to be extremely efficient in ensnaring and eliminating various types of flying bugs, such as mosquitoes, flies, moths, and gnats. Their effectiveness extends to diminishing the annoyance caused by these bothersome creatures within enclosed areas [12].

Zeropest indoor bug catcher: Indoor bug zappers are designed to lure and eliminate airborne insects indoors. These devices provide a convenient and effective solution for dealing with mosquitoes and pests without the use of chemicals or manual intervention [19].

What indoor bug zappers work: Indoor insect traps utilize a combination of ultraviolet (UV) light and an electric grid to entice and eliminate flying bugs. The UV light acts as bait, attracting insects towards the device. When the insects contact the electric grid, they experience an electrical shock that quickly eliminates them.

Benefits of indoor bug zappers

a. Chemical-Free Solution: Bug zappers offer an alternative to conventional insect control methods that rely on chemicals. This chemical-free approach is especially advantageous for those who prioritize natural and non-toxic pest management solutions.

b. Ease of Use: Indoor insect zappers are often straightforward to use. They are connected to standard electrical sockets, and these devices require minimal maintenance. Certain models even come equipped with removable trays for easy disposal of deceased insects.

c. Wide Application: Bug zappers can be utilized in various indoor settings, including residences, office spaces, dining establishments, and commercial establishments. They provide effective bug management in areas like kitchens, living areas, bedrooms, and dining areas.

d. Reduced Noise and Odour: Bug zappers, unlike traditional pest control methods such as bug sprays or insect repellents, operate silently and do not emit strong odours. As a result, they are suitable for indoor use without causing any disturbances or unpleasant smells.

e. Coverage Area: Bug zappers come in different sizes, each with its own coverage area. When selecting a bug zapper for indoor use, it's crucial to take the size of the space into account and opt for a model that can adequately cover that area.

Considerations for indoor bug zappers

a. Safety measures: When searching for insect zappers, it is important to find ones that have safety features like screens or grids to prevent accidental contact with the electrified parts. This is particularly important in households with children or pets.

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b. Maintenance and Cleaning: Ensure that the insect zapper you choose has removable trays or accessible grids to make cleaning and maintenance easier. It is crucial to regularly clean the zapper in order to ensure optimal performance.

c. Placement: The effectiveness of the insect zapper depends on its proper placement. It should be positioned in areas where flying insects tend to gather, such as near windows, doors, or areas with high insect activity.

d. Environmental Impact: Although bug zappers are highly effective in getting rid of flying pests, it's important to keep in mind that they can also have an impact on beneficial insects like bees and butterflies. To prevent any negative effects on these helpful creatures, it is recommended to use bug zappers sparingly and alongside other pest control methods.

Promising future tools

Numerous innovative approaches are dedicated to enhancing traditional methods. Modified mosquitoes at a genetic level employ techniques such as controllable lethal genetic systems and gene drives to decrease native populations. Strategies based on microbiomes aim to introduce Wolbachia bacteria that limit the proliferation of pathogens. The effective dispersal of these self-sustaining mutant mosquitoes could contribute to reducing transmission across generations. Advancements in medical treatments may present alternative strategies for controlling illnesses. While more than twelve potential malaria vaccines are currently being developed, establishing their effectiveness remains challenging. On the other hand, there are already two approved dengue vaccines that offer reasonable protection against specific strains of the virus. Additionally, monoclonal antibodies under development for both prevention and treatment of dengue could complement vaccination efforts [15].

Threats of climate change and urbanization

According to experts, the global increase in temperatures is expected to expand the areas where mosquitoes can thrive, potentially exposing new regions to the risks they pose. The impact on disease transmission varies, with certain studies indicating that warmer climates may result in shorter periods of disease incubation. The concentration of populations near mosquito breeding sites due to rapid urbanization influences patterns of interaction between humans and vectors. To address these changes, it will be necessary to reassess treatment approaches based on emerging epidemiological factors.

Conclusion

Since ancient times, mosquitoes have caused tremendous suffering through the illnesses they spread. Continued research into multi-pronged current approaches gives potential to eventually lessen mosquitoes' catastrophic impact on human health and economy. In this comprehensive review, we explored that the biology, life cycle, diseases transmitted by mosquitoes is crucial for designing effective control measures. Integrated mosquito management strategies that integrate source reduction, insecticides, biological control, and personal protective measures are crucial for decreasing the burden of mosquito-borne diseases. By adhering to novel control strategies, we can decrease the impact of mosquito-borne diseases and preserve human populations internationally..

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