A Review on the Surveillance Methods of the *Aedes aegypti* Mosquito for the Prevention of Dengue

By

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A thesis submitted to the Department of Brac University in partial fulfillment of the requirements for the degree of

Bachelor of Pharmacy

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Declaration

It is hereby declared that

1. The thesis submitted is my own original work while completing the degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material that has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I have acknowledged all main sources of help.

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Approval

The thesis titled "A Review on the Surveillance Methods of the *Aedes aegypti* mosquito for the Prevention of Dengue" submitted by Md. Murad Hossain 18346096 of Summer 2018 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Pharmacy.

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Ethics Statement

This review adheres to the ethical principles of research and the relevant guidelines and regulations. The sources cited in this review were obtained by ethical standards, and their authors were properly cited. The goal of this review is to provide an objective and comprehensive analysis of dengue prevention methods, with the ultimate aim of improving public health outcomes.

Abstract

Dengue fever is a significant public health concern worldwide. It is a vector-borne disease caused by the dengue virus and transmitted to humans through the bites of infected Aedes mosquitoes. There is currently no specific treatment or vaccine for dengue fever, and prevention remains the most effective strategy for controlling the disease. The review aims to provide a comprehensive overview of the various prevention methods available for detecting *Aedes aegypti* mosquito. In this review, various surveillance techniques were analyzed for each method and evaluating their effectiveness, feasibility, and sustainability in various settings. The review also explores the challenges and opportunities for implementing these prevention strategies, particularly in Bangladesh. Larval Survey method might be one of the most effective techniques for Bangladesh for its case of work, feasibility and cost effectiveness but it is time consuming. For this reason, In Bangladesh, the implementation of artificial intelligence and machine learning algorithms in dengue surveillance will be a promising development that could provide faster and more accurate information on outbreaks.

Keywords: Dengue, Mosquito-borne viral disease, Aedes mosquito, Prevention, Mosquito Traps, Artificial Intelligence (AI), Machine learning(ML)

Dedication

This review paper is dedicated to my parents for their immense support and also to my supervisor. Also, friends whose unwavering support and encouragement have sustained me throughout this journey. May this review contribute to the ongoing efforts to develop effective and sustainable dengue prevention methods.

Acknowledgment

All praise to Almighty Allah, and I would like to commence by expressing my gratitude to Him for the continuous blessings.

Then I want to express my gratitude to my thesis advisor Dr. Nishat Zareen Khair Assistant Professor, School of Pharmacy, BRAC University), for allowing me to work under her supervision. Her guidance, counsel, and patience helped me finish my project in large part from beginning to end. Also, I would like to express my gratitude for the support, inspiration, and leadership of Professor Dr. Eva Rahman Kabir (Dean, School of Pharmacy, BRAC University) and Professor Dr. Hasina Yasmin (Program Director and Assistant Dean, School of Pharmacy, BRAC University). Moreover, I am grateful to all the faculty members of the School of Pharmacy, BRAC University for their enormous efforts for the accomplishment of my graduation. Additionally, I want to express my sincere appreciation to the lab officers and staff for their tremendous support and positive attitude, both of which were necessary for the task to be completed successfully. Finally, I want to thank my friends and seniors for their guidance, as well as my family members for their support.

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Chapter 1 Introduction

1.1 Background of Dengue

Dengue is a viral illness instigated by one of the variants of the dengue viruses. It is a mosquito-borne disease that affects millions of people worldwide and is considered a major public health problem. The World Health Organization (WHO) estimates that there are around 390 million dengue infections globally each year (WHO, 2021). Dengue is a principal reason for infection and demise in many countries in Asia and Latin America. In recent years, dengue has become more widespread, with outbreaks occurring in new geographical areas. Dengue fever stands for the utmost communal process of dengue and is categorized by a sudden onset of fever, headache, muscle and joint pain, and a rash. Severe dengue, also known as dengue hemorrhagic fever, is a more severe form of the disease that can lead to severe bleeding, organ failure, and death (WHO, 2021). The severity of dengue can vary, and some people may have mild symptoms or no symptoms at all. The dengue virus is a member of the flavivirus family and is transmitted to humans by the bite of an infected Aedes mosquito. However, scientists probably have a naive understanding of the dengue virus, as continuity rather than distinct antigen clusters appear to form. (Deore et al., 2019). Dengue fever is an extremely dangerous disease caused by a member of the Flavivirus family of arboviruses (a virus transmitted by an arthropod). More than 70 viruses belong to the family Flaviviridae, including some that cause encephalitis, such as the yellow fever virus, and the tick-borne, Japanese, and St. Louis encephalitis viruses, West Nile virus. (Hegde & Bhat, 2022). There are four prime types of the dengue virus (DEN-1, DEN-2, DEN-3, and DEN-4), and infection with one serotype does not provide immunity to the other three (WHO, 2021). A person can be infected with dengue multiple times, and each infection increases the risk of developing severe dengue. The dengue virus is transmitted to humans by the bite of an infected Aedes mosquito. The virus is present in the saliva of the mosquito and is introduced into the human bloodstream during the bite. The virus then replicates in the human body, leading to the development of dengue fever (WHO, 2021). Dengue is a global problem, with the majority of cases occurring in tropical and subtropical regions. According to the WHO, dengue is a leading cause of illness and death in many countries in Asia and Latin America. As a consequence of a sharp rise in occurrence over the last several generations, dengue is now endemic in more than 100 nations. (Deore et al., 2019). Numerous countries in tropical America, the Caribbean, and Southeast Asia have endemic dengue; across the Atlantic and Europe, dengue outbreaks are less frequent. Many regions with a substantial DENV population are also hyper-endemic, which is defined as the occurrence of all DENV subtypes in a specific region. (Añez & Rios, 2013) In recent years, dengue has become more widespread, with outbreaks occurring in new geographical areas (WHO, 2021). Prevention and controlling dengue is complex and challenging, and a multidisciplinary approach is required. The primary means of controlling dengue is by controlling the mosquito population. This can be achieved through measures such as removing breeding sites, using insecticide-treated mosquito nets and screens, wearing protective clothing, and using insect repellents. In addition, there are several community-based initiatives aimed at reducing the mosquito population, such as regular cleaning of stagnant water and the use of larvicides(Allan et al., 2023) The control and prevention of dengue are complicated by several factors, including the increasing global movement of people, the rapid spread of the Aedes mosquito, and the lack of a specific treatment for dengue. Additionally, dengue is difficult to diagnose, and many cases are misdiagnosed or not diagnosed at all. This can lead to underreporting of dengue cases, which makes it difficult to determine the true burden of the disease (Brady & Wilder-Smith, 2021)

1.2 Dengue spread process

Dengue is a viral illness instigated by one of four variants of the dengue virus. The virus is spread to humans through the bite of an infected Aedes mosquito. The Aedes mosquito is a day-biting mosquito that typically feeds on humans and is the primary vector for dengue transmission. (Allan et al., 2023) The dengue virus is present in the saliva of the infected mosquito and is introduced into the human bloodstream during the bite. After entering the human body, the virus replicates in the liver and spreads to other tissues, leading to the development of dengue fever. (Hussain et al., 2022) The symptoms of dengue fever typically appear within 4 to 7 days after the bite of an infected mosquito. The severity of dengue can range from mild to severe, with severe dengue (dengue hemorrhagic fever) potentially leading to severe bleeding, organ failure, and death. Dengue is a complex virus and the exact mechanism by which it causes disease is not fully understood. It is believed that the immune response to dengue infection may play a role in the development of severe dengue, as secondary infections with different serotypes of the virus have been associated with an increased risk of severe disease. (Sessions et al., 2009)

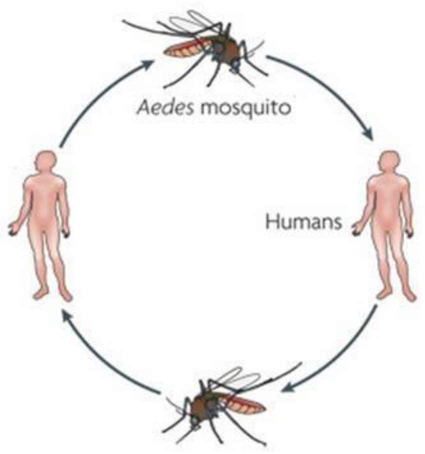

Figure 1: Dengue transmission from mosquito to human (2007 Nature Publishing Group Adapted from Whitehead, S. S. et al. Prospects for a dengue virus vaccine. Nature Reviews Microbiology 5, 518–528 (2007)

1.3 Global scenario of dengue

1.3.1 Dengue scenario in the United States of America

Within the previous two decades, the incidence of dengue fever cases has surged to extreme measures across the globe. Over three and a half billion individuals are thought to reside in dengue-endemic regions. (Martin et al., 2022). In the first half of the 20th century, dengue epidemics were observed across the United States, notably in the gulf and southeastern states (Alabama, Florida, Georgia, Louisiana, Mississippi, and Texas), Caribbean and Pacific Ocean, Hawaii. (Añez & Rios, 2013). Each of these dengue outbreaks can be traced back to the same three underlying causes: the insect vector, the favorable environmental conditions for disease transmission, and the preexisting vulnerability of the local population. Dengue-carrying Aedes aegypti and Aedes albopictus mosquitoes have been found in many counties around the United States, especially in the South and Southeast. (Añez & Rios, 2013)

1.3.2 Dengue scenario in Brazil

Brazil is affected by dengue severely more than most other countries because of poor infrastructures also for a huge population. The highest yearly incidence in the country (326.6% per 100,000 persons or more than 500,000 cases) of dengue since the 1990s occurred in 1998. Since 1994, there has been an exponential increase in reported instances. Viruses at this period were able to infect a considerably larger region. Between 1994 and 1995, the number of municipalities (or counties) reporting an event increased from 155 to 638. After DEN-3 split off in December of 2000, Rio de Janeiro saw a fourth large epidemic that began in January of 2001 and lasted for two years, much like the prior epidemics. The city's prevalence rate was higher than 470,1 and 1,735,2 instances per 100,000 residents, respectively, over those two years. (Teixeira et al., 2005)

1.3.3 Dengue scenario in Europe

According to the European Centre for Disease Prevention and Control (ECDC), between 2010 and 2019, a total of 2,076 cases of dengue were reported in Europe, including both locally acquired and imported cases. From 2012 to 2020, the World Health Organization (WHO) established a plan to combat the global spread of dengue disease. The annual incidence of dengue is estimated by the WHO to be between 50 and 100 million. (Sousa et al., 2012)

1.3.4 Dengue scenario in Asia

Southeast Asia has been afflicted by an endemic population of several dengue virus strains for a very long period. (Halstead, 2006). Dengue fever has been the most prevalent and fastest-increasing vector-borne disease in recent years. Approximately 1.3 billion people in ten Southeast Asian countries are at risk of acquiring dengue fever, out of a total of 3.5 billion globally. (World Health Organization)

1.3.4.1 Dengue scenario in India

As of October 31st, 2022, 110 473 cases and 86 fatalities have been recorded. (European Centre for Disease Prevention and Control)

1.3.4.2 Dengue scenario in Pakistan

As of 5 December 2022, 76 210 cases and 136 fatalities have been recorded. Since November 8, 2022, there have been 11,443 new cases and 52 further fatalities. (European Centre for Disease Prevention and Control)

1.3.4.3 Dengue scenario in Sri Lanka

There have been 59 977 instances documented so far in 2022, but no fatalities as of December 16 of that year. Since November 22, 2022, there has been a rise of 4,477 instances. (European Centre for Disease Prevention and Control)

1.3.4.4 Dengue scenario in Bangladesh

As of 17 December 2022, the Ministry of Health and WHO have recorded 81 064 cases and 292 deaths. There has been an increase of 15,010 cases and 34 deaths since November 22, 2022. (Gisan et al, 2022)

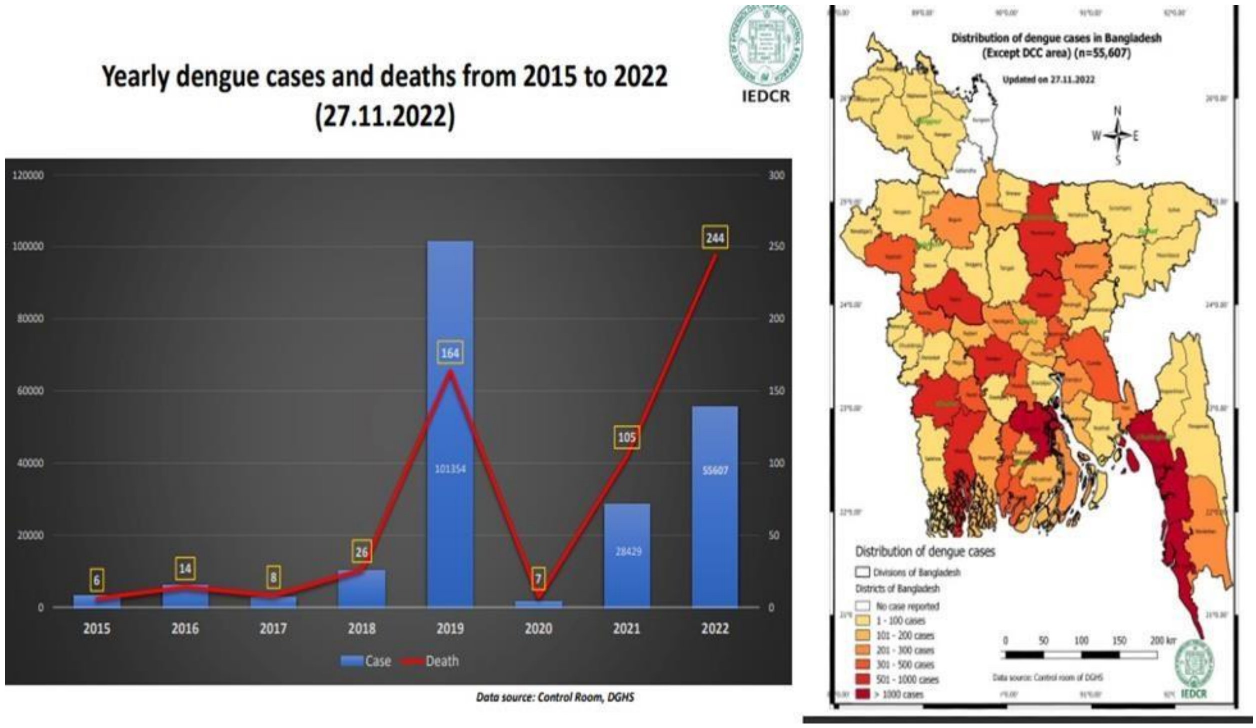

Figure 2: Dengue scenario across Bangladesh (IEDCR,2022)

From the picture, it is visible that dengue did not raise suddenly, it was rising continuously since 2015. The death was in 2016 only 6 but in 2019 was 164. But in 2021 death increased by 106 and in 2022 was 244.

Not only Bangladesh also various countries may have these reasons for spreading dengue:

Climate Change: Dengue mosquitoes thrive in warm, humid environments and are more likely to breed in these conditions. Changes in global temperatures due to climate change could be contributing to the spread of the disease. (Tabachnick, 2016)

Urbanization: Urbanization can lead to the creation of new mosquito breeding sites, as well as increased human exposure to mosquitoes, as people are more likely to live and work in areas where mosquitoes are prevalent. (Wu et al., 2009)

Mosquito Resistance: The evolution of mosquitoes that are resistant to insecticides can contribute to the spread of the disease, as control measures become less effective. (Gan et al., 2021). Lack of Prevention and Control Measures: A lack of effective dengue prevention and control measures, such as the elimination of mosquito breeding sites, the use of personal protective measures, and the implementation of vector control strategies, can contribute to the spread of the disease. (Budi et al., 2022)

1.4 Objective of the study

Dengue is a viral illness that spreads through mosquitoes and requires early detection and response to prevent further spread. Surveillance and monitoring of mosquito populations are essential for prevention and control of dengue The objective of dengue surveillance review is to find out the *Aedes aegypti* mosquito through different surveillance techniques. In this review various surveillance techniques are mentioned which are currently being used and newer technologies. Their advantages and disadvantages as mentioned and also which process is being widely used and which process can be best for Bangladesh. Larval surveys and adult mosquito traps are commonly used methods to assess the abundance and distribution of mosquito populations, and entomological indices are used to evaluate mosquito control programs. Remote sensing and GIS are emerging tools that can aid in mosquito surveillance and control by mapping and monitoring mosquito breeding sites and their associated environmental factors. By using a combination of these methods, targeted interventions can be implemented to reduce the frequency and spread of mosquito-borne diseases. The main objective of this review study is to know various surveillance techniques to detect *Aedes aegypti* mosquitos also know the merits and demerits of these techniques and implement one of the techniques according to the need.

All of the methods mentioned can be applied in Bangladesh, but one method that may be particularly useful is larval surveys. Bangladesh is a country with many water bodies, including ponds, ditches, and rice fields, which can serve as breeding sites for mosquitoes. Larval surveys can help identify and map these breeding sites, allowing for targeted interventions such as larviciding or source reduction. This method can also provide valuable information on the types of mosquito species present, which can inform control strategies. Additionally, larval surveys can be easily conducted by trained personnel and can be more cost-effective than adult mosquito traps or remote sensing methods.

Chapter 2 Methodology

For this scientific review on dengue fever prevention methods, I compiled information from a variety of reputable sources, including scholarly journals and databases such as PubMed, Web of Science, and Scopus, as well as renowned publications such as Nature, Google Scholar, MDPI, Cell, and Frontiers. I have selected precise search terms such as "dengue fever" and "prevention technique" to narrow my emphasis on the most relevant papers. Then I evaluated the contents of pertinent publications and books in order to get a comprehensive grasp of the issue. Using this approach, I was able to identify critical knowledge gaps and formulate a research topic to assist fill them. Furthermore, 90 articles I have checked and skimmed through their techniques according to my topic then selected 50 articles from the them to make this review. Next, I have produced a precise outline with key headers and subheadings to arrange my review. Using Mendeley Desktop to create in-text citations and references, I have made certain that all sources were properly credited and quoted throughout the writing process.

Chapter 3 Different Detection Technique of *Aedes aegypti* Mosquito

3.1 Current Different Techniques of Surveillance to Detect Dengue Mosquito

Surveillance techniques to detect dengue involve the methodical gathering, investigation, and interpretation of statistics on the incidence, prevalence, and distribution of dengue cases. The key goal of dengue surveillance is to monitor and detect outbreaks early, which can enable prompt and effective control measures to be implemented**.**

The techniques below are being used to detect *Aedes aegypti* mosquito currently:

3.1.1 Larval Survey

Larval Surveys involve searching for mosquito larvae in potential breeding sites, such as water-filled containers and artificial containers. The surveyor inspects these containers and identifies the presence of mosquito larvae, which can then be used to estimate the abundance of the Aedes mosquito in a particular area. This information is then used to prioritize control measures and allocate resources effectively. (Ridha & Sulasmi, 2022) Larval Surveys are an essential tool for monitoring the presence and abundance of the Aedes mosquito, which is the main vector for the transmission of the dengue virus. The Aedes mosquito is an aggressive daytime biter that is well-adapted to urban environments and can breed in a variety of containers, including artificial containers such as water tanks, drums, and flower pots. (Allan et al., 2023) The primary aim of Larval Surveys is to detect the presence of the Aedes mosquito as early as possible so that control measures can be implemented to reduce the risk of dengue transmission. By detecting mosquito larvae, health authorities can determine the level of risk for dengue transmission and prioritize control measures accordingly. This can include the implementation of control measures such as the removal of breeding sites, the use of larvicides, and public education campaigns.

Larval Surveys are conducted regularly in many countries and are an important component of dengue surveillance programs. They are typically carried out by trained personnel and are supported by national health authorities and international organizations. In some countries, community-based programs are also implemented to involve the public in the detection and removal of mosquito breeding sites. (Hossain et al., 2022) One of the benefits of Larval Surveys is that they are a cost-effective and efficient means of monitoring the presence and abundance of the Aedes mosquito. They are simple to conduct and do not require sophisticated equipment or technology. In addition, they provide valuable information on the distribution of mosquito breeding sites and can be used to inform control measures and allocate resources effectively. (Dja et al., 2022) Larval Surveys also give a significant part in the early detection of dengue outbreaks. By detecting the presence of mosquito larvae in a particular area, health authorities can take action to reduce the danger of dengue spread and minimize the impact of dengue on public health. This can include the implementation of control measures such as the removal of breeding sites, the use of larvicides, and public education campaigns. (Enamul et al., 2023)

In Bangladesh, the larval survey has been used in combination with other control measures, such as insecticide-treated bed nets, environmental management, and community mobilization. The success of these interventions depends on the timely identification of breeding sites, which can be achieved through larval survey.

Moreover, the larval survey can be used to monitor the effectiveness of control measures and identify areas that require further intervention. For instance, if the survey finds that breeding sites are still present in areas that have been treated with insecticides, it may be an indication that the insecticides used are not effective or that the coverage is insufficient

3.1.2 Adult mosquito traps

Adult mosquito traps are a commonly used surveillance technique for monitoring the presence and abundance of the Aedes mosquito, which is the primary vector for dengue virus transmission. These traps work by using attractants, such as carbon dioxide or other chemical lures, to attract adult mosquitoes into a trap where they can be captured and identified. The results of adult mosquito trap surveys be able to offer important data on the distribution and abundance of Aedes mosquitoes, which can help guide control measures and prioritize resources. (Chen et al., 2023)

Figure 3: Adult Mosquito Trap (Institute of Clinical Pathology and Medical Research (ICPMR)

Carbon dioxide-baited light traps offer a straightforward method for sampling adult mosquitoes, with a particular focus on female mosquitoes that are actively searching for hosts. This approach not only allows for the effective assessment of local nuisance-biting levels but also presents a valuable opportunity for analyzing these captured specimens to detect the presence of potentially harmful pathogens. (Photo: Cameron Webb, Medical Entomology, Pathology West– ICPMR Westmead.)

One of the key advantages of adult mosquito traps is their high efficiency in capturing mosquitoes. In comparison to other surveillance techniques, such as larval surveys or entomological indices, adult mosquito traps are more likely to accurately reflect the presence of adult mosquitoes, which are the stage of the mosquito that transmits the dengue virus. This information is particularly important for detecting outbreaks early, reducing the spread of the virus, and minimizing the impact of dengue on public health. (Carla et al., 2022)

Adult mosquito traps are also an effective means of reducing mosquito populations. These traps work by using a combination of attractants to lure female mosquitoes into the device where they are captured, preventing them from biting humans and spreading the virus. As a result, the use of adult mosquito traps can significantly reduce the number of mosquitoes and decrease the incidence of dengue fever in a given area. The use of adult mosquito traps in Bangladesh can provide a unique and effective approach to reducing the spread of dengue fever. These traps can be used in combination with other control measures to monitor and reduce mosquito populations, providing valuable information on the effectiveness of interventions and helping to develop targeted approaches to disease prevention.

3.1.3 Entomological Indices

Entomological Indices are a widely used dengue mosquito surveillance technique that involves measuring various parameters related to the presence and abundance of Aedes mosquitoes in a particular area. These indices can be used to determine the level of risk for dengue transmission and to prioritize control measures. Some common entomological indices include the Breteau index, which is the number of positive containers per 100 households, and the House Index which is the proportion of houses with at least one positive container. (Ligsay et al., 2022)

The mechanism of this technique involves visiting households and searching for mosquito larvae in potential breeding sites, such as water-filled containers, to assess the presence of the Aedes mosquito. The results of these surveys are then used to calculate the entomological index, which provides an estimate of the mosquito density in a particular area. (Nakpih, 2023)

The efficiency of entomological indices as a dengue surveillance technique depends on several factors, including the size and representativeness of the sample, the accuracy of the data collected, and the method used to calculate the index. Despite these limitations, entomological indices are widely used due to their simplicity and ease of implementation, making them a cost-effective and practical tool for monitoring dengue transmission. (Amierul et al., 2022)

In Bangladesh, entomological indices are already there but can be implemented efficiently by training local health workers to perform household surveys and collect data on the presence of Aedes mosquitoes. The results of these surveys can then be used to calculate the entomological indices and determine the level of risk for dengue transmission. In addition, the data collected can be used to support decision-making and resource allocation by the local health authorities, including the allocation of resources for dengue control and prevention efforts. Overall, entomological indices are a valuable tool for monitoring dengue transmission and guiding control measures. They give significant information on the presence and abundance of Aedes mosquitoes in a particular area, which can be used to prioritize control measures and allocate resources effectively.

3.1.4 Remote Sensing

Remote Sensing is a powerful tool that can be used to monitor the spread of the Aedes mosquito, the primary vector for dengue virus transmission. This technique involves the use of satellite imagery, aerial photography, and other remote sensing data to identify areas with high potential for dengue transmission. The use of remote sensing data can support dengue surveillance by providing a cost-effective, large-scale approach to monitoring the distribution of the Aedes mosquito. (Kumar et al., 2022)

Remote sensing data can be used to identify areas with high densities of vegetation and water- filled containers, which are key habitats for the Aedes mosquito. By mapping these areas, remote sensing can provide valuable information on the distribution of the mosquito and its potential for spreading dengue. In addition, remote sensing can also be used to monitor land use and land cover, which can affect the distribution and abundance of the Aedes mosquito. (Franklinos et al., 2019)

In Bangladesh, remote sensing can be implemented in dengue surveillance by partnering with institutions that have expertise in remote sensing and GIS technology. For example, the Bangladesh Institute of Technology (BIT) has expertise in using remote sensing data to monitor the environment and the health of the environment. By partnering with institutions like the BIT, Bangladesh can leverage the power of remote sensing to support dengue surveillance and control efforts.

The efficiency of remote sensing in the dengue surveillance can be improved by incorporating other data sources, such as ground-based entomological data, to validate the accuracy of remote sensing data and to provide a more comprehensive picture of the distribution of the Aedes mosquito. In addition, the use of remote sensing can also be enhanced by integrating it with other surveillance techniques, such as larval surveys and adult mosquito traps, to provide a more complete picture of the distribution and abundance of the Aedes mosquito. (Nguyen & Pineda-cortel, 2020)

In conclusion, remote sensing is a valuable tool for dengue surveillance, and its use can support the efforts of public health officials to monitor the spread of the Aedes mosquito and control the spread of dengue virus. By partnering with institutions that have expertise in remote sensing and GIS technology, Bangladesh can leverage the power of remote sensing to support its dengue surveillance and control efforts and improve public health outcomes. (Kumar et al., 2022)

3.1.5 Geographical Information Systems (GIS)

Geographical Information Systems (GIS) is a powerful tool for mapping and analyzing data related to dengue transmission. The technique involves using computer-based systems to capture, store, manage, analyze and visualize data in a geographic context. The data can then be used to generate maps and other visual representations that help to identify trends and patterns in the distribution of dengue cases, as well as the presence and distribution of the Aedes mosquito, the primary vector for dengue transmission. (Bryan et al., 2022)

The mechanism of GIS involves collecting data from various sources, including public health records, satellite imagery and other remote sensing data, and integrating this data into a single system. The data can then be analyzed using a range of spatial analysis tools, such as spatial clustering and regression analysis, to identify areas with a high risk of dengue transmission. (Sulaiman et al., 2022)

The efficiency of GIS in dengue surveillance is due to its ability to handle bulky quantities of data and to assimilate data from different sources, making it possible to identify patterns and trends in the distribution of dengue cases and the presence of the Aedes mosquito. Furthermore, GIS technology is highly flexible and can be easily customized to meet the specific needs of different communities, making it a highly effective tool for guiding decision-making and resource allocation in dengue control and prevention programs. (Ligsay et al., 2023)

To implement GIS in Bangladesh for dengue surveillance, several steps can be taken. Firstly, a comprehensive database of dengue cases and the distribution of the Aedes mosquito in Bangladesh should be established. This data can be collected from various sources, including public health records, larval surveys, adult mosquito traps and remote sensing data. Secondly, the data can be integrated into a single GIS system using appropriate software and tools.
Finally, the GIS system can be used to generate maps and other visual representations of the data, which can be used to guide decision-making and resource allocation in dengue control and prevention programs in Bangladesh.

In conclusion, Geographical Information Systems (GIS) is a highly effective tool for dengue surveillance and control. The ability of GIS to handle large amounts of data, integrate data from different sources and generate visual representations of data makes it a powerful tool for guiding decision-making and resource allocation in dengue control and prevention programs. Implementing GIS in Bangladesh can help to improve the effectiveness and efficiency of dengue control and prevention efforts, and ultimately help to reduce the impact of dengue on public health. (Sekarrini et al., 2022)

Table 1 Advantages of Larval Surveys, Adult Mosquito Traps, Entomological Indices, Remote Sensing, and Geographical Information Systems (GIS)

Larval Surveys	Adult Mosquito Traps	Entomological Indices	Remote Sensing	Geographical Information Systems (GIS)
Directly targets the source of dengue transmission by identifying potential breeding sites	Provides information on the presence and abundance of adult Aedes mosquitoes, which are directly involved in dengue transmission	Provides a standardized and quantitative method for assessing the abundance of the Aedes mosquito	Provides a broad overview of areas with high potential for dengue transmission	Provides a comprehensive view of the distribution of the Aedes mosquito and dengue transmission
Provides detailed information on the presence and distribution of the Aedes mosquito	Allows for monitoring trends in mosquito populations over time	Determines the level of risk for dengue transmission and helps prioritize control measures	Can be used to identify areas with high densities of vegetation and water-filled containers that may serve as potential breeding sites	Allows for the integration and analysis of multiple data sources
Helps prioritize control measures and allocate resources effectively	Can be used to assess the effectiveness of control measures	Easy to use and requires relatively low levels of training and equipment	Can be used to support decision-making and resource allocation in large-scale dengue control efforts	Supports evidence-based decision-making and resource allocation in dengue control efforts

Table 2: Disadvantages of these Larval Surveys, Adult Mosquito Traps, Entomological Indices, Remote Sensing, and Geographical Information Systems (GIS)

Larval Surveys	Adult Mosquito Traps	Entomological Indices	Remote Sensing	Geographical Information Systems (GIS)
Can be time Consuming and labor intensive Especially in largescale surveys	May not provide a comprehensive picture of the entire mosquito population as some mosquitoes may not be attracted to the traps	May not accurately reflect the actual mosquito population as it depends on the presence of potential breeding sites in the area	May not provide detailed information on the actual presence of the Aedes mosquito	Can be complex And require Specialized training And equipment to use effectively
Requires trained personnel to identify mosquito larvae correctly	Can be costly to purchase and maintain the traps	May not provide Detailed information on the distribution and presence of the Aedes mosquito	May not be effective in areas with limited access to remote sensing technology or data	Can be limited by the availability and quality of data sources such as satellite imagery or ground based surveys
May miss potential Breeding sites that are not easily accessible or visible	May require frequent monitoring And maintenance to ensure reliable Data collection	May not be effective in areas with limited access to water sources or with low mosquito populations	Can be affected by Weather conditions, such as cloud cover or haze that limit the quality of the satellite imagery	May not accurately reflect the actual mosquito population, as it depends on the quality and reliability of the data sources

Chapter 4 Newer technology to detect dengue mosquito

New technologies are being developed to detect dengue, including mosquito traps, sensors, drone-based surveillance, artificial intelligence and machine learning, and genetic engineering. Mosquito traps use light, heat, and CO2 to attract and trap mosquitoes, while mosquito sensors detect their presence based on wingbeat frequency. (Pan et al., 2022) Drones equipped with cameras and sensors can survey large areas for mosquito breeding sites, and AI and ML algorithms can analyze data on mosquito behavior. Genetic engineering aims to develop mosquito's resistant to the dengue virus. These new technologies hold promise in the fight against dengue, but a combination of strategies will likely be necessary for effective control. (Pollak et al., 2023.)

4.1 Mosquito trap

Fan-Traps and Gravitraps for Mosquito Surveillance

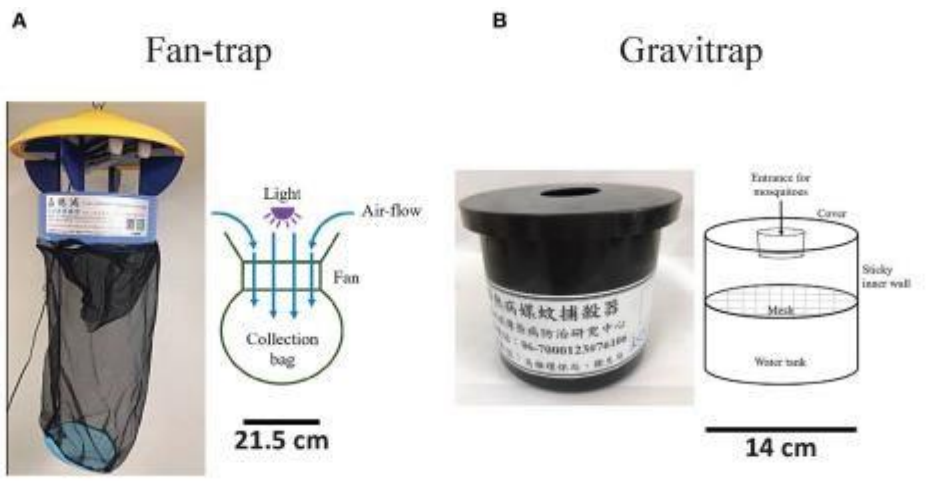

Figure 4: Fan trap and Gravity Trap (Pan et al., 2022)

A fan trap is a type of mosquito trap that uses a combination of light and airflow to capture mosquitoes, including those that transmit the dengue virus. The trap consists of a fan that creates an airflow, which draws mosquitoes towards the trap. The mosquitoes are then sucked into a collection chamber, where they are trapped and can be counted or analyzed.

The fan trap uses two key features that are attractive to mosquitoes: light and airflow. Mosquitoes are attracted to light, particularly ultraviolet (UV) light, which is why they are often seen hovering around outdoor lights at night. The fan trap uses a UV light to attract mosquitoes towards the trap.

Once the mosquitoes are attracted to the light, the fan creates a gentle airflow that draws them towards the trap. The airflow also mimics the natural wind currents that mosquitoes use to navigate and locate potential hosts, making the trap even more effective. (Pan et al., 2022) The fan trap occurs when multiple breeding sites are present near each other, leading to increased populations of mosquitoes in a given area. This increase in mosquito populations leads to increased contact with human hosts, increasing the likelihood of dengue transmission. (Su et al., 2014)

To mitigate the effects of a fan trap in the context of dengue mosquitoes, it is necessary to identify and eliminate mosquito breeding sites. This is attained by a variation of approaches, as well as the use of chemical larvicides, physical removal of breeding sites, and the use of screens or other barriers to prevent mosquitoes from accessing potential breeding sites. (Pan et al., 2022)

A Gravity Trap, on the other hand, refers to a method of capturing mosquitoes using a device that relies on the force of gravity to trap mosquitoes. Gravity traps work by using a light source and a downward-sloping surface to attract and capture mosquitoes. The mosquitoes are attracted to the light source and then fall onto the downward-sloping surface, where they are trapped. Gravity traps have been used successfully in the control of dengue mosquitoes, as they provide a simple and effective method of reducing mosquito populations in a given area. By reducing the number of mosquitoes in a given area, the likelihood of dengue transmission is also reduced. (Lee et al., 2013)

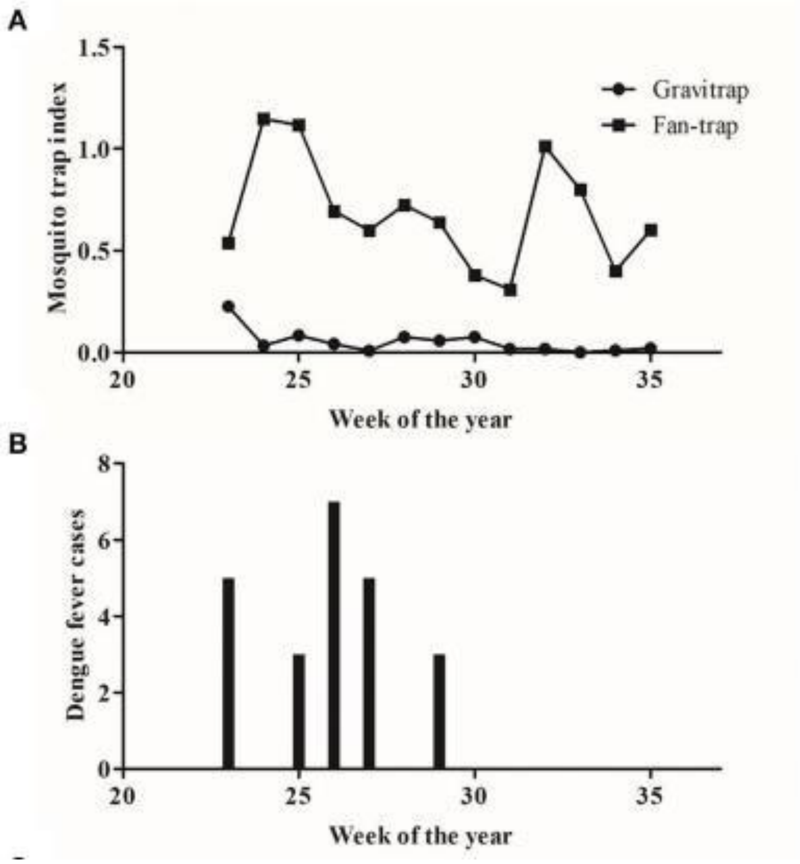

Figure 5: Numbers of mosquito trapped by the traps (Pan et al., 2022*)*

A weekly analysis was performed to determine the alteration in seizure amid the two traps. The findings indicated that the fan-trap (FI) was improved allied by the variabilities of described dengue fever circumstances and indigenous raindrops records than the gravitrap (GI).

These outcomes maintain the use of fan-traps for dengue fever surveillance. The higher capture rate of female and male Aedes mosquitoes by fan-traps suggests that they are more effective in detecting the presence of dengue-transmitting mosquitoes and therefore, can offer more accurate data for dengue fever regulation and prevention. (Pan et al., 2022) In conclusion, this study highlights the importance of selecting the appropriate trap type for dengue fever surveillance. The outcomes maintain the procedure of fan-traps as an effective tool for monitoring dengue transmission in endemic areas. (Pan et al., 2022)

4.2 Mosquito sensors

Biosensors offer a rapid, selective, and sensitive method of detection for diagnosing analyses from very tiny sample volumes. These analytical systems consist of the transduction system, which may contain a biological recognition element, and the automated device, which may comprise input boosters, processors, and a display. (Zainuddin et al., 2018)

Variations in flow, resistance, and voltage are used by biosensors to convert bio sensing components. Electrochemical transduction is a frequent use of biosensors for identifying human illnesses. Biosensors are useful for virus detection due to their real-time monitoring and quick detection capabilities. (Anusha et al., 2019) Due to the importance of quick detection in slowing the development of viral epidemics, continuous research is being conducted to identify and quantify virus particles as small molecules and nanoparticles. Virions or viral particles are monitored using amperometric, potentiometric, voltammetric, and impedimetric techniques in electrochemistry. (Zida et al., 2021)

In recent years, much work has been devoted to the development of electrochemical biosensors for the detection of the dengue virus. This research illustrates the expanding application of biosensor technology for the early identification and monitoring of viral outbreaks.

4.3 Drone-based surveillance

Figure 6: *Drone to detect dengue mosquito to prevent spread (picture taken from the International Atomic Energy Agency (IAEA*)

Drones equipped with thermal imaging cameras and remote sensing technology can detect areas with elevated body temperatures and map areas with high mosquito populations, respectively. This information can be analyzed to track the spread of the disease and inform targeted control efforts. In Bangladesh, drone-based surveillance able to give valuable data on the distribution and spread of dengue mosquitoes, which can be used to inform the deployment of control measures, such as insecticide application or the release of sterilized mosquitoes.(Achmad Ali Fikri, Syamsul Arifin, 2022) Drones can be equipped with specialized software and algorithms to analyze the data collected by these sensors, providing health authorities with valuable information on the distribution and spread of dengue mosquitoes.(Carrasco-Escobar et al., 2022) This information can be used to inform targeted control efforts, such as the application of insecticides or the release of sterilized mosquitoes.

Drone-based surveillance for dengue mosquitoes holds great promise for the future of public health, particularly in countries such as Bangladesh where the spread of the disease poses a significant threat to the population. (Mechan et al., 2023) The ability of drones to cover large areas quickly and efficiently, combined with their ability to detect areas with high mosquito populations and elevated body temperatures, provides valuable information to health authorities. However, it is important to note that the technology is still in its early stages of development and further research is needed to fully understand its potential and limitations. Nevertheless, the continued development and implementation of drone-based surveillance for dengue mosquitoes in Bangladesh will be a crucial step in controlling the spread of this disease and improving public health outcomes. (Carrasco-Escobar et al., 2022)

4.4 Artificial intelligence and machine learning

AI and ML techniques can be used to analyze large amounts of data from a variety of sources, including satellite imagery, weather data, and mosquito surveillance data, to identify areas with high mosquito populations and elevated body temperatures, which can be a sign of dengue fever. These techniques can also be used to predict the spread of the disease, based on patterns and relationships between environmental variables and dengue incidence. (Mayrose et al., 2023)

4.5 Applications of newer dengue surveillance technologies

AI and ML can be applied in Bangladesh in a variety of ways to enhance dengue mosquito surveillance and control efforts, including:(Hamdani et al., 2022) Mosquito Detection: AI and ML can be used to automatically detect mosquitoes in images and videos, allowing for more efficient and accurate mosquito surveillance in Bangladesh. (Siddiqua et al., 2021)

Disease Prediction: AI and ML can be used to predict the spread of dengue fever in Bangladesh, based on patterns and relationships between environmental variables and dengue incidence. (Naher et al., 2022)

Vector Control: AI and ML can be used to identify areas with high mosquito populations in Bangladesh and prioritize control efforts, such as the application of insecticides or the release of sterilized mosquito. (Mayrose et al., 2023)

Table 3 Advantages of Artificial intelligence and machine learning, Drone-based surveillance, Biosensors, Fan-Traps and Gravitraps to detect dengue mosquito

Artificial intelligence and machine learning	**Drone-based surveillance**	**Biosensors**	**Fan-Traps and Gravitraps**
AI and ML can process large amounts of data more quickly and accurately than traditional methods, allowing for more efficient mosquito surveillance	Drones can cover large areas in a short amount of time allowing for more comprehensive mosquito surveillance	Biosensors can detect low levels of disease-causing pathogens allowing for more accurate detection of dengue carrying mosquitoes	Fan-traps and gravitraps can be used to target specific mosquito species, allowing for more effective control efforts.
AI and ML algorithms can identify patterns and relationships in data that may be missed by human analysts, leading to more accurate predictions and improved control efforts.	Drones can access areas that may be difficult to reach on foot, such as remote or hard to reach locations leading to more accurate surveillance data	Biosensors can produce results quickly, allowing for more efficient mosquito surveillance and control efforts	Fan-traps and Gravitraps have high capture rates leading to more accurate surveillance data.
AI and ML can be used to predict the spread of dengue fever based on patterns and relationships between environmental variables and dengue incidence	Drones can collect a variety of data including high resolution images and videos allowing for more comprehensive surveillance and control efforts	Biosensors can be easily transported and deployed in a variety of locations allowing for more comprehensive surveillance efforts	Fan-traps and gravitraps are relatively simple to use allowing for more widespread deployment in a variety of locations.

Table 4 Disadvantages of Artificial intelligence and machine learning, Drone-based surveillance, Biosensors, Fan-Traps and Gravitraps to detect dengue mosquito

Artificial intelligence and machine learning	**Drone-based surveillance**	**Biosensors**	**Fan-Traps and Gravitraps**
Implementing AI and ML algorithms can be expensive requiring significant investment in hardware, software, and personnel.	Drone-based surveillance systems can be expensive to purchase, operate and maintain, making them cost-prohibitive for many communities and countries.	Biosensors can be expensive to purchase and maintain making them cost prohibitive for many communities and countries.	Fan-traps and gravitraps are limited in them effectiveness, as they may not attract or capture all mosquitoes' in an area.
AI and ML algorithms can be complex requiring specialized expertise and knowledge to implement and maintain	Drone based surveillance systems require specialized technical expertise to operate and maintain, which can limit their use in many settings.	Biosensors require Specialized technical expertise to operate and maintain, which can limit their	Fan-traps and gravitraps can be expensive to purchase and maintain, making the cost prohibitive for many communities and countries.
AI and ML algorithms may be opaque making it difficult to understand how decisions are being made leading to questions about their accuracy and reliability	The use of drones for surveillance purposes can raise privacy concerns as they have the potential to gather sensitive information about individuals and communities	Biosensors have a limited range making them less effective in larger areas or in areas with complex environments.	Fan-traps and gravitraps require regular maintenance, which can be time-consuming and labor intensive making them less practical for use in many settings

Chapter 5 Key findings

In this surveillance study the main findings of this review is to know or find out different surveillance techniques which are currently being used like the Larval Surveys, Adult Mosquito Traps, Entomological Indices, Remote Sensing, Geographical Information Systems (GIS). From all of these techniques larval survey is widely used because of its low cost and easy to imply this technique. Also, newer technologies such as Artificial intelligence and machine learning, Drone-based surveillance, Biosensors, Fan-Traps and Gravitraps to detect dengue mosquitoes are being used in short term but can be used widely to reduce the spread of *Aedes aegypti* mosquito worldwide. In Bangladesh, the implementation of artificial intelligence and machine learning algorithms in dengue surveillance is a promising development that could provide faster and more accurate information on outbreaks.

Chapter 6 Conclusion

Dengue is a rapidly emerging public health threat that is affecting many parts of the world, particularly in tropical and subtropical regions. Over the previous few years, several surveillance techniques have been technologically advanced to detect and monitor the transmission of dengue. Bangladesh, being a tropical country with a high incidence of dengue, has been implementing various dengue surveillance techniques. One of the primary methods used in Bangladesh is the passive surveillance system, which relies on health facilities to report cases of dengue to the government. While this system has proven to be effective in detecting dengue cases, it is often criticized for being slow and having limited reach, as not all dengue cases may be reported. Additionally, the passive surveillance system does not provide realtime information, which makes it difficult to respond quickly to outbreaks. In recent years, Bangladesh has made strides in implementing active surveillance techniques, such as the use of geographic information systems (GIS) and remote sensing technologies, to supplement the passive surveillance system. These techniques have shown promising results in detecting outbreaks more rapidly and providing more accurate information on the distribution of dengue cases.

Chapter 7 Future of Dengue Surveillance in Bangladesh

As new technologies and techniques continue to emerge, the future of dengue surveillance in Bangladesh looks bright. In the future, the use of artificial intelligence and machine learning algorithms in dengue surveillance may become more prevalent, providing faster and more accurate information on outbreaks. Additionally, the use of drones and other remote sensing technologies may become more widespread, allowing for real-time monitoring of outbreaks and rapid response.

Moreover, increased collaboration between the government and health organizations will be key in ensuring the success of dengue surveillance efforts in Bangladesh. This may include the implementation of community-based surveillance programs, which engage communities in the surveillance process and improve the reach and accuracy of data collection.

In conclusion, the future of dengue surveillance in Bangladesh holds great potential for improvement and innovation. By leveraging new technologies and techniques, and by working together to overcome the challenges posed by the disease, it is possible to significantly reduce the burden of dengue in Bangladesh and ensure a brighter future for its citizen

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