Dengue Innovation: A Sustainability Approach for Preventing and Controlling of Dengue Diseases Outbreaks via IoT Technology

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Abstract. Dengue is a mosquito-borne viral disease that is surging and becomes worldwide serious issues. Currently, due to lack of specific treatment or vaccine against dengue, many forms of vector control remains a key strategy for dengue fever prevention. In response to the issue, this paper introduces an AedesTech Mosquitoes Home System (AMHS) that is equipped with a special trade secret formulation or also called as Insecticide Growth Regulator (IGR) and combines with Internet of Things (IoT) technology for vector control. An IGR is a pheromone-like liquid formulation that is a chemical that serves to stimulate and have sexually attract the male and female that will attract and lure adult female mosquitoes to lay eggs in them, and the adult mosquitoes will soon die after lying eggs. Those eggs that already laid with the chemical will not hatch or die at an expected of 99% rate, or go beyond the pulp level. Our sustainable approach offers for two (2) novel features. First, to monitor the collection of Aedes eggs in our MHS, we develop a mobile apps called AedesTech Apps (ATA) for Aedes eggs auto-counting and data collection are stored in cloud based server. Second, to monitor the level of liquid formulation (IGR) in AMHS, we utilize an Arduino water based sensor to real time track the IGR level status and we called as Intelligent Mosquito Home System (iMHS). Our iMHS will automatically alert the user when refill is needed. Both technologies are related to IR 4.0 that could be a new approach for preventing and monitoring of dengue outbreaks. This sustainability approach are environmental friendly and cost saving that provide the solution to the world’s global issue of dengue.

Keywords. AedesTech Mosquitoes Home System (AMHS), IoT, AedesTech Apps, Insecticide Growth Regulator (IGR)

1. Introduction

*Aedes aegypti*, the main vector borne diseases such as dengue and other epidemiologically significant viruses such as Chikungunya, Yellow fever, and Zika [1]. It is a domestic endophilic mosquito that has
expanded its habitable range in recent decades and will likely continue to spread [2]. The Aedes mosquitoes have 4 life stages: egg, larva, pupa and adult. Mosquitoes can live and reproduce inside and outside the home. The entire life cycle, from an egg to an adult, takes approximately 8-10 days. Pupae develop into adult flying mosquitoes in 2-3 days. Dengue hemorrhagic fever (DHF) or dengue fever (DF) cases are on the increase. According to [3], in year 2018, 80615 DHF/DF cases were reported with 147 mortalities in Malaysia. Aedes aegypti and Aedes albopictus are two (2) major vector mosquitoes of DHF and DF. Vector control is one of the most effective approaches in combating DHF or DF. As DHF and DF can be transmitted transovarially [4-5] vector control of Aedes species in the immature stages is very important. Although chemical control of adult mosquitoes provides quick knockdown (mortality), resistance of mosquitoes to insecticides has been widely reported. Resistance of Aedes aegypti to organophosphate (temephos, malathion, fenthion and propoxur) [6-7], permethrin [8], DDT and dieldrin [9] have been well documented.

A pyriproxyfen, an insect growth regulator (IGR) also has been reported to be effective against vector mosquitoes such as aegypti [10], Culex [11-12] and Anopheles [13]. The pyriproxyfen mimics a natural hormone in insects and disrupts their growth. It is a type of insect growth regulator that affects mostly young insects and eggs. The pyriproxyfen affects many types of insects, including fleas, cockroaches, ticks, ants, carpet beetles, and mosquitoes. It has been registered for use in pesticides by the Environmental Protection Agency (EPA) since 1995 [14]. The pyriproxyfen prevent the immature mosquito to be emerged to adult. However, pyriproxyfen products such as Sumilarv 0.5 (pyriproxyfen 0.5% w/w) does not kill larvae but has extended residual activity that inhibits adult emergence in vector mosquitoes.

This paper presents two (2) novel approaches in preventing and controlling dengue outbreaks. First, our AedesTech mobile Apps (ATA) that able to scan and capture images of Aedes eggs and transfer for an automated image processing system to first segregate between Aedes eggs with non Aedes eggs and then, count its total for a further data analytic process. Second, our intelligent AedesTech Mosquito Home System (iMHS) with the embedded water based sensor in our AedesTech Mosquito Home System (AMHS) to track for the liquid formulation, Insecticide Growth Regulator (IGR) status, equipped in our AMHS. Our approaches offer for an efficient automated counting of Aedes eggs while reducing manpower cost to check and change for IGR refill in each particular AMHS.

2. Methodology of Dengue Control Using AedesTech Mosquito Home System (AMHS)

AedesTech Mosquito Home System (AMHS) as shown in Fig. 1, which consist of devices designed to attract Aedes mosquitoes and target container-breeding mosquitoes by providing an attractive water source for gravid females seeking oviposition sites. Females attracted to the device are killed and reproduction is eliminated. AMHS is an auto-dissemination device, consisting of a regular ovitraps containing pyriproxyfen, to contaminate gravid female mosquitoes during oviposition, allowing them to disseminate the chemical to other Aedes oviposition sites. Auto-dissemination is a ‘pull’ and ‘push’ technology which allows mosquito control professionals to treat larval habitats in a timely and economical fashion [15]. The objective of the AMHS is by using the “Lure & Kill Technology” to control & eliminate mosquitoes during all development stages, be it as eggs, larvae, pupae or adults, and thus to reduce the overall mosquito population. A total of 400 units of AMHS were set up surrounding the trial site, outside each of the residential house, at the fence, gate or at the front door. The AMHS’s refill was refilled at monthly basis. The AMHS installation began in September 2018, for a period of one year until August 2019 at X sites in Kedah.
2.1 Design of AMHS

AMHS is designed to suit the green technology environment and sleek enough to be installed in the outdoor or inner sites or location. The device measured 19.7cm (height) x 14.6cm (width) and consists 500ml of 40 ppm PPF treated water. Egg collection tissue will be placed in inner wall of AMHS. The interior skeleton of AMHS is depicted in Fig. 2. The idea comes prior to examining the details of mature adult mosquitoes, which will lay eggs in 5 or more breeding sites. Adult mosquitoes will ensure the survival of their eggs to the larvae level and eventually become adult mosquitoes. As a result of this research, the Mosquito Home System has created a formulation (IGR) that contains 500ml of 40 ppm PPF treated water. It pollutes the new reproductive site, when the adult mosquitoes lay eggs in the Mosquito Home System, they will remove the formulas and kill the entire larvae in the breeding ground. The IGR is placed upside down in the AMHS and the “lure and kill” solution is allowed to fill the AMHS slowly, which can last for a minimum of one month.

3. Development of Aedestech Apps (ATA) for Mosquitoes Eggs Counting

Through this project, the mobile AedesTech Apps (ATA) is developed to collect data related to Aedes mosquito eggs directly from AMHS and stored in a cloud database. For this purpose, a rectangular piece of tissue is clipped to similar size of transparency slides and both materials are circularly attached around the inner part of AMHS. The reason is to allow for a slowly absorption of the IGR into the tissue that allow for breeding process of female Aedes mosquitoes. The tissue is then taken out to be scanned by ATA and transfer the digitized images to the Excel file for an auto counting for Aedes eggs via MATLAB AutoCountMe [16] system. Through this system, the exact images of Aedes eggs are
identified from non Aedes eggs through digital image processing technology to be developed. A new algorithm will be proposed to expedite the process of counting the mosquito eggs directly using only mobile devices or mobile phones either offline or online. Refer to Fig. 3 for the overall project framework. The large data from various installations of the whole AMHS in geographically apart locations are then collected and compiled into the central cloud database for further numerous data mining and forecasting analysis. Example of the analysis would be to projection of the mosquito population rate for a region or location and it can extend to the parties for follow-up actions and comparative results that can be utilized for the manufacture decision [17].

![Figure 3. ATA Development Framework](image)

The unique feature that ATA offers is for an in-situ data collection. All digitized images of an Aedes eggs are collected and auto-counting using this apps. Refer to Fig. 4 for an ATA user interface. The ATA Standard Operating Procedures are as follows:

1. **Login and Password (By Location of the user access)**
2. **Setup Pot or MHS trap and labeling using QR or Bar Coded as identification for each trap**
3. **Setup and configure the location of the trap using Global Positioning System (GPS)**
4. **Click the camera inside the apps and scan the QR-Coded then select the image and click the scan and count the Aedes eggs.**
5. **Next save in cloud or in the mobile if not internet access is available**
6. **Statistical and data visualization by each AMHS trap will visualize automatically.**
7. **By using this apps will also can retrieve and done several data mining for the related data based on Aedes eggs image captured.**

![Figure 4. User Interfaces of AedesTech Apps](image)
4. Development of iMHS: Intelligent Mosquitoes Home System Using IoT Sensor

The iMHS design framework relies upon 3-tier architecture comprises of Client Application (Presentation tier), Business layer (Application tier) and Data Layer (Data tier). The Presentation tier includes User Interface part that interfacing with client. The Application tier is the middle part between client and data layers where logic operations such as validation, calculation, and data related operations take place. The role is to ease of communication between client and data layers. Then, the Data tier consists of actual database that includes methods such as insert, delete, update and get data from/to database.

4.1 Hardware Component

The three (3) basic components of iMHS devices include the microcontroller, a water level sensor to perform the intended task and the source of power, an AA battery. The first component, an IoT based microcontroller called as ESP8266 [18-19]. It is a Wi-Fi embedded microcontroller that utilizes standard everyday Wi-Fi band frequency at 2.4 GHz. The second component of iMHS, an Arduino water level sensor [20]. This type of sensor is an easy to use water level sensor that is effective for water level drop detection. It offers for an easy completion of the water conversion to analog signals, and the simulated value of the output can be read directly by the Arduino development board, to achieve the water level alarm. Lastly, the third component refers to an AA battery [20] or also called a double A or Mignon (French for "cute" or "adorable") battery, a standard size single cell cylindrical dry battery. The AA batteries are common in portable electronic devices that compose of a single electrochemical cell which may be either a primary battery (disposable) or a rechargeable battery. Detailed hardware components are tabulated in Table 1 along with the connection of the circuit is illustrated in Fig. 5. The internal architecture and the actual implementation of our Arduino water level sensor in AMHS is depicted in Fig. 6. We use MySQL Database Management System (DBMS) and PHP 7 for page scripting.

![Figure 5. iMHS Circuit Board Design](image-url)
5. Result and Discussion

5.1 Result for ATA

For the evaluation of ATA, we used a dataset provided by [21] together with their ICount tool. There are five images taken from a camera called 'macro images' and five microscopic images called 'micro image'. Fig. 7 shows samples of 'macro image' and 'micro image', respectively. We compare our proposed method with two tools that available for free download which is ICount [21] and EggCounter [22]. As a gold standard, ImageJ was used to manually count the eggs to confirm the accuracy of each tool. Table 1 shows the number of eggs obtained by our proposed tool, ICount and EggCounter using 'macro image'. From the table, it is found that EggCounter unable to detect even a single egg.

![Macro Image](a) Macro Image ![Micro Image](b) Micro Image

*Figure 7. Macro and Micro Image of Aedes Eggs*

The results obtained by ICount are comparable to our tool, but it needs user intervention. Different parameters setting will produce different results which eventually can lead to biased or unreliable estimation. The proposed tool contrarily to ICount where a user loads the image and then the eggs are automatically counted. The results presented by the proposed tool are satisfactory with only 0.01 to 0.04 percent of error.

**Table 1**: Comparison between ImageJ, the ATA method, ICount and EggCounter using Macro Images

| Dataset     | ImageJ | ATA Method | % Error | ICount | % Error | Egg Counter | % Error |
|-------------|--------|------------|---------|--------|---------|-------------|---------|
| IMG_225bis  | 153    | 155        | 0.01    | 146    | 0.05    | 0           | 100     |
| IMG_2253bis | 479    | 479        | 0.04    | 482    | 0.01    | 0           | 100     |
| IMG_2256bis | 348    | 352        | 0.01    | 344    | 0.01    | 0           | 100     |
5.2 Result of iMHS

In iMHS, the issue arise regarding the battery power source lifetime. We run several tests to Arduino water based sensor with the AA battery in two different interval of data sent to cloud database. The results are as depicted in Table 2. Implementation results reveal that the battery lifetime solely depends upon the setting of interval time of sending data to cloud server. Changing in interval time proportionately resulting in changing the lifetime of battery power energy. The iMHS overall results show for a half an hour interval, battery could last for a half of a month whereas for an hour interval time set, it could last for a month.

**Table 2:** Results of battery lifetime in different interval

| Interval time (in second) of Data Send | Battery lifetime (in month) (AA Battery) |
|---------------------------------------|-----------------------------------------|
| 1800                                  | 0.5                                     |
| 3600                                  | 1                                       |

The Arduino water level sensor in iMHS project is set to read in three (3) different level status i.e. low, medium and high. We have set different distances in centimeter (cm) for each status. The main interface of iMHS is illustrated in Fig. 8. Each location of iMHS devices is viewed by its longitude and latitude, while the detailed of each longitude and latitude location can be browsed through Google map.

![Figure 8. User interface of iMHS](image)

6. Conclusion and Future Works

The development of AMHS, Aedestech Apps (ATA) and iMHS is considered to successfully embed the Internet of Things (IOT) technology for our dengue innovation project related to Industrial Revolution (IR) 4.0. This research collaboration has transferred the knowledge and technology between universities as well as its industry partner. As a recapitulation, AMHS offers for effective alternative in controlling dengue. The ATA provides effective way in getting the input images of Aedes egg to further process of auto-counting of Aedes eggs send to cloud storage for extensive analysis. And lastly with our iMHS, the cost for labor to manually check and track for the emptied IGR is significantly reduced and cut-off
through the real-time IGR status visualization. The main objective of this project for reducing manpower usage in controlling the dengue disease at the national as well as international level. The concept of auto-detection device can be applied for other industry domain that might as well create new business opportunities in the near future.

Acknowledgment

We thanks all our research institutions-industry collaborators i.e. UniSZA, UMT, UniKL and One Team Network (OTN) Sdn. Bhd. under matching grant, UniSZA/2018/PKP/01 with project code R0047-R001. A sincere gratitude goes to the MHS co-founder, One Team Network Sdn. Bhd. As well as for supporting our work in reviewing for spelling errors and synchronization consistencies and also for the constructive comments and suggestions.

References

[1] Hemingway, J., Beaty, B. J., Rowland, M., Scott, T. W., & Sharp, B. L. “The Innovative Vector Control Consortium: improved control of mosquito-borne diseases.” *Trends in parasitology*, 22(7), 2006. 308-312.

[2] Buchman, A. Stephanie G., Ming L., Igor A., Shin-Hang L., Shin-Wei W., Chun-Hong C. "Broad Dengue Neutralization in Mosquitoes Expressing an Engineered Antibody." *CELL-D-19-01515* (2019).

[3] Seng C. M., and Jute N. “Breeding of Aedes aegypti (L.) and Aedes albopictus (Skuse) in urban housing of Sibu town, Sarawak”. Southeast Asian Journal of Tropical Medicine and Public Health. 1994, Sep;25:543.

[4] Han Lim L., Mustafakamal I., and Rohani A. "Does transovarial transmission of dengue virus occur in Malaysian Aedes aegypti and Aedes albopictus?." Southeast Asian Journal of Tropical Medicine & Public Health 28.1 (1997): 230-232.

[5] Lee, H. L. "Environmental friendly approaches to mosquito control." Mosquitoes and Mosquito-borne Diseases. Ng, FSP and Yong, HS (eds.). Kuala Lumpur: Academy of Science Malaysia (2000): 223-233.

[6] World Health Organization. Dengue hemorrhagic fever: diagnosis, treatment, prevention and control. World Health Organization, 1997. George G. P., and Taylor C. E. "Genetic and biological influences in the evolution of insecticide resistance." Journal of economic entomology 70.3 (1977): 319-323.

[7] Malcolm C. A., and Wood R. J. "Location of a gene conferring resistance to knockdown by permethrin and biresmethrin in adults of the BKPM3 strain of Aedes aegypti." *Genetica* 59.3 (1982): 233-237.

[8] World Health Organization. Test procedures for insecticide resistance monitoring in malaria vectors, bio-efficacy and persistence of insecticides on treated surfaces: report of the WHO informal consultation, Geneva, 28-30 September 1998. No. WHO/CDS/CPC/MAL/98.12. Geneva: World Health Organization, 1998.

[9] Loh P. Y., and Yap H. H. Laboratory Studies on the Efficacy and Sublethal Effects of an Insect Growth Regulator, Pyriproxyfen (S-31183) Against Aedesaegypti (Linnaeus). 1989.

[10] Kamimura K., and Arakawa R. "Field evaluation of an insect growth regulator, pyriproxyfen, against Culex pipiens pallens and Culex tritaeniorhynchus." *Medical Entomology and Zoology* 42.3 (1991): 249-254.

[11] Schaefer C. H., and Mulligan F. S. "Potential for resistance to pyriproxyfen: a promising new mosquito larvicide." *Journal of the American Mosquito Control Association* 7.3 (1991): 409-411.

[12] Okazawa T. "Research & Reports." *Journal of the American Mosquito Control Association* 7.4 (1991): 604-607.
[13] Pyriproxyfen, General Fact Sheets. Available: http://npic.orst.edu/factsheets/pyriprogen.html
[14] Unlu I, Suman D. S., Wang Y, Klingler K., Faraji A., and Gaugler R. "Effectiveness of autodissemination stations containing pyriproxyfen in reducing immature Aedes albopictus populations." Parasites & vectors 10, no. 1 (2017): 139.
[15] Wan Yussof, Wan Nural Jawahir Hj, Mustafa Man, Muhammad Suzuri Hitam, Abdul Aziz K. Abdul Hamid, Ezmamarul Afreen Awalludin, and Wan Aezwani Wan Abu Bakar. "Wavelet-based Auto-Counting Tool of Aedes Eggs." In Proceedings of the 2018 International Conference on Sensors, Signal and Image Processing, pp. 56-59. ACM, 2018.
[16] Man, Mustafa, Wan Aezwani Wan Abu Bakar, Wan Nural Jawahir Wan Mohd Yusoff, and Mustafa Afenddi Mat Nor. "AedesApps: Image Processing Algorithm on Aedes Eggs Auto-Counting Mobile Apps."
[17] NodeCMU Documentation. Available: https://nodemcu.readthedocs.io/en/master/
[18] Patnaik Patnaikuni, D. R. "A Comparative Study of Arduino, Raspberry Pi and ESP8266 as IoT Development Board." International Journal of Advanced Research in Computer Science 8, no. 5 (2017).
[19] AA Battery. Available: https://en.wikipedia.org/wiki/AA_battery.
[20] G. P. Nayaka, KV. Pai, G. Santhosh, J. Manjanna, “Dissolution of cathode active material of spent Li-ion batteries using tartaric acid and ascorbic acid mixture to recover Co. Hydrometallurgy”, 2016 May 1;161:54-7.
[21] Gaburro J., Duchemin J.B., Paradkar P.N., Nahavandi S., and Bhatti A., “Assessment of ICount software, a precise and fast egg counting tool for the mosquito vector Aedes aegypti”. Parasites & vectors, 2016. 9(1), p.590.
[22] Mollahosseini, A., Rossignol, M., Pennetier, C., Cohuet, A., dos Anjos, A., Chandre, F. and Shahbazi, H.R., 2012. A user-friendly software to easily count Anopheles egg batches. Parasites & vectors, 5(1), p.122.