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Technologies to Combat Aedes Mosquitoes: A Model Based on Smart City

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Abstract

Aedes aegypti and Aedes albopictus mosquitoes are responsible for the transmission of diseases such as dengue fever, yellow fever, chikungunya fever, zika virus fever, some of which can cause irreversible central nervous system problems and death. This study investigates what technologies are being used for combatting and monitoring the Aedes mosquitoes and to propose joining these technologies into a single and complete solution using the Smart Cities concept. A search for newscasts on Google and mobile apps in app stores were performed to identify technological solutions for combat to Aedes mosquitoes. Also, a model for joint technology was proposed. Results identified the following technologies: 170 software, two sensors, two drones, one electronic device, ten mosquito traps/lures, seven biological tools, six biotechnologies, and eight chemical formulations. Technological resources and adoption of preventive measures by the population could be a useful method for the mosquito control. Examples include a georeferenced model for identification and examination of larvae, application of chemical/biological products, real-time mapping, sending of educational materials via email or social media for the population, and alerts to health professionals in the zones of combat/risk. In combination, these technologies may indicate a better solution to the current problem.

Keywords: Mosquito control, Aedes, Technology.

Introduction

Aedes aegypti and Aedes albopictus mosquitoes are responsible for the transmission of viruses, including diseases such as dengue fever, yellow fever, chikungunya fever, zika virus fever, Mayaro fever, West Nile fever and Japanese Encephalitis viruses [1,2]. Both mosquitoes are distributed mainly in the regions of Africa, Asia, North, Central and South America, Mediterranean region, Southern Europe, and Australia. The major epidemics were in some countries such as Taiwan, Brazil, Indonesia, Thailand, Australia, India, Malaysia, USA, Mexico, Cuba and others [2,3]. In Brazil the mosquito has spread yellow fever for more than 300 years; specifically, dengue fever since 1846, Chikungunya fever and Zika virus since 2014 [4,5].

In the last decade, there was an increase in dengue cases in Brazil, while Zika, Chikungunya, and yellow fever presented a large outbreak between 2015 and 2017. Many cases of these diseases were recorded, mainly hemorrhagic fever, dengue shock syndrome, Guillain-Barre syndrome, transverse myelitis, meningitis, placental insufficiency, fetal death, fetal growth restriction and microcephaly in newborns [5,6,7,8]. In 2016, 1.483.623 probable cases of dengue were reported with 678 deaths; 277.882 cases of Chikungunya with 204 deaths; 216.207 cases of Zika with 16 deaths, with 10.867 cases in pregnant women; with 1837 cases of microcephaly and 582 deaths by microcephaly in newborn between 2015 to 2016. Between 2016 and 2017, there were also 1336 cases of yellow fever with 215 deaths [8,9,10]

The Brazilian government has tried to combat the transmission of these diseases for at least 100 years with sanitation, urban reforms, chemical interventions, fumigation of environments, information, education and social communication. In 2016, vaccination against dengue began in Brazil, but the primary focus is still the fight against the mosquito breeding [10,11]. The governmental sector of epidemiology and health surveillance of Brazilian municipalities with the action of the Agents to Endemic Combat, seeks to track and combat the outbreaks of Aedes mosquitoes. They use technology as software for the Rapid Survey of Aedes aegypti Infestation Index (LIRAa), designed to identify sites with mosquito outbreaks in municipalities, collect data that can assist in the planning of mosquito control and combat actions [12].

The need to control mosquito proliferation has resulted in innovations, such as genetically modified mosquitoes, mosquitoes infected with Wolbachia bacteria, software for epidemiological surveys, mosquito monitoring and tracking, drones equipped with cameras, sensors, and devices [13].

Technology is a product of science that involves a set of techniques to problem-solving. Information technology is a tool used to collect, process, transmit, exchange, access and store information, which usually includes technologies mediated by the use of computers, mobile devices, and networks. New technologies have been developed, mainly in the form of integrated technology, such as the concept of smart cities, which are cities that incorporate information technology to solve problems in several areas such as sustainability, transportation, public management and health. In this context, there are also new proposals for applicability using smart cities/internet of things (IoT) with features like fog computing, cloud computing, big data, mobile technology, wearable and sensors for development of more complete software for mosquito monitoring and control [14, 15, 16, 17].

There are many technologies focused on mosquito monitoring and control. However, these are scattered and with partial objectives. In this paper, we investigate what technologies are used for combatting, tracking, and monitoring of the Aedes. We also propose a single and complete solution based on the technologies that have been used, gathering them and using the smart cities concept to integrate the technology already used by the government of Brazil so far (i.e. LIRAa software).

Methods

We chose search newscasts and app stores because many technologies developed are not published in research paper, many are sold, and made available for downloads. And, generally reported technologies are in use or being tested.

We searched for technologies to combat the Aedes mosquito. A search was conducted in newscasts of the Google site (google.com.br) in the Portuguese language, from 01/01/2010 to 05/01/2017, with three sets of keywords: "application software combat tracking aedes", "device combat aedes aegypti" and "innovation combat monitoring aedes aegypti".

The search for mobile app in app stores including Play Store (Android) and APP Store (IOS) with six keywords: "mosquito aedes", "aedes", "dengue", "zika", "chikungunya" and "yellow fever".

The information collected in the search was the name, type, and applicability of the technologies. The inclusion criteria were technologies to combat and monitoring the Aedes mosquito, including that based on computer, mobile resources, sensors, electronics and new development chemical and biological. Technologies published in another language and out of date included were excluded.

After surveying the technologies, a model with the combination of the main used technologies was proposed. Usually, the proposed technologies are presented in separate with different goals, which makes it difficult to collect and to monitor information. In this context, we propose to integrate the existent technologies with different objectives, working in a single application, providing a more efficient and complete concept, based on the smart cities model.

Results and discussion

We found a total of 536 pages in the newscasts search from Google, 146 with the keywords "software applications combat tracking aedes", 200 pages with "device combat aedes aegypti", and 190 with "innovation combat monitoring aedes aegypti".

The search for mobile apps was conducted in the Play Store (Android) and App Store (IOS) and returned a total of 192 applications. The applications are distributed according to keywords, being 55 applications for "mosquito aedes", 37 "aedes", 43 "dengue", 35 "zika", 19 "chikungunya" and 3 "yellow fever", which together with 20 mobile apps identified in the newscasts search from google, totaling 212 mobile apps. The duplicates were deleted, resulting in 168 mobile apps, of which 36 are for iOS only, 82 for Android only, 50 for iOS and Android (Table 1 and Table 2).

There were found 206 technological applications of which 170 software applications (including 2 desktop software, 2 mobile app + software desktop and 166 mobile apps); 2 sensors; 2 drones; 1 electronic device; 10 mosquito traps / baits; 9 biological tools (1 fungus base, 5 bacterial base, 1 fish, 2 plant base); 6 biotechnological (3 genetic modifications, 2 vaccines and 1 molecular examination to verify viral alteration of the mosquito); 6 formulations (2 insecticide, 2 larvicide and 2 formulations and chemical devices).

According to the objective of the 206 technological applications, 76 aims to transmit knowledge and educational games; 75 aims to track and monitor the mosquito outbreaks/geolocation; 33 aims to repel mosquito and eliminate larvae and mosquitoes; 21 aims to stimulate prevention and health education, and 1 is an examination that aims to identify mutation of the virus transmitted by the mosquito (Table 2).

The results show that the technologies are focused on monitoring, tracking, identifying mosquito outbreaks. These have largely involved the population to indicate through the applications locations with outbreaks and risk factors, as rubbish in vacant lots and water stop with larvae. In addition, there are many resources to educate the population (educational games, maintenance of the environment without the mosquito, signs, and symptoms of the disease), since it is believed that it will only be able to combat dengue when there is an awareness by the population and the effective use of available technologies.

Table 1– Technologies to combat mosquito Aedes.

Technologies	***n***
Mobile App	166
Desktop software + Mobile app	2
Desktop software	2
Mosquito Trap	10
Biological formulations	9
Chemical formulations	6
Biotechnology	6
Sensor	2
Drone	2
Electronic dispositive	1
Total	**206**

Governmental authorities and municipal health departments have used several applications, including desktop software, smartphones, mosquito traps and larvae, to monitor municipalities. It is necessary for the government to play a role by continuing to improve basic sanitation conditions, monitor wetland and mosquito-friendly climates, and clean waste lands and garbage collection sites, georeferenced through complaints and records [18].

In this context, from 206 technologies found, 50 technologies (software, mobile apps and electronic dispositive) have been used by municipal health secretariats and city halls to track and monitor Aedes aegypti and Aedes albopictus outbreaks. These technologies have been used with a location map of the outbreaks and foci in the municipality through sensors and photos of environments with larvae and mosquitoes by users and health professionals. Others 16 technologies include traps, drones, biotechnologies and software, e.g. traps distributed in the municipality, called Aedes' Intelligent Monitoring, where the Endemics Combat Agent collects samples for laboratory analysis, where at the same time inserts information in the applications regarding the foci in the neighborhoods and places where it passes by surveying and collecting samples. These technologies are used in the sense of fighting the eggs, larvae and Aedes mosquitoes.

The Proposed Model of Technology based on Smart Cities

We believe that this range of technologies found in monitoring and fighting the Aedes mosquito can be united to a common goal and achieve better results. It would be a technology in an interesting model to be used in the municipalities. The integration of cloud computing, big data, mobile phones, Internet of things - based sensor devices, Google Maps web service, Internet in a concept of smart cities, can contribute in this area [16].

Table 2– Objective of technologies to combat and monitoring of Aedes mosquito.

Objective	Type of technologies	n=206	Technologies' names
Track and monitor mosquito outbreaks / geolocation	Mobile apps - report outbreaks, geolocation, health care facilities	61	Aedes em Foco, Aedes em Foco-Cidadão, Aedesinfo, Aedes na Mira, Aedes na Mira Cruz Vermelha, Aedes na Mira DF, Aedes na Mira RR, AeTrapp, Águas sem Dengue, Alerta Dengue, Alert DB, AntiZika, Caça Aedes, Caça Aedes Dengue Zika, Caça ao Aedes em Jardim Brasil, Caça Mosquito, Cidade Legal Contra Dengue, Click Dengue, Combate à Dengue, Combate Aedes, Contra o Mosquito, Dengue Cidadão, Dengue Radar, Dengue Zero no Brasil, De Olho no Mosquito, Detona Aedes, DeuZikaChico, Dfoco, Geodengue, Guardiões da Saúde, Ilhabela sem Dengue, iMosquito, I Moustique, Juntos pela Saúde, Kidenga App, Mapa da Dengue, Mapa do Aedes, Marcador do Mapa do Aedes V. 2, ModVida Plataforma Telessaúde, MOLI, MoskiTracker, Mosquito Zero, Na luta contra o mosquito, Patrulha da Dengue, Radar Cidadão, Radar Dengue, Radar do Aedes 1.1, RS Contra Aedes, Se liga no Sinop, Sem Dengue, Sentinelas - Febre Amarela, Spectra, Vistoria da Dengue, Xô Aedes, Xô Zika, ZIKApp, Zika Tracker, Zika Virus Alert & Prevention, Zika Virus News & Maps, ZikaZoom, 100Aedes
	Software - intelligent monitoring	4	Aime/Pitch Gov, LIRAa, Observatório do Aedes aegypti*, Sai Zika*
	Drone	2	Aero Drone Brasil, Drone Combate Aedes
	Trap	6	Ecovec, Monitoramento Inteligente do Aedes – MI Aedes, Monitoramento Extermínio Inteligente da (Dengue) - PULTRUTECH, Monitoramento Inteligente Vírus - M.I. Vírus (Ecovec), Ovitrampas, VectorWeb
	Eletronic dispositive - insect detection	1	LBS
	Biotechnology - Mosquito marking - DNA	1	Aedes do Bem
Repel or eliminate larvae and mosquito	Mobile apps - sound emission to ward off mosquitoes	10	Anti-Mosquito Sound, iHateMosquito - Assassino, Mosquito Repelente, Mosquito Guard, Q Mosquito, Q Mosquito Effective Repellent, Repelente de Insetos, Zika Guard - Mosquito Guard, Zikalert, Zika Zap
	Biotechnology - male genetically modified	2	Aedes aegypti do bem - Oxitec, Mosquito transgênico- Joint-venture (Oxitec and Moscamed)
	Trap -capture and kill mosquito	4	Armadilha BG-Sentinela, Gravid Aedes Trap (GAT), Armadilha para monitorar e combater o Aedes, Mosquitrap
	Sensor - use of artificial intelligence that identifies and kills only selected mosquitoes	2	Armadilha inteligente, Project premonition - Microsoft
	Biological formulations - affects mosquito breeding or causes larvae and mosquito death	9	Bacillus thuringiensis israelensis - Biolarvicide, Biovech - Biolarvicide, Bactéria Wolbachia, Metarhizium anisopliae - insecticide, Bacillus thuringiensis - Biolarvicide and repellent, Tablets of Bacillus thuringiensis israelensi, larval fish (Poecilia reticulata), saffron root (Curcuma longa), Biorepellent (Montrichardia liifera)
	Chemical formulations - kill larvae	6	Lime and chlorine in constructions, Pyriproxyfen - Larvicide, SPLAT BAC, Floating photocatalytic devices, Unidades disseminadoras - Insecticide, Vectrax
Prevention and Health Education	Mobile apps - guidelines for preventing and combating mosquitoes, collaborative participation	19	Aedestrói, Aedestruction, Aedes Zero, Agente Cidadão, Aqui mosquito não se cria, BH Sem Mosquito, Busca Dengue, Combatendo o mosquito, Dengue APP, Desafio Zika Zero, Febre Amarela, Mosquiz, O Fim da Picada Botucatu, O Fim da Picada Lençois, SP X Dengue, UNA SUS Dengue, Xô Mosquito, Zika Vírus - Pregnancy Symptoms and Sex, 2+ Dengue
	Biotechnology - vaccine	2	Vaccine against Aedes aegypti, Vaccine modified for mosquito to be contaminated when itch immune human (in development)
Knowledge/Education Games	Mobile apps - games, general informations and news	76	Acabe com o mosquito, Aedes Game, Ariê e Yuri contra mosquitos, AZ Infections Disease Resource, Bad Mosquito, Brinquelonas Super Agente, Caçadores dos focos perdidos, Case-PubMed, ChikaZikaFree, Chicungunya, Chicungunya (informations), Chicungunya Admon Web, Chicungunya Notícias, ChicungunyApp, Chicungunya Treatment, Chicungunya ZE-SAM, Cidade em Foco, Combate Aedes, Contra a Dengue o Jogo, Dengame, Dengue Blaster, Dengue Combat, Dengue- Manejo clínico - Adulto e Criança, Dengue no Alvo, Dengue x Chik x Zika, Dengue Terminator, Dengue UNA-SUS, Detona Aedes, Deu Zika, Dr Chicungunya, D-Xtermine, Fim da Picada, Flappy Zika, Focus Dengue, Fuja da Dengue, Hugo Contra a Dengue, Info Chicungunya, Jogo da Dengue, Kill Zica, Legend of Aedes, MalariaSpot, Mosquito.buzz, Mosquito Hunter, Mosquito Não, Mosquito Raiders, Mossie Slaper, Pega Mosquito, Previna Zika, Projeto Citronela, Skeeter Blaster, Slap Mosquitoes, Strike Aedes, Super Agente, Symptons of Dengue, TAMU Zika, Vivo Guia da Mamãe, Xô Dengue, Zap-a'quito, Zero Morte Dengue, Zika das Galáxias, Zika Dilma, Zika Killer, Zika Mater, Zika Runner, Zika Seeka, Zika Smash, Zika Vírus - Notícias, Zika Virus e Microcefalia, Zika Vírus Inf And News, Zika Vírus Infection, Zika Virus Info, Zika Vírus - Minha Vida, Zika Virus 3D, Zika Vírus 3D Animação, Zika Zero, #naoficoparado
Examinations for mutations	Biotechnology - identifies new viruses	1	Epiome

*Software + mobile app.

Based on the survey of the technologies and several studies [13,14,15,16,17,18,19], several opportunities of integrating existing technologies exist. Among technologies identified in this review, examples could include:

1. Installation of traps (Ovitrampas, mosquiTRAP, Adultrap, Ecovec, Pultrutech, GAT) to capture eggs and larvae;

2. Collection of eggs and larvae and online filling of georeferenced information through Agents to Combat Endemics;

3. Laboratory analysis of eggs and larvae to identify if they are contaminated and what type of virus they are, and add information to the system;

4. Installation of mosquito sensors (mosquito type recognition) to identify outbreaks of the adult mosquito population in the municipality;

5. Installation of sensors for environmental conditions (humidity, carbon dioxide concentration, temperature and climatic conditions favorable for flooding and/or water accumulation);

6. Registration of photos of outbreaks through smartphones through the Endemic Disease Agent and population through the mobile app with "check-in" (verifying the viability of the correct identification through pattern recognition);

7. Real-time mapping system with combat zones, identified from the intersection of information entered into the system, such as contaminated larvae (with the virus type - dengue, chikungunya, zika virus, yellow fever), spot locations, confirmed and suspected cases of diseases in the population (type of virus), based on the GPS markings. The map will not indicate the specific location of the dwelling, to preserve the identity of the resident and avoid privacy issues. A more comprehensive area around the locality, called a combat/risk zone, will be indicated;

8. Application of insecticides, larvicides, Wolbachia bacteria in locations of possible outbreaks or combat zones, through agents to combat the endemic or employing drones (in quantities and types not harmful to humans, also analyzing the resistance of the mosquito in laboratory tests);

9. Sending educational materials, booklets, residence announcements in a combat zone via e-mail, social networks, or SMS to the population of the municipality to stimulate health care and education. For this, it is necessary to have the population registered to the system;

10. Sending SMS and e-mail from combat/risk zones to health professionals (doctors, nurses, agents to fight against endemic diseases and health managers) for warning and attention to the admission of patients in risk with symptomatology for diseases transmitted by the mosquito Aedes - Hospitals and Government agencies;

11. Immunization campaigns in combat zones along with nursing teams, such as the Family Health Strategy Program, in the Basic Health Units of the neighborhood or with active search directly in the residences by the traveling teams.

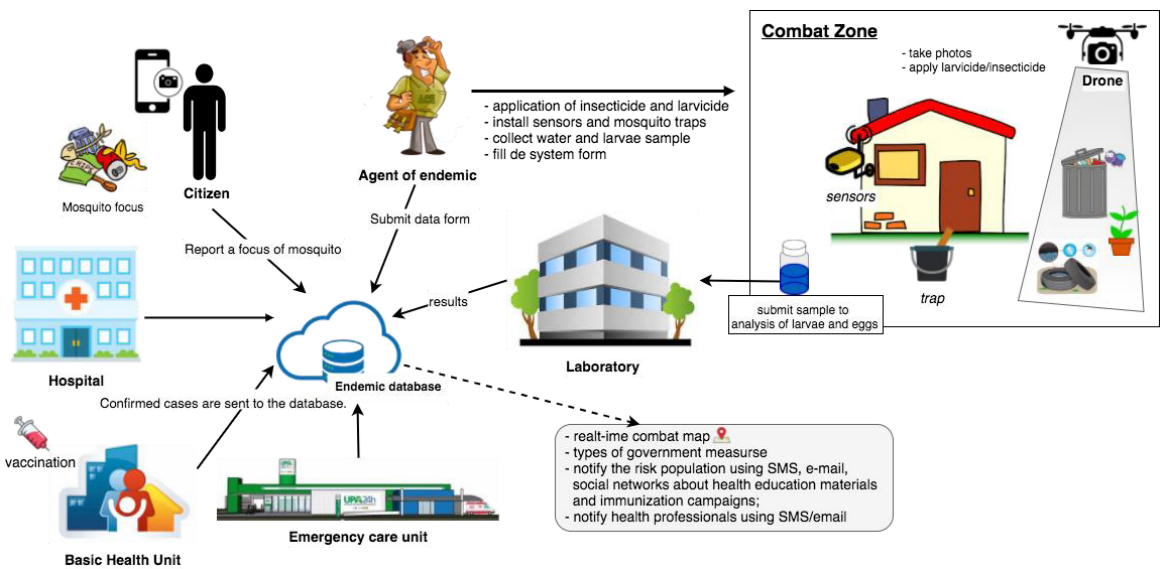

Figure 1– Model of technology based on Smart Cities to combat and monitoring of Aedes Mosquitoes.

Figure 1 represents the integration model of the technologies items 1 to 11 above. For this, it is necessary that the government agencies provide software with registry of the citizens and Internet. The Endemic Combat agent installs traps, sensors, sends larval samples for laboratory tests and feeds software with the information collected and georeferenced. The laboratory also feeds the system with the results of the analyzes, type of mosquito and type of virus found. At the same time the population can report foci of eggs, larvae and mosquito through photos and georeferenced location. Hospitals, emergency care units and basic health units report suspicious and confirmed cases to the system using patient registry. The software then displays risk zones on the map in real time so that professionals in the government sector take the necessary measures to combat larvae and mosquitoes in critical zones. Also, the software can trigger warnings and health education materials for citizens living in combat zones and also for health professionals working in areas subject to endemics.

Concluding remarks

In this study, the aims were to assess the technologies for monitoring and combat Aedes mosquitoes and propose a solution based on the technologies that have been used, gathering them and using the smart cities concept. We identified 206 technologies that include transmit knowledge and promote education, track and monitor the mosquito outbreaks/geolocation, repel mosquito and eliminate larvae and mosquitoes, stimulate prevention and health education, and examination that aims to identify a mutation of the virus transmitted by the mosquito. The combination of these artifacts based on smart cities approach may indicate a better solution for meeting the reduction of larvae, eggs, mosquitoes and consequently cases of disease transmitted by mosquito. These findings can be used to inform authorities in the struggle against Aedes mosquitoes.

The limitations of this study involve that was not analyzed the scientific articles from databases for the survey of the technologies in use. They were limited only to the newscasts and app stores. Another point is that if stakeholders involved do not adhere to the model proposed in this study, there may be degradation of service quality. As future work, it is needed to integrate these technologies into practice and to evaluate the model in real-life.

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