



RESEARCH ARTICLE

Regenerating Motivation to Prevent Mosquito Breeding and Implementing a Novel Technology in Residential Spaces in Singapore

Minako Jen Yoshikawa^{1*}, Christina Liew²¹Centre for Southeast Asian Studies, Kyoto University, Japan²Strategic and Media Communications, National Environment Agency, Singapore²School of Biological Sciences, Nanyang Technological University, Singapore

ARTICLE INFO	ABSTRACT
Received: Sep 18, 2024 Accepted: Nov 29, 2024	Dengue is rapidly spreading in the world today. An additional mosquito control tool is being explored in field trials in Singapore, although a comprehensive mosquito surveillance and control programme has already been in place for many decades. The National Environment Agency, Singapore, has been testing the <i>Wolbachia-Aedes</i> suppression technology at residential areas of Singapore. Evaluation of the technology in Singapore's context has been studied considerably, including gaining a high level of support from local residents for testing of the technology at their residential areas. However, rather less attention has been paid to the underlying motivation amongst local residents to prevent mosquito propagation in their living spaces and the roles of science communications in implementing the technology in society. Our survey on local residents has found negative feelings toward mosquito bites, adoption of official advice, and recognition of own responsibility in preventing mosquito breeding. This research has also attempted to analyse activities that target social implementation of the novel technology from a viewpoint of science communications. We elucidated characteristics that worked in favour of these objectives: the process to ensure consistency, speed in responding to enquiries from local residents, suitability of content when tailoring messages, integrity in honouring scientific evidence, and dynamism from the communicators. The overall results identify the sociopolitical environment in Singapore that facilitates effectual science communications. Direction towards virtual reality and digital society in community education, as well as inclusion of the total population in community engagement, are also discussed.
Keywords Mosquito Control Technology Science Communications Local Residents Singapore	
*Corresponding Author: yoshikawa.minako.a86@kyoto-u.jp	

1. INTRODUCTION

1.1 *Aedes* mosquitoes and dengue virus

Dengue virus infection (hereinafter 'dengue') is recognised as the most rapidly spreading mosquito-borne infectious disease on a global scale. Dengue is an acute febrile viral disease, and the pathogen is transmitted by *Aedes (Stegomyia)* genus mosquitoes. *Aedes* mosquitoes mediate other medically important viruses, including Chikungunya, Zika and Yellow Fever. The efficient primary vector of Dengue virus (hereinafter DENV) is the *Aedes aegypti* mosquito. The infection causes a spectrum of

disease, ranging from asymptomatic, to symptomatic dengue fever (headache, retro-orbital pain, joint and muscle pain, skin rash, nausea, vomiting, bleeding from nose or gums, or easy bruising of skin), to the potentially fatal severe dengue shock syndrome. Female *Ae. aegypti* mosquitoes bite humans mostly during the day, and breed in and around human residences and other premises. Mosquito control remains the key public health measure to curb dengue incidence.

1.2 Characteristics of the present research location, Singapore

The geographical position of Singapore confines the country within the endemic region of infectious diseases caused by Dengue, Chikungunya and Zika viruses. Situated 137km north of the equator at the southern tip of the Malay Peninsula, Singapore has a land area of 734.4km². This urban country with abundant greenery is a popular tourist destination as well as a vibrant business hub, with 19.1 million international visitor arrivals in 2019 (Ministry of Trade and Industry, Singapore, 2019), and population density of 8,058/km² as of June 2023 (Ministry of Trade and Industry, Singapore, 2023). In 2023, the total 5.9 million population of Singapore comprised 3.6 million citizens (61%), 0.5 million permanent residents (8%), and 1.8 million others (31%). The majority (77%) of the population reside in public apartments, 16% in private apartments, 6% in private houses (with land), and the remaining 1% in other types of housing such as shophouses. Ethnic composition of the citizens and permanent residents are: Chinese (74%), Malays (14%), Indians (9%), and others (3%) (Ministry of Trade and Industry, Singapore, 2023).

1.3 Mosquito control and the disease situation in Singapore

The National Environment Agency, Singapore (hereinafter 'NEA'), was established in 2002 as a statutory board under the Ministry of the Environment (now known as the Ministry of Sustainability and the Environment). NEA is responsible for leading the national dengue control programme, collaborating with other ministries, town councils, community associations, research and academic institutions, as well as the private sector. Thorough public health measures are administered nationwide, such as: mosquito control, vector and virus surveillance and research, community engagement and mobilisation, information disclosure and law enforcement. A study evaluated the reduction in mosquito breeding sources, and other environmental management measures minimised mosquito propagation in Singapore (Sim *et al.*, 2020). An indicator that measures the dengue mosquito vector population is the *Aedes* house index, and a figure of 0.26% in 2014 (Ministry of Health, Singapore, 2015) was the lowest between 2011 and 2020.

The number of reported dengue cases rose sharply in 2013 and 2014 in Singapore, where all serotypes (DENV-1, DENV-2, DENV-3 and DENV-4) co-circulate. Hapuarachch *et al.* (2016) attributed the two-year outbreak to several reasons: a replacement of the predominant Dengue virus serotype, a newly-emerged genotype strain, and wider distribution of the *Ae. aegypti* mosquito vector. Building on these findings, Ong *et al.* (2019) elaborated on the geographical expansion of *Ae. aegypti* into former non-dengue epidemic areas, and advocated a new risk indicator, i.e., 20% or above *Ae. aegypti* mosquito breeding amongst total *Aedes* breeding habitats. A study by Rajarethina *et al.* (2018) noted more frequent dengue incidence amongst men, Chinese ethnicity, and those living in landed houses between 2004 and 2016.

1.4 Selection and testing of *Wolbachia-Aedes* technology in Singapore

Dengue continued to expand geographically with intensity, and Singapore experienced dengue outbreaks in 2005 and 2007. NEA explored a complementary tool to control mosquitoes, and eventually selected the *Wolbachia* suppression technology for *Ae. aegypti*, conducting a risk assessment, including safety for both humans and ecology, in 2012. When a female urban *Ae. aegypti* mosquito mates with a male *Ae. aegypti* mosquito carrying the *Wolbachia* bacterium, her eggs will not hatch. Thus, the population of the primary dengue vector will be reduced over time (Ng *et al.*, 2017).

'Project *Wolbachia* – Singapore' was launched in October 2016, with the first field releases of male *Wolbachia*-carrying *Ae. aegypti* mosquitoes at Braddell Heights in the Central part of Singapore, Tampines West in the Eastern part of Singapore, and Nee Soon East in the Northern part of Singapore. The three study sites were selected depending on characteristics of the residential estates in Singapore; previous records of dengue outbreaks and/or presence of *Ae. aegypti* mosquitoes there; and availability of historical data (three years) of the *Aedes* mosquito population (NEA, 2016).

Surveys conducted in Singapore before and during the first field releases in 2016 reveal that 'knowledge of the technology', 'awareness of dengue as a serious issue' and 'approval of government's efforts to control dengue' influenced people's 'acceptance and sentiments' towards the novel technology (Liew *et al.*, 2021b). Another survey carried out between 2019 and 2020 found only a small percentage (4.4%) of the survey respondents disagreeing with the releases. The primary reason given was that they believed in low chances of getting mosquito-borne infectious diseases in Singapore (Soh L.T. *et al.*, 2021). In another study by Lwin *et al.* (2022), 'general knowledge about the new technology', 'perceived severity of mosquito bites', 'perceived density of mosquitoes' and 'social responsibility' were shown to drive 'hesitancy and receptivity toward the project'. The authors noted the tendency for more socially responsible people to support 'initiatives meant to benefit the community at large'.

Analysis by the Project *Wolbachia* – Singapore Consortium (2021) reports the promising interim results of the application of *Wolbachia*-based incompatible insect technique. After three years of testing in 2019, a 92.7% and 98.3% reduction in the *Ae. aegypti* mosquito population, as well as 71% and 88% decrease in dengue cases, were noted at the two study sites, respectively. Building upon this progress, a controlled study by Ong *et al.* (2022) evaluated the national level efficacy; and Tan *et al.* (2017) underscored probable benefits of the new technology to Singapore due to its additional applicability to control Chikungunya and Zika virus infections.

1.5 Activities conducted and materials prepared for community education and engagement

Liew *et al.* (2021a) provided a comprehensive list of NEA's preparation for Project *Wolbachia* - Singapore, especially the impactful communications and engagement activities conducted for several years, well in advance of the first field release in 2016. The 'community education and engagement' is focused as the core groundwork towards the implementation of *Wolbachia* technology at the residential sites. Dialogues were held with the broad range of stakeholders, such as local residents in and out of the study sites, medical and scientific professionals, and the government sector. The agency offered more than 100 engagement sessions; and the outreach activities ranged from scientific seminars, lectures, workshops, on-site discussions with the community, educational programmes at schools and childcare centres, door-to-door house calls, conversational sessions over coffee, apartment block and garden parties, mass outreach roadshows, to guided tours at the facility to mass produce *Wolbachia*-carrying *Aedes* mosquitoes.

Materials prepared by NEA for the community included publicity brochures, banners and posters, online video series, and media releases. The topics included: 'how the technology works', 'why it is the most suitable for Singapore', 'the technology is safe and natural', 'male mosquitoes do not bite or transmit disease' and 'the project only targets *Ae. aegypti* mosquitoes.' The mode of information dissemination encompassed print and online mainstream media, social media, websites and other channels. Additionally, a system was installed for the community to make inquiries, express opinions and/or report problems (Liew *et al.*, 2021a).

1.6 Towards the nationwide application of the novel mosquito control technology

An explosive dengue outbreak was reported in Singapore in 2020, with 35,169 local and 17 imported cases (Ministry of Health, Singapore, 2023). DENV-3 became the predominant serotype locally for the first time in almost three decades (Sim *et al.* 2020), and affected Singapore residents with low

herd immunity. Also, the strict anti-COVID-19 social distancing measures implemented in Singapore seem to have impacted dengue prevention and control efforts. More people worked from naturally ventilated residences instead of air-conditioned workplaces where they could have had some protection from day-biting *Aedes* mosquitoes (Lim *et al.* 2021). NEA aims to expand the new technology on a national scale. Full implementation requires the regular release of male *Wolbachia*-carrying *Ae. aegypti* mosquitoes throughout the country. Soh S. *et al.* (2021) supports the economic advantage of nationwide implementation in Singapore.

Collectively, considerable research attention has been devoted to the evaluation of *Wolbachia-Aedes* mosquito control technology in Singapore's context. The very low level of objection in the community and the desirable interim results are encouraging. However, what motivates local residents to desire preventing mosquito propagation in the first place remains a question, and roles of science communications in the implementation of the novel mosquito control technology in society has been insufficiently discussed.

This research therefore first delves into the underlying motivation behind anti-mosquito actions practised by the local residents, and their opinions toward mosquito control in the residential areas in Singapore. We will then analyse the ways by which the agency conducted community education and engagement from the perspective of science communications in public health. The results of this research will show importance of regenerating motivation amongst the local residents to control mosquitoes, and elaborate on elements of science communications in facilitating implementation of previously unknown technologies in society.

2. METHODS

In addition to the review of previous literature, this research employed two methods: a survey in an urban residential area in Singapore; and participants' observations at three events hosted by the Singapore Government.

The face-to-face structured questionnaire was carried out in a location with heavy human traffic near public apartment blocks at Ang Mo Kio in the North-East Region, for two days in March 2017. With consent from the local authority, the questionnaire was administered by Japanese academia and two local independent volunteers, until the first 100 responses were collected (50 each of male and female respondents). Prior to the agreement by the respondents to participate in the survey, they were assured of anonymity and presented with a written information sheet describing the survey purposes, the surveyors, the time required (15 minutes or less), and future academic use of the results. The information sheet, questions and answer choices were prepared in English, and Chinese translation was provided below the English language. Upon completion, each respondent was offered a token souvenir from Japan (costing about five US dollars). Data entry and statistical analysis were conducted using IBM SPSS Statistics version 24. Descriptive statistics of the questionnaire results were examined using crosstab analysis with Fisher's Exact Test. *P*-values below 0.05 were considered statistically significant.

Participants' observations were noted at the First Release of Male *Wolbachia Aedes* Mosquitoes on 28 Oct 2016 at a historical dengue high-risk residential study site at Tampines West; and at the launch of the territory-wide educational 'Clean and Green Singapore' events on 2 Nov 2019 and 3 Dec 2022.

3. RESULTS

3.1 Profile of the respondents of face-to-face survey

The demographic profile of the survey respondents, with Gender, Age and Ethnic categories, is summarised in Table 1. The mean age of the respondents was 50.6, ranging from 18 to 84 years of

age. Four groups in the age category were merged into two to facilitate more even distribution across the age groups, although the group in the 60's remained over-represented. Since our survey included foreigners living in Singapore, no adjustment was made to mirror the population structure of Singapore citizens and permanent residents.

Table 1: The demographic profile of respondents in the face-to-face survey (n=100)

Categories	Groups and the number of respondents	
Gender	Male	50
	Female	50
Age	20's and below	20
	30's and 40's	21
	50's	18
	60's	28
	70's and above	13
Ethnic	Malay	8
	Chinese	76
	Indian	10
	Others	6

3.2 The frequency of anti-mosquito actions practised by the survey respondents

The frequency of six anti-mosquito actions practised by the respondents is shown in Table 2. There was no significant difference in the Gender category. However, there was a proportionately higher number of respondents in the 60's who answered that 'I check for the presence of *Aedes* eggs and/or larvae inside home every day' ($p = 0.015$). The Malay and other ethnic groups revealed more frequent use of mosquito repellent ($p = 0.002$). In contrast, the total number of 'mosquito coils and/or electrical mats' users represented below 20%. Neither 'I wear long sleeves' nor 'I wear long trousers' was a popular action to avoid mosquito bites.

Table 2: Frequency of anti-mosquito actions practised by the respondents (n = 100)

Actions/Frequencies	Every day	Every other day	Once a week	Once a month	Less than a month	Never	No answer
I use mosquito repellent.	3	12	16	4	17	48	
I use mosquito coils and/or electrical mosquito mats.	2	3	1	2	11	80	1
I check for the presence of <i>Aedes</i> eggs and/or larvae inside home.	21	14	18	11	12	23	1
I scrub the inner side of flower vases and/or other containers.	15	14	13	4	9	43	1
I wear long sleeves to avoid mosquito bites.	5	3	0	3	11	78	
I wear long trousers to avoid mosquito bites.	13	3	3	2	12	67	

3.3 The underlying motivations to practise anti-mosquito actions amongst the survey respondents

Questions asking for reasons for practising anti-mosquito actions (Table 3) revealed that 10% of the respondents had their own history of dengue infection, and the percentages climbed up as the subject

involved family members (15%) and acquaintances (37%). The reason of 'I do not want to pay fine for breeding mosquitoes' was selected by 67% of the respondents. Furthermore, 76% of the respondents answered 'I find mosquito bites annoying', and 88% of respondents affirmed 'I follow health advices and anti-mosquito information available in Singapore.' Only 7% of respondents have been fined so far. Female respondents were more likely to take actions to avoid fines ($p = 0.005$). The respondents below 40's worried more about annoyance due to mosquito bites, compared to older respondents ($p = 0.04$). There was no significant difference within the Ethnic category.

Table 3: Reasons for practising anti-mosquito actions (n=92) with exclusion of eight respondents who answered 'Never' to all previous questions about the frequency of anti-mosquito actions.

Reasons for actions/Groups	Male	Female	Below 20's	30's & 40's	50's	60's	Above 70's
I experienced a mosquito-borne disease, such as dengue.	5	4	1	1	2	4	1
I have <u>family members</u> who experienced a mosquito-borne disease, such as dengue.	8	6	3	3	2	4	2
I have my <u>acquaintances</u> who experienced a mosquito-borne disease, such as dengue.	18	15	7	6	5	10	5
I find mosquito bites annoying (itchy, red swelling, etc.).	35	35	16	18	12	17	7
I follow health advices and anti-mosquito information available in Singapore.	36	44	13	18	17	21	11
I do not want to pay fine for breeding mosquitoes.	24	38	13	14	14	13	8
I was fined for breeding mosquitoes in the past.	1	5	0	1	1	2	2

3.4 Opinions towards mosquito control expressed by the survey respondents

Agreement by the respondents with each opinion about mosquito control is summarised in Table 4. All but one agreed that it is his/her responsibility to keep own home free from *Aedes* mosquito eggs/larvae. To collect opinions about compliance of others, the same question was asked for 'Singapore citizens and permanent residents'; 'foreign employment pass holders'(professional); and 'foreign workers' (e.g. construction, factory and shipyard workers, and house maids). While 84 respondents agreed that 'Singaporeans and permanent residents make sure that there is no *Aedes* egg and/or larva in our community', 67 respondents answered the same for both groups of foreigners. The majority (52 respondents) agreed that 'I need to avoid mosquito bites during the night more than day time to prevent dengue'. Female respondents were more likely to agree that 'NEA inspects my home for *Aedes* mosquitoes at least once a year' ($p = 0.013$). No significance was found in the Age or Ethnic categories.

Table 4: The number (percentage within the groups) of respondents who agreed with opinions about mosquito control (n=100).

Opinions	Male	Female
It is my responsibility to make sure that there is no <i>Aedes</i> egg and/or larva at my home.	49	50
Singaporeans and permanent residents make sure that there	40	44

is no <i>Aedes</i> egg and/or larva in our community.		
Foreign employment pass holders in Singapore make sure that there is no <i>Aedes</i> egg and/or larva in their community.	33	34
Foreign workers in Singapore make sure that there is no <i>Aedes</i> egg and/or larva in their community.	32	35
I need to avoid mosquito bites during the night more than day time to prevent dengue.	24	28
National Environment Agency (NEA) inspects my home for <i>Aedes</i> mosquitoes at least once a year.	35	45

3.5 The first release of male *Wolbachia*-*Aedes* mosquitoes in 2016

The first release of male *Wolbachia*-carrying *Ae. aegypti* mosquitoes by NEA took place at Tampines West, starting at 7a.m. on 28 October 2016. The weather in Singapore between 7 and 8 a.m. that day was partly sunny with broken clouds, with east wind of 0 to 2 km/h, temperature of 26 to 27°C, and humidity of 84 to 89%.

Here, we identified NEA researchers and staff, local residents, industry partners and interested parties, such as academic researchers, at the open field surrounded by the high-rise apartment blocks (Fig. 1a). High-profile individuals were also present, such as Mr. Masagos Zulkifli, the then Minister for the Environment and Water Resources, and Mr Ronnie Tay, the then Chief Executive Officer of NEA. Following opening remarks by the agency, each participant, including the Minister and the NEA CEO, picked up a plastic container holding male *Wolbachia*-carrying *Ae. aegypti* mosquitoes (Fig. 1b), scattered within the designated area. Each participant released the male mosquitoes into the air. NEA staff assisted the local residents, especially small children, when mosquitoes were unwilling to fly out of the containers. The operation was completed in about 30 to 40 minutes.

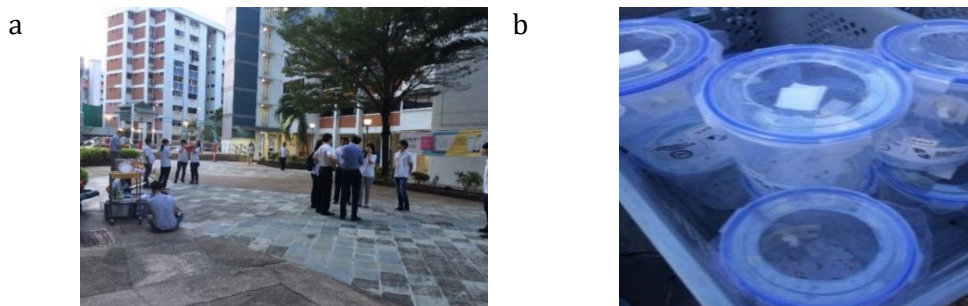


Figure 1: (a) The meeting point before commencement of the release of male *Wolbachia*-carrying *Ae. aegypti* mosquitoes; (b) the sealed containers holding the live male mosquitoes.

The study site comprised 29 residential blocks within the blue solid line on a map at the right-hand side of the banner (Fig. 2). The same map was also made available on the NEA website and brochures produced by the agency.



Figure 2: The publicity banner of the project with a map of the study site.

3.6 Clean and green Singapore, 2019

The national strategy to balance environmental management and development is reflected by annual events, especially 'Clean and Green Singapore'. The event was held for 3 days from 2 to 4 November 2019, mainly at a community hub at Jurong East in the West Region of Singapore. Shifting mindset was encouraged to 'view waste as a resource' by Mr Teo Chee Hean, the Senior Minister and Coordinating Minister for National Security, who presented scientific facts in his speech. The main venue was full of exhibits, games, and a flock of visitors (Fig. 3).

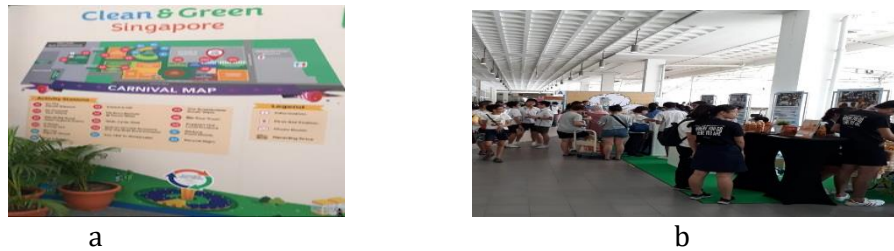


Figure 3: (a) A floor chart at the main venue; (b) A corner of the outdoor venue bustling with many visitors.

A variety of activities were offered to encourage the community to choose a clean, green and sustainable lifestyle, care for and protect the environment. Dengue prevention and control elements were integrated into the annual event. Visitors viewed exhibits and participated in action-oriented games to gain hands-on experiences, while interacting with staff from the government sector and students from local schools (Fig. 4). Appropriate collateral was distributed, such as foldable fans, reusable shopping bags, mosquito repellent, in addition to anti-mosquito stickers and badges.



Figure 4: (a) An example of an educational exhibit; (b) A corner to learn about the life cycle of mosquitoes.

3.7 Clean and green Singapore, 2022 The launch ceremony of Clean and Green Singapore 2022 took place inside the auditorium of the main building at Eunoia Junior College in the Central Region of Singapore, on 3 December (Fig. 5a). The importance of public health in relation to the COVID-19 pandemic was highlighted by Mr Heng Swee Keat, the Deputy Prime Minister and Coordinating Minister for Economic Policies. The launch ceremony was held with low key publicity, despite the year 2022 representing a milestone for Singapore. NEA marked its 20th anniversary and the Ministry of Sustainability and Environment celebrated its 50th anniversary after its founding as the Ministry of the Environment. His presentation was followed by an award ceremony. The audience was composed of the organisers, awardees, and their families and friends. A small corner was set up to display environmentally friendly products outside the main building (Fig. 5b). Limited interaction was observed between the participants and organisers.

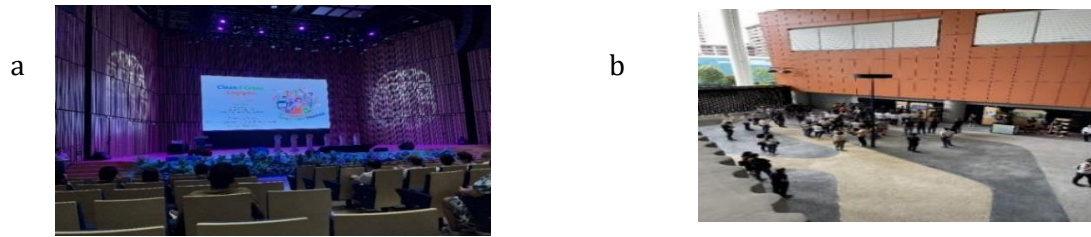


Figure 5: (a) A quiet indoor ceremony attended by the small audience: (b) Several learning booths set up outside the auditorium.

Although the event in 2022 was dramatically downscaled, the series of ‘satellite events’ preceded months before the launch ceremony, including tree-planting, kayak litter-picking, beach clean-ups, recycling drives, a youth sustainability short film premiere, and local community eco-carnivals. All the events were attended by high-profile policy makers and government officials (Table 5). Exhibits and video workshops were also made available online, covering the topics of: climate change, waste, recycling, dengue prevention, public toilets and littering.

Table 5: Public education activities carried out as the satellite events in October and November, 2022.

Date	Event name, venue	Major purposes, main activities	High-profile individuals in attendance
Saturday, 29 Oct	Project Blue Wave, Pasir Ris Park	Marine biodiversity and sustainability through a beach and sea clean-ups and tree planting	Dr Koh Poh Koon, Senior Minister of State for Sustainability and the Environment
Sunday, 13 Nov	Hong Kah North Eco Carnival 2022, Hong Kah North Community Club	A new Eco-Hub for residents, featuring a trash-for-groceries recycling drive, eco workshops, art competition and exhibition booths to showcase green living tips	Dr Amy Khor, Senior Minister of State for Sustainability and the Environment
Tuesday, 22 Nov	‘Road to Zero’ Youth Sustainability Film Premiere, Temasek Shophouse	Environmental Sustainability movement to stir conversations and encourage youth advocacy for Singapore’s environment	Mr Baey Yam Keng, Senior Parliamentary Secretary for Sustainability and the Environment
Saturday, 26 Nov	Yuhua Clean and Green Singapore 2022, Yuhua Community Club	A Forward Singapore Conversation launching the Bloobox, a recycling container to encourage a habit of regular recycling at home	Ms Grace Fu, Minister for Sustainability and the Environment

Source: Modified from NEA website (NEA, 2022).

In addition, two learning opportunities were offered in November and December. ‘Our Water Story’ referred to physical guided tours at the NEWater Visitor Centre and the Sustainable Singapore Gallery at Marina Barrage. This experience facilitated participants learning how the four national taps meet the demand of water supply in Singapore, and tips to conserve water in daily life. ‘Our Fight Against Dengue’ delivered interactive virtual trips for viewers to learn about symptoms of dengue, life cycle of mosquitoes, tips to prevent dengue, in addition to how Project *Wolbachia* - Singapore works in the battle against dengue (NEA, 2022).

4. DISCUSSION

4.1 Regenerating anti-dengue motivation

While advancement in medicine is clearly critical to reduce dengue fatality and cases of serious complications, individual awareness of dengue risk and behavioural change outcomes need to be emphasised to minimize the health impact of dengue on communities (Yoshikawa, Kusriastuti and

Liew, 2020). Providing knowledge and sustaining a high level of awareness amongst the community through education is possible. However, it is challenging to motivate the community to take action. It is also necessary to sustain and regenerate such motivation.

Several endeavours are made in Singapore in this regard. The first example is the 'Intensive Source Reduction Exercise' to search and destroy potential mosquito breeding habitats, which has been conducted in Singapore since 2006. The regular exercise aspires to lower the population of disease-mediating mosquitoes ahead of the high season for transmission of infectious diseases such as dengue (Ministry of Health, Singapore, 2015). Each year, information is disseminated about disease trend, distribution of *Aedes* mosquitoes, research development and (tightened) penalties for breeding mosquitoes at the concurrently held campaigns. The exercise and campaigns function to regenerate motivation for local residents to manage mosquito propagation.

The second example is a slogan, 'Do the Mozzie Wipeout, Our Lives. Our Fight', which NEA has promoted for years to encourage individuals and the community to practise anti-mosquito actions. The practices are: turn the pail (or turn over all water storage containers), tip the vase (or change water in vases/bowls on alternate days), flip the flower pot plate (or remove water from flower pot plates on alternate days), loosen the hardened soil and clear the roof gutter and place *Bti* insecticide. The slogan functions to remind local residents of critical actions and appropriate frequencies for their conduct.

The third example is NEA's vector surveillance operations, which includes inspections conducted at residential and non-residential premises, construction and industrial sites, and other places. In our face-to-face survey, 80% of respondents remembered 'NEA inspects my home for *Aedes* mosquitoes at least once a year' (Table 4). Aik *et al.*, (2019) noted that residences with longer intervals between NEA's home inspections were more likely to have mosquito breeding habitats. The finding may suggest that a frequent reminder may be necessary to keep engaging residents, for each inspection also serves as a public education opportunity to remind residents of precautionary measures needed (Yoshikawa, 2013). These inspections also motivate residents to keep their homes free from mosquito breeding for another reason, which we will discuss the next.

The fourth example is law enforcement in Singapore. Our face-to-face survey revealed that 67% of respondents exercised anti-mosquito actions because they 'do not want to pay fine for breeding mosquitoes'. The efficacy of the provision to fine for breeding mosquitoes could be underscored by 53% of the respondents who 'check for the presence of *Aedes* eggs and/or larvae inside home' more than once a week. An even higher percentage of 58% of the 60's age group answered that they do so every day or every other day (Table 3).

Evaluation of NEA's efforts is outside the scope of this research. However, there are supporting findings that show good progress. In our face-to-face survey, 88% of respondents answered that 'I follow health advices and anti-mosquito information available in Singapore' as a reason to take anti-mosquito actions (Table 3). Also, all but one respondent felt 'responsible to keep their home free from *Aedes* eggs/larvae' (Table 4).

In August 2020, the agency started marketing personal protection measures, targeting residents at dengue high-risk areas in response to the explosive outbreak. 'S-A-W' steps comprise: 1) Spray insecticide in dark corners around the house; 2) Apply insect repellent regularly; and 3) Wear long-sleeve tops and long pants (NEA, 2020). The new message is short and 'easy to remember' as recommended by Liew *et al.*, (2021b). However, it may take time for expected awareness and behavioural change amongst the community to materialise. In our face-to-face survey conducted in Singapore in March 2017, five months after the local outbreak of Zika was contained in Singapore, only 15% of respondents used mosquito repellent every day or every other day, and 48% never used repellent. Similarly, 78% and 67% of respondents never wore long sleeves or long trousers to avoid

mosquito bites in the tropics with high temperature and humidity all the year around (Table 2). Although *Ae. aegypti* mosquitoes commonly feed during the day time, especially at dusk and dawn, 52% of the respondents agreed that they 'need to avoid mosquito bites during the night more than day time' for dengue prevention. These findings may suggest that even the dedicated and comprehensive community education efforts in Singapore could be improved upon. Alternatively, respondents may have actually experienced mosquito bites more frequently at night, which is worth investigating further.

4.2 Process, aspects and dynamics in Singapore's style of science communications

Science communications refer to public communications about science. Scientific findings are presented to convey information, which will be taken in and translated by the target audience. People's beliefs in science are influenced by the societal and political environment, in addition to reflections framed by mass media; and further complicated by cultural and interpersonal factors (Akin and Scheufele, 2017). Because interpretations of science communications are functions of complexity, poor science communications may fail to neutralise biased opinions, pre-empt or respond to anxieties amongst the audience.

NEA's process in avoiding conflicting messages embraced consistency, which in turn facilitated evaluation of the risks and benefits of the new technology amongst the target audience. Besides consistency, four other aspects stand out in Singapore's style of science communications. First, speed is emphasised when providing updates on the progress of the technology implementation and responding to the community's needs. Second, simplicity is endorsed in a brief key message that is easy to remember when promoting actions. Third, suitability is promoted when tailoring messages and using infographics to explain concepts of the new technology for the audience with no scientific training while maintaining accuracy (Liew et al., 2021a). Fourth, integrity is honoured as the contents reflect scientific evidence. A study on mosquito samples collected across Singapore affirmed NEA's messages of susceptibility of *Ae. aegypti* mosquitoes toward *Wolbachia* and its wide existence in nature (Ding et al., 2020).

The dynamics of Singapore's style of science communications lie in the science communicators. The roles are often assumed by political leaders and policy makers, in addition to scientists and technical specialists. As seen in the case of the opening ceremony of Clean and Green Singapore, 2019, scientific evidence is often communicated to the community by high-profile politicians.

4.3 Political backing for public health management

Unsuccessful public health management can hinder public confidence in the health system and government. Hence, it is essential to secure the attention of policy makers and the administration. In the history of Singapore's fight against infectious diseases, the embodied political will in a total governmental approach was exemplified during the SARS outbreak in 2003 (Yoshikawa, 2012). As seen in the examples of the First Release of male *Wolbachia*-carrying *Ae. aegypti* mosquitoes in 2016, Clean and Green Singapore ceremonies and the satellite events (Table 5), policy makers actually attend numerous events and campaigns nationwide. The direct messaging to, and interactions with the community in close proximity, help convey governmental commitment while increasing the visibility of political backing in initiatives to benefit the community at large.

Matthews et al., (2021) noted the high level of confidence and satisfaction shown by citizens with the Singapore Government, especially in the areas of handling public health. Involvement and devotion of political leadership in public health management might partly explain such confidence, in addition to a good track record of infectious disease management. It is possible to say that the successful social implementation of the otherwise possibly controversial novel mosquito control technology in Singapore is owed to the socio-political context between local residents and politicians. Actually, the high level of receptivity towards Project *Wolbachia* - Singapore may be attributable to a high level of

trust felt by the general public towards the Government of Singapore, and ‘approval of government’s efforts to control dengue’ influenced people’s ‘acceptance and sentiment’ towards the novel technology (Liew *et al.*, 2021b). Such a special socio-political environment cannot be easily duplicated elsewhere.

4.5 Moving forward with digital and social media?

Increasing global trend is evident in the application of new media in public communications. The tendency to rely on new media, such as online news sites, virtual and digital platforms and social media, was further escalated by the COVID-19 pandemic, which challenged the way we act in society. The strict social distancing and stay-at-home measures made it extremely difficult for the government to carry out face-to-face dialogue and distribute printed materials. This shift toward new media shows no signs of abating. While new media offers more options, easier access and convenience for the audience; and social media enables interactive communications, there are drawbacks that require attention in the area of public education.

First, it may be difficult for new media to offer the same joy of collective learning that events like Clean and Green Singapore carnivals offered to groups of seniors and students, pairs of parent-child and families, pre-COVID-19 pandemic. A complete transformation to virtual reality and digital society means the fun part of carnival experiences will be foregone, including opportunities to socialise with neighbours, collect rewards, and interact with scientists, government officials and staff. Second, heavy reliance on new media may attract only those who are proficient with new media literacy and active in learning. The digital divide, especially amongst the older people, will be an issue as the proportion of residents aged 65 years and above in Singapore increased to 15% in 2020 from 6% in 1990 (Ministry of Health, Singapore, 2023). Mechanisms and measures to promote community bonding is in place in Singapore, but hybrids of communication methods at educational events might be desirable.

4.6 Inclusion of the total population in Singapore

Similar to digital divide, integration of foreigners into community education is an imminent challenge in Singapore because they comprise 31% of the total population (Ministry of Trade and Industry, Singapore, 2023). Yoshikawa, Hamada and Liew (2023) cautioned about the low receptivity of NEA’s anti-dengue messages amongst Japanese residents in Singapore. Whilst 84 of 100 respondents in our face-to-face survey agreed that ‘Singaporeans (and Permanent Residents)’ practise anti-mosquito measures to ‘make sure that there is no *Aedes* egg and/or larva’ in the community, a significantly lower number of 67 respondents agreed that foreigners do so.

The inclusion of Singapore citizens and permanent residents in community education and engagement are often achieved at NEA’s events, which are typically held at public estates and community centres. The majority of occupants there are Singapore citizens and permanent residents with fluency in all or at least one of the four official languages of Singapore. It is therefore more difficult to conduct outreach to foreign residents. Since sustainability efforts are showcased for the whole society of Singapore in recent years, it bears repeating that attempts to engage foreign residents can only increase the effectiveness in Singapore’s efforts to care for environment.

4.7 Implications for non-dengue-endemic countries

It is challenging for other countries to prepare for the introduction of a novel mosquito control technology with the same magnitude and intensity of community education and engagement demonstrated by NEA. The case of Singapore indicated importance of careful planning for implementing a novel mosquito control technology into residential areas. Nevertheless, the list of tasks shown by NEA provides practical information.

Once a local dengue outbreak is confirmed, the first step for countries with no previous dengue endemicity might be to promote actions that people can take individually to mitigate their own risk. Behavioural change outcomes could include seeking early medical attention, even before discussing mobilisation of the community for mosquito source reduction or introducing a novel mosquito control technology as a complementary public health intervention measure.

There is a finding from Singapore that is a cause for concern for a country like Japan. The first exposure to dengue for the majority of residents in Singapore was delayed to adulthood, and severe symptoms were suffered by the elderly (Ho *et al.*, 2023). Almost all residents in Japan are susceptible to all Dengue virus (DENV) serotypes, and the proportion of residents aged 65 years and above is 29% as of May 2023 (Ministry of Internal Affairs and Communication, Japan, 2023) – much higher than that of Singapore. With the increasing trend in population aging and depopulation in various rural parts of Japan, vaccine development and roll-out may be prioritised while labour-intensive mosquito control efforts remain underdeveloped, including both mosquito source reduction and new mosquito control technology. It suggests that the risk of other mosquito-borne infectious diseases will remain to threaten the aging society, even after a safe and effective dengue vaccine becomes available.

4.8 Limitation of this research and future direction

These research findings are limited by the small sample size and the overrepresented 60's age group in the face-to-face survey. Therefore, our sample cannot represent a portion of the total population in Singapore. The choice of location for the survey may have also affected the results, because Ang Mo Kio did not represent the high-risk area of dengue in Singapore at the time of survey. Whilst the Chinese translation was printed on the information sheet and questionnaire, the Malay and Tamil translations could have also been presented. The research activities by means of participant observation methods were interrupted for over two years due to the restriction of international travel and social distancing measures, which compromised data collection at additional events held in Singapore.

It should be also noted that our analysis from the perspective of science communications has primarily focused on community education and engagement in the exploration and early stages of Project *Wolbachia* - Singapore.

Future research efforts could be invested in the promotion of proper recognition of dengue risk. People disagreeing with the release of male *Wolbachia*-carrying *Ae. aegypti* mosquitoes in Singapore were found to consider their risk of contracting mosquito-borne infectious diseases low (Soh L.T. *et al.*, 2021). Achieving and sustaining appropriate recognition of dengue risk amongst the wider audience, without scaring them, is a hard task for all governments.

5. CONCLUSION

The face-to-face survey of this research revealed underlying factors motivating actions in and opinions towards mosquito control amongst local residents in Singapore. Yearly endeavours of the Singapore Government in regenerating the motivation for individuals and the community to prevent mosquito breeding was elaborated. Inquiries from the perspective of science communications elucidated the process, aspects and dynamics in community education and engagement, which aimed to implement *Wolbachia-Aedes* technology in living spaces of local residents. Although Singapore's style of science communications is facilitated by the country's sociopolitical setting, the multi-way dialogues and activities demonstrated by NEA contribute to the formation of the future landscape of effective science communications in public health.

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