REVIEW ARTICLE

Oman Medical Journal [2019], Vol. 34, No. 5: 391-396

Innovative Preventive and Resilience Approaches Against *Aedes*-linked Vector-borne Arboviral Diseases Threat and Epidemics Burden in Gulf Council Countries

Ernest Tambo[1,2]*, Ashraf G. El Dessouky[2,3] and Emad I.M. Khater[2,3]

[1]Biochemistry and Molecular Biology Unit, Public Health Pests Laboratory, Jeddah, Saudi Arabia
[2]Pesticides and Bait Unit, Public Health Pests Laboratory, Jeddah, Saudi Arabia
[3]Microbiology Unit, Public Health Pests Laboratory, Jeddah, Saudi Arabia

ARTICLE INFO

Article history:
Received: 4 July 2017
Accepted: 24 October 2018

Online:
DOI 10.5001/omj.2019.73

Keywords:
Mosquito Vectors; *Aedes*; Zika Virus; Arboviruses; Dengue; Information Dissemination; Saudi Arabia.

ABSTRACT

Facing the local and imported borderless *Aedes*-linked vector-borne viral diseases threat and epidemics burden, the Health Committee of the Gulf Cooperation Council (GCC), including the Saudi Arabian government, announced that all Gulf countries are still free from the threat of a Zika virus epidemic. This article provides a vision of integrated eco-friendly and sustainable behavioral communication change (BCC), biological control preparedness and resilience approaches, and innovations implementation in Saudi Arabia and GCC for the purpose of controlling the threat of *Aedes*-linked vector-borne viral diseases. Implementing innovative *Aedes*-linked arboviral preventive and resilient control measures is pivotal in improving community-based surveillance-response systems, BCC multidisciplinary and empowerment methods, and in enhancing community social mobilization and risk communication strategies. Moreover, boosting social, cultural and ecological preparedness, and prompt management approaches are necessary against the threat of local and global zoonotic epidemics and pandemics. Nurturing evidence and proven tick or mosquito vector populations' reduction, planned urbanization, climate change and waste management systems, and implementing data sharing and tailored mitigation solutions are crucial against the persisting *Aedes* competence and the public health threat of dengue, MERS-CoV, and influenza outbreaks. Sustained investment and ample financial allocation are needed to improve Muslim pilgrimage (Hajj and Umrah mass gathering) including point of entry screening and treatment, community-based education and awareness campaigns, and increasing mosquito vector viral pathogens surveillance interventions. Increasing evidence-based population participation and resilient emergency community preparedness and rapid response programs integration are critical to reduce mosquito breeding sites, dengue, and other arboviral infections.

With people in Saudi Arabia increasingly living in urban and semi-urban areas, the country may face a bigger threat of sudden outspread of mosquito vectors of dengue and Zika virus.[1] A total of 2926 confirmed cases of dengue fever were documented in 2016 in Saudi Arabia alone,[2] and dengue infection remains a major public health concern in the Western and South-western areas of Saudi Arabia and Yemen. Most cases are related to predominant dengue virus serotypes (DENV 1, 2, 3, and 4), climate change/extreme weather and urbanization drivers facilitate the proliferation of the incriminated disease vector (*Aedes* mosquito species).

Saudi Arabia recorded 6000 cases of dengue fever in 2015, and six infected patients died.[2] *Aedes aegypti* and *Ae. albopictus* female mosquito species may bite both day and night and feed indoors and outdoors, which increases transmission in Saudi Arabia.[1–3] Dengue is closely related to other mosquito-borne flaviviruses within the Flaviviridae family such as Zika, yellow fever, West Nile, and Japanese encephalitis.[1,3–5] In 2006, a total of 10 000 infected dengue cases were recorded compared to a significant upsurge of more than 2.5 million at risk in 2016 in more than 130 countries. Zika virus causal factor infection is associated with congenital malformations (microcephaly) and neurological

*Corresponding author: ✉tambo071@gmail.com

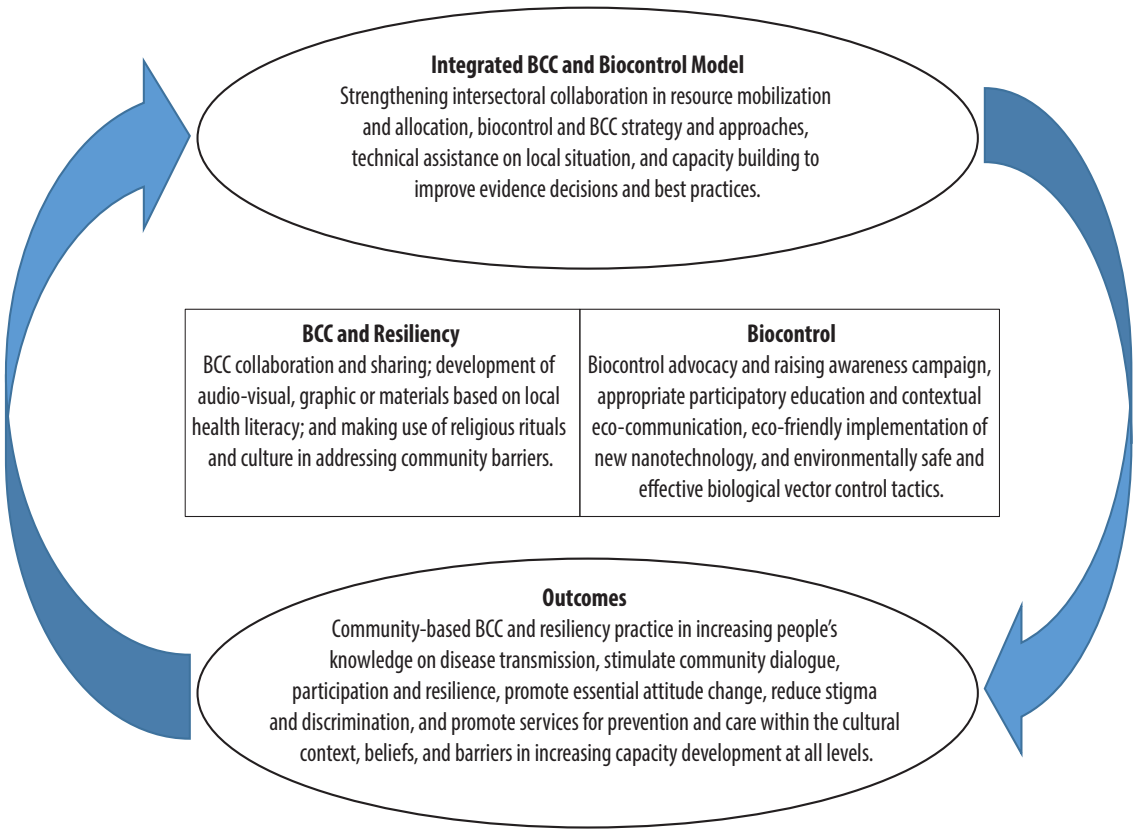

Figure 1: Flow chart of new integrated behavior communication change (BCC) and biological control approaches and strategies in dengue and other arboviral diseases control and elimination in Saudi Arabia and Gulf Cooperation Council.

complications (Guillain-Barré syndrome) in children and maternal health issues and remains a serious concern in neighboring *Aedes*-prone countries.[1,4–6]

The current integrated vector management (IVM) drawbacks and operational challenges to rid *A. aegypti* and *Ae. albopictus* female mosquitoes breeding sites and case management costs have been highlighted by the persistent and changing pattern of *Aedes sp*.[1,3,4,5,6] Understanding the drivers of mosquito abundance and competence, dengue and other arboviral infection threshold and seroconversion requires further research to elucidate viral host reservoirs and transmission routes (e.g., blood products transfusion, breastfeeding, transplacental, and sexual intercourse). Surveillance and monitoring of performance metrics are the keys to control and eliminate these viruses in Gulf Cooperation Council (GCC) *Aedes*-prone countries.[1,2,5,6]

Elucidating dengue and other emerging arboviral asymptomatic carriers, antigenic diversity and phylogenetic of DENV 1–4 and other arboviral diseases in Saudi Arabia, Yemen, and other Middle Eastern countries is crucial for timely prevention and case management strategies in Saudi citizens, Muslim pilgrims, and expatriate workers.[7–10]

Although the Health Committee of the GCC announced that all Gulf countries are free from Zika virus, innovative preventive and control methods are encouraged.[11] A regional 'One Health' policy should comprise of innovative and sustainable vector prevention, environmental management, IVM, and care delivery solutions including enhanced community engagement and education, integration of new biocontrol approaches to law enforcement/regulations, regular laboratory screening of mosquito/blood-borne arboviral diseases, quality standards integration, and preparedness and capacity building strategies. Such strategies are crucial to reduce adult and larval mosquito populations. Investment in research and development is required to guide novel, affordable, and effective strategies and tools for timely preparedness and emergency response/containment, point of care diagnostics, and safe and effective vaccines and drugs.

This review seeks to highlight the urgent need to implement effective and contextual integrated ecofriendly behavioral communication change (BCC) and biocontrol approaches against persisting *Aedes* mosquitoes and other disease vectors including ticks, fleas, mites, and sandflies, which pose a significant public health threat in Saudi Arabia.

Improving community behavioral communication change approaches

Fostering practical approaches for sustainable development in human/community awareness and improving BCC impact are important in reducing and eliminating the persistent public health threat of dengue and emerging arboviral diseases and their vectors. In achieving this goal, leveraging on the community-based 'One Health' approach is paramount in elucidating the relationship between animal-human and environment interactions. Also, there is a need to increase vulnerable populations awareness and for health education promotion in schools/universities, culture/faith-based, stands/tribunes, and community/mass gatherings to improve people's knowledge of vector-borne and zoonotic diseases, incriminated vectors breeding habitats, biological behavior, disease transmission dynamics, and complications to develop robust and sustainable community-based sanitation and hygiene practices to combat arboviral/zoonotic disease temporal/spatial spread.[9,11] Additionally, social media and traditional media options can be used to accelerate community awareness and health education outreach, and acceptance and participation with biocontrol reductionist methods.

Such an approach is vital to support policy-making and emergency response management teams, adequate resource allocation, sufficient and sustained supervision, and evaluation of integrated programs incorporating Muslim religious and cultural (tradition and custom) concepts and experiences to satisfy residents healthcare needs.[9–12] Community-based programs associated with governmental ministries, municipalities, social agencies, and interested stakeholders (health, education, environment, agriculture, irrigation, customs affairs, information, communication, and media) are needed to enhance community social mobilization and communication in Saudi Arabia, Oman, Yemen, UAE, Qatar, and Kuwait regarding the threat of dengue, Zika, and other arboviral diseases [Figure 1].[1,2,10,13]

Consolidating innovative and integrated biological control solutions implementation

Increasing funding and financial allocations are crucial for the development and deployment of innovative biological control solutions, which includes scaling-up community-based programs for awareness and empowerment as an effective eco-friendly weapon against disease vectors.

Eco-friendly biological control measures, such as genetically modified mosquitoes artificially infected with Wolbachia — a bacterium that stops dengue — placed in large water-storage reservoirs/tanks and rain fall streams were deployed successfully in *Aedes* vector control in China, Brazil, Singapore, and parts of America. Another biological control measure is the use of fish/copepod predators, which can prey upon, parasitize, and compete with the wild vector and reduce the target vector populations.[2,14–16] Deployment of genetically engineered mosquitoes, sugar toxic baits, and biologically new larvicide or adulticide agents' complements are crucial tools in improving biocontrol approaches and strategies and should be used in parallel with insecticide resistance monitoring and development of appropriate countermeasures.[17–19] Strengthening local-tailored and proven effective communities' preventive and resilience methods coupled with educative approaches are needed in delivering vulnerable populations coverage against re/emerging public health threats (particularly maternal-child healthcare).[13,14] Furthermore, adoption and adaptation of the CDC Pregnancy Risk Assessment Monitoring System to improve tracking and monitoring of Zika-related fetal development and birth defects, Guillain-Barré syndrome, and related motherhood and childhood complications in all endemic countries are highly recommended among the local population and expatriate workers. There is also need to establish green space to mitigate climate change as well as to develop a biodiversity conservation culture, which incorporates improved sanitation and drainage systems and mosquito repellants plants and waste management to develop a healthier environment. When introducing Wolbachia into urban or rural communities, it is important to understand mosquito host fitness and coexistence, the influence of biological competition

outcomes, and the impact of vector competence as well as the ecological and bacterial profile in control and elimination.

Expanding sero-surveillance and response approaches implementation among the asymptomatic population at risk of arboviral diseases

Expansion of field and laboratory sero-surveillance and research among asymptomatic populations at risk (including pilgrims, school children, and expatriate workers) is crucial in documenting and generating data on arboviral diseases prevalence and potential risk factors. This is vital to establish robust evidence-based and sustainable early warning indices, policy planning and prediction, response approaches, and action plans. Moreover, it is imperative to enhance quality data and data sharing for evidence community-based risk reduction tactics and management. Promoting community participation and education programs remain key prevention and elimination tactics particularly during annual Hajj and seasonal Umrah pilgrimage, which may need quarantine measures in place to protect tourists from tropical and subtropical endemic high-risk areas in the GCC, Central/South America, Latin America, Asia-pacific, and Africa.[10,13,14]

It is worth noting that the use of window and door screens, air-conditioning, approved insect repellents (DEET and permethrin, which are safe and effective for pregnant women when used in accordance with the product label), and wearing long-sleeved shirts and long pants as protection against mosquito bites are the best prevention.[2,4]

Strengthening early warning system and risk communication to promote evidence-based preparedness and decision making

The use of pilot surveillance stations for early warning detection of disease outbreak accompanied by efficient data analysis and the implementation of remote sensing technologies and geographical information system analysis to predict communities at risk and forecasting the spatial/temporal landscape occurrence of the disease incriminated vectors could be used to sustain control and eliminate the threat of arboviral diseases. The use of such a modeling approach is of vital importance to enhance community/government preparedness and resilience tactics, pathogenic vector mapping, and implementing behavior change.

Integrating a contextual national 'One Health' approach is core in providing an integrated and improved understanding of human, animal, and environment interaction in tackling arboviral emerging threats and outbreaks. While concerted efforts in adapting the Sendai Framework Disaster Risk Reduction of United Nations is essential in reducing public health hazards, behavioral and environmental risks and implementing performance-based projects/programs that offer new opportunities for shared *Aedes* mosquitoes risk/burden reduction engagement in the GCC. Essentially, strengthening laboratory and epidemiological surveillance as well as insecticide resistance and monitoring *Aedes* mosquito behavior changes is needed to elucidate vector exposure versus immune profile diversity and phylogeography. The approach relies on generating comprehensive data to formulate reliable, effective, and sustainable decision-making policies, which can be used to inform projects and interventions in different vulnerable settings. This includes updates to travel information to protect pilgrims of Hajj and Umrah, and prevention and control packages on Zika, Chikungunya, and dengue co-infections. It has been noted that improving proven conventional entomological indices surveillance and monitoring analysis (i.e., house index; percentage of households with larvae or pupae and container index; percentage of water-holding containers with larvae or pupae/containers and Breteau index; number of positive containers with larvae or pupae per 100 households inspected) is crucial. In addition, fine risk mapping and early warning systems implementation should be done for timely case detection and monitoring, enhanced risk communication and rapid actions against emerging local and global circulating *Aedes*-linked dengue and arboviral diseases threats and pandemics in Saudi Arabia, the GCC, and worldwide.

Strengthening governmental/private research and development renewed commitment and investments

Although laudable financial support has been devoted to fighting dengue, the threat of dengue and other arboviral diseases epidemic potential remains a public health concern locally and in the region. Promoting public-private stakeholders

partnership (e.g., health and environment providers, pharmaceutical companies, non-government organizations, and other sectors), renewed leadership commitment and investment in collaborative and participative research in regional biosecurity including ample funding of research and development is essential for more sensitive diagnostics and tailored cost-effective community-based programs. Importantly, safe and effective dengue and Zika drugs and vaccines discovery for pilgrims/traveler immunization programs should remain a priority in curbing the global health security and other emerging pandemics.[2,5,10,14,15,17,19]

CONCLUSION

The threat of *Aedes*-linked vector-borne arboviral diseases epidemics represents a continuous and increasing public health concern in GCC countries. Strengthening robust, integrated preventive, and resilient multidisciplinary local and cross borders collaboration in resource mobilization and allocation is needed to scale-up integrated and sustainable *Aedes* vector control. Enhanced field epidemiological and laboratory importance surveillance is imperative to generate quality data and database sharing for evidence-based decision-making, biological control, and BCC approaches and targeted programs and interventions.

Establishing joint local and international experts, committee technical assistance to oversee, evaluate and monitor programs performance and impact on local dengue or potential pandemics threats situation and sustaining building capacity to improve alert warning alerts and best practices implementation is core.

Strategic inter-regional collaboration and contextual early detection and monitoring programs, including remote sensing/satellite and fine risk mapping analysis and safety practices monitoring, is crucial. Moreover, sustained community behavioral change, awareness, and resilience in emerging vector-borne diseases threat and epidemics innovations in control and eventual elimination in Saudi Arabia and its neighbor countries. Likewise, increasing monitoring and evaluation of single and multiple vector control projects in defining effective indicators and metrics of effectiveness and quality outcomes is crucial in promoting scale citizenry engagement and resilience in access to and uptake of sustained *Aedes*-related arboviral diseases preventive and control interventions.[19]

Disclosure

The authors declared no conflicts of interest. No funding was received for this study.

Acknowledgements

The authors would like to thank the Golden Eyes Ets. for the enabling environment and support.

REFERENCES

1. Benelli G, Jeffries CL, Walker T. Biological control of mosquito vectors: past, present, and future. Insects 2016 Oct;7(4):E52.
2. WHO. Dengue control. Biological control. 2016 [cited 2016 October 24]. Available from: http://www.who.int/denguecontrol/control_strategies/biological_control/en/.
3. Petersen LR, Hayes EB. Westward ho?–The spread of West Nile virus. N Engl J Med 2004 Nov;351(22):2257-2259.
4. Tambo E, Chuisseu PD, Ngogang JY, Khater EI. Deciphering emerging Zika and dengue viral epidemics: Implications for global maternal-child health burden. J Infect Public Health 2016 May-Jun;9(3):240-250.
5. Hayes E. (2009). Zika virus outside Africa. Emerging Infectious Diseases 2009 Sep;15(9):1347.
6. Madani TA, Abuelzein TM, Al-Bar HM, Azhar EI, Kao M, Alshoeb HO, et al. Outbreak of viral hemorrhagic fever caused by dengue virus type 3 in Al-Mukalla, Yemen. BMC Infect Dis 2013 Mar;13(13):136.
7. Azhar EI, Hashem AM, El-Kafrawy SA, Abol-Ela S, Abd-Alla AM, Sohrab SS, et al. Complete genome sequencing and phylogenetic analysis of dengue type 1 virus isolated from Jeddah, Saudi Arabia. Virol J 2015 Jan;12:1.
8. Murugan K, Labeeba MA, Panneerselvam C, Dinesh D, Suresh U, Subramaniam J, et al. Aristolochia indica green-synthesized silver nanoparticles: A sustainable control tool against the malaria vector Anopheles stephensi? Res Vet Sci 2015 Oct;102(102):127-135.
9. Aziz AT, Al-Shami SA, Mahyoub JA, Hatabbi M, Ahmad AH, Md Rawi CS. Promoting health education and public awareness about dengue and its mosquito vector in Saudi Arabia. Parasit Vectors 2014 Nov;7:487.
10. Banneheke H, Paranavitane S, Jayasuriya V, Banneheka S. Perceived risk of dengue in ones' living environment as a determinant of behavior change through social mobilization and communication: evidence from a high risk area in Sri Lanka. J Arthropod Borne Dis 2016 Jan;10(3):392-402.
11. Al-Tawfiq JA, Gautret P, Benkouiten S, Memish ZA. Mass gatherings and the spread of respiratory infections. Lessons from the hajj. Ann Am Thorac Soc 2016 Jun;13(6):759-765.
12. Parveen S, Islam MS, Begum M, Alam MU, Sazzad HM, Sultana R, et al. It's not only what you say, it's also how you say it: communicating nipah virus prevention messages during an outbreak in Bangladesh. BMC Public Health 2016 Aug;16:726.
13. Sanchez L, Perez D, Cruz G, Castro M, Kourí G, Shkedy Z, et al. Intersectoral coordination, community empowerment and dengue prevention: six years of controlled interventions in Playa Municipality, Havana, Cuba. Trop Med Int Health 2009 Nov;14(11):1356-1364.
14. Adalja A, Sell TK, McGinty M, Boddie C. Genetically modified (GM) mosquito use to reduce mosquito-transmitted disease in the US: a community opinion survey. PLoS Curr. 2016 May 25;8.
15. Mains JW, Brelsfoard CL, Rose RI, Dobson SL. Female adult Aedes albopictus suppression by wolbachia-infected male mosquitoes. Sci Rep 2016 Sep;6:33846.
16. Murugan K, Priyanka V, Dinesh D, Madhiyazhagan P,

Panneerselvam C, Subramaniam J, et al. Predation by Asian bullfrog tadpoles, Hoplobatrachus tigerinus, against the dengue vector, Aedes aegypti, in an aquatic environment treated with mosquitocidal nanoparticles. Parasitol Res 2015 Oct;114(10):3601-3610.

17. Singh G, Prakash S. Virulency of novel nanolarvicide from Trichoderma atroviride against Aedes aegypti (Linn.): a CLSM analysis. Environ Sci Pollut Res Int 2015 Aug;22(16):12559-12565.

18. Govindarajan M, Kadaikunnan S, Alharbi NS, Benelli G. Single-step biological fabrication of colloidal silver nanoparticles using Hugonia mystax: larvicidal potential against Zika virus, dengue, and malaria vector mosquitoes. Artif Cells Nanomed Biotechnol 2017;45(7):1317-1325.

19. Tambo E, Chen JH, Zhou XN, Khater EI. Outwitting dengue threat and epidemics resurgence in Asia-Pacific countries: strengthening integrated dengue surveillance, monitoring and response systems. Infect Dis Poverty 2016 May;5(1):56.