Original Article

Entomological Surveillance System for Invasive *Aedes* Mosquitoes at Points of Entry in West Azerbaijan Province: Strengths and Weaknesses

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Abstract

Background: Global trade and travel are key factors affecting the initial introduction of vectors and VBDs (vector-borne diseases) in a country. Vectors know no borders; it is essential to establish systems for the surveillance of vectors and vector-borne diseases (VBDs). This study was conducted to investigate the strengths and weaknesses of a newly established entomological surveillance system for *Aedes* mosquitoes at points of entry (PoE) in West Azerbaijan Province.
Methods: The *Aedes* surveillance system was implemented in West Azerbaijan Province from 2019 to 2023. Following national guidelines, *Aedes* eggs and larvae were surveyed at eight international PoEs using ovitraps and by collecting larvae from natural or artificial habitats. A specific checklist designed for this study was employed to evaluate the program.
Results: Over 9008 ovitraps were deployed, while 552 had eggs, including species from the families Phasmatidae and Psychodidae, as well as species from the genus *Culex* and *Aedes caspius*. Additionally, 506 larvae were collected during the surveillance period. The program had several key strengths, including a well-structured reporting system, robust technical support, knowledgeable personnel, designated health staff spaces at PoE, standardized surveillance tools, initiatives for environmental enhancement, the establishment of an entomology laboratory, cross-border collaborations, and public health education campaigns. Identified weaknesses comprised staff and entomologist shortages, the absence of a functional insectary, limited engagement of volunteer groups, and inadequate availability of insecticides and tools for emergency vector control.
Conclusions: The study outcomes shed light on the challenges and suggest operational and practical solutions to address the identified shortcomings.

Keywords: *Aedes aegypti*; *Aedes albopictus*; Points of entry; West Azerbaijan; Iran

Introduction

Dengue, Chikungunya, and Zika viruses, transmitted by *Aedes* mosquitoes, pose a significant threat to public health in tropical and sub-tropical regions worldwide. Notably, the number of dengue cases has escalated 30 times over the past 50 years (1). Today, dengue poses a threat in over 129 countries, putting half of the global population at risk (2). The most affected areas are the World Health Organization (WHO) Americas, Southeast Asia, and the Western Pacific Regions. In addition, Asia accounts for approximately 70% of the global disease burden (3). Chikungunya is another viral disease transmitted by *Aedes* mosquitoes, with symptoms similar to those of dengue fever (2, 4). In recent years, widespread outbreaks have

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occurred in countries neighboring Iran, including Saudi Arabia, Yemen, and Pakistan (5). Zika is a newly emerging disease spread by *Aedes* mosquitoes, with local transmission having been reported in 33 countries (6).

Aedes aegypti is the primary vector of the agents causing the mentioned diseases. This vector is well adapted to living close to human dwellings, prefers to feed on human blood, and typically bites multiple people during its feeding period (7). In contrast, *Aedes albopictus* is the main vector for dengue and chikungunya in certain regions, but it is considered a secondary vector. Outbreaks in areas where only *Ae. albopictus* tend to be less severe than those occurring where *Ae. aegypti* is present.

Originally, *Ae. albopictus* was found in Southeast Asia, the islands of the Western Pacific, and the Indian Ocean. However, it is now widespread globally (8). This mosquito species has been reported in countries surrounding Iran, including western Türkiye (Edirne province, adjacent to Greece), Bulgaria, Romania, southern Russia, Pakistan, Afghanistan, India, Abkhazia, Saudi Arabia, Sudan, Armenia, Georgia, and Yemen (9–17). *Aedes aegypti*, which originated from African forests, is now found in most tropical and subtropical regions around the world (18).

Limited information is available about invasive *Aedes* mosquitoes in Iran. Although *Ae. albopictus* was reported in southeastern Iran in 2009 and 2013, subsequent studies did not confirm its presence and establishment in the area (19, 20). Recent reports indicate that the primary disease vector, *Ae. aegypti*, reappeared in southern Iran in 2018 after an absence of approximately 70 years (21–23) and is now present throughout the southern provinces. There are also reports of *Ae. albopictus* presence on the southern shore of the Caspian Sea in Guilan Province (24).

Entomological surveillance is crucial for monitoring potential vectors and their impact on disease transmission. It helps in tracking changes in the distribution and population of these vectors, evaluating control programs, measuring their population over time, and making timely decisions about interventions. In the southern region of Iran, entomological surveillance successfully identified the presence of *Ae. aegypti*, which is crucial for early detection to prevent and control *Aedes*-borne agents causing diseases (25, 26).

Entomological surveillance involves actively collecting, analyzing, and interpreting data on vector-borne diseases (VBDs) and their vectors, and promptly sharing this information with health authorities. This surveillance is carried out in regions at risk of VBD transmission and vector spread. Invasive species such as *Ae. aegypti* or *Ae. albopictus* are often introduced to new regions through trade or passenger travel. Points of entry (PoE) play a crucial role in preventing, detecting, and responding to the international spread of diseases and vectors. Increasing the number of checkpoints in the surveillance system improves the likelihood of detecting these vectors. While negative results are reported, this information may not definitively prove the absence of these species within a county. Regular entomological surveillance on a large scale is expensive and labor-intensive. As a result, it is not feasible to conduct these investigations everywhere. The *Aedes* national advisory committee recommends focusing the surveillance on the main PoEs (27). The surveillance system is complex and multifaceted, so experts emphasize the importance of properly implementing and monitoring the plans.

In this research, three key factors are considered for effective care systems: human resources, vector surveillance, and facilities. This system will help health authorities maintain and evaluate sustainable, community-based, locally adapted prevention and control strategies to keep the Province safe and reduce the probable burden of *Aedes*-transmitted arboviruses. The study aims to investigate the strengths and weaknesses of the *Aedes* entomological surveillance system in West Azerbaijan Province to identify existing challenges. Through this, the

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expansion of the vectors to other areas will be prevented by the timely detection of their entry.

Materials and Methods

Study area

The study area for this research was West Azerbaijan Province, located at 45.08º E, 37.55º N, with an elevation of approximately 1332 meters above sea level. This Province is situated in northwestern Iran and shares borders with Türkiye, the Republic of Azerbaijan, and Iraq. West Azerbaijan Province covers about 15% of the country's total border length and has a combined water and land border with neighboring countries stretching 850 km. The Province has multiple points of entry, including Urmia International Airport, the Razi Railway border, and main land transportation routes for passenger traffic from the official borders of Sero, Bazargan, Poldasht, Razi, and Tamarchin. Additionally, the customs warehouses located in the suburb of Urmia are examined as the eighth point. The characteristics and location of the PoE of the study area are shown in Table 1 and Fig. 1. Currently, 20% of the country's border terminals are situated in West Azerbaijan Province. These terminals facilitate the daily travel of thousands of passengers and the transportation of commercial goods and essential commodities between the Province and its neighboring countries. The study was conducted over a period from March to October, covering the years 2019 to 2023.

Aedes surveillance using ovitrap

In all PoE, 50–100 ovitraps were placed every 15 days. Each ovitrap is a one-liter black plastic bucket with an overflow hole, lined with filter paper soaked in water to collect eggs laid by female *Aedes* mosquitoes. Two-thirds of the ovitrap volume is filled with a 10% hay infusion and 90% dechlorinated water. The hay infusion is prepared by mixing 100 grams of hay with ten liters of water and allowing it to ferment in the shade for a week. The ovitraps were placed near buildings in shady, quiet, and visible locations. They are checked every three days, and the filter papers are removed, placed in a container with damp towels or cotton, and taken to the laboratory away from direct sunlight (28). During each inspection, ovitraps are cleaned, and new paper and water are added. The temperature of each location is recorded, and specific details regarding the international borders of West Azerbaijan Province are noted.

In case of any positive ovitrap, the eggs on filter papers are reared to adults and then identified based on a morphological identification key (29). The papers containing eggs were stored in a closed container at room temperature for 2 to 3 days. After this, the papers were placed in dechlorinated water in a plastic tray to increase the hatching rate of the egg, and 10% commercial yeast extract (1 g/liter) was added. Larvae were fed fish food and reared in the insectary of the Pathogens and Vectors Research Center, Urmia University of Medical Sciences, at 29±1 °C and 70±5% relative humidity, under a 12:12 light: dark cycle. The cages used to keep mosquitoes were wooden cubes measuring 30 cm×30 cm×30 cm, covered with fine mesh.

Larval surveillance

We conducted surveys of all potential larval breeding sites of *Aedes* mosquitoes in each study site, such as small waterholes, pools, and ponds, water stored for human and animal use, water under cooling coolers, water pots, watering cans collected in small containers, and garbage. We collected larvae and pupae by dipping, pipetting, or emptying the containers. Surveys were carried out every two weeks, and we revisited the same locations each time. All larvae and pupae were collected in 25 ml vials containing 70% alcohol and then transported to the Urmia Health Center, Disease Control Unit. According to the guidelines of Iran, if eggs or larvae of invasive *Aedes* are caught, adults will be caught. Therefore, in this study, the adult investigation was not done.

Equipment and facilities

The entomological equipment and facilities listed in the national guidance were assessed for shortages (28). Additionally, the strengths and weaknesses of the *Aedes* entomological surveillance system in West Azerbaijan Province were documented.

Monitoring and evaluation framework

To meet the objectives of the national *Aedes* entomological surveillance system, a monthly checklist was prepared and completed (Table 2). The questions of this checklist have been compiled based on WHO instructions and have been localized according to the opinion of the focal point of vector control in Iran (30). The program's key indicators were interpreted using an analytical framework and listed separately for each PoE in a matrix format. Following the completion of the checklist and site visits, perceived needs were categorized into three groups: (a) "adequate" (no need for intervention), (b) "somewhat sufficient/partly adequate" (need for intervention), and (c) "inadequate" (clear and urgent need for intervention).

Results

Entomological surveillance

To evaluate the strengths and weaknesses of the entomological surveillance system, we first assessed the status of key factors based on Table 3.

The entomological surveillance findings for 12 months of the year were logged based on the Ministry of Health portal by the personnel at PoEs. Health center specialists provided technical assistance to all PoE.

Over 9008 ovitraps were placed, out of which 552 contained eggs of unknown origin. All the eggs were hatched in the insectary. Among the hatched eggs, 518 were from the family Psychodidae, 23 were from the genus *Culex*, 9 were from the genus *Aedes* (*Aedes caspius*), and 2 were from the family Phasmatidae.

A total of 506 larvae collected using droppers were examined and identified using a morphological identification key (32). During this study, 239 larvae of *Culiseta* (47%) and 267 larvae of *Culex* (53%) were identified.

Based on recommendations, larval source reductions were carried out at all PoEs. Only at the Razi Railway station, the filling of larval breeding sites did not commence during the study period. However, in other cases, such as at Bazargan PoE, filling, removal, or destruction of breeding sites were carried out during the study.

Based on Table 3, fortunately, there was no suitable larval habitat for *Aedes* mosquitoes at the airport and the land borders of Bazargan, Poldasht, Tamarchin, and Razi. However, there were identified potential temporary larval habitats at the land border of Sero and Razi train station. Specifically, rainwater collection inside the imported tires at Sero and water collection at the base of the trees at the Razi train station were identified as the weak points of this surveillance program.

Human resources

The human resources status surveyed in this study is summarized in Table 4. The survey focused on skills and experience, having sufficient information on the subject, and the number of technical staff. The findings from the present study indicate that health workers received adequate training and supervision. They possessed sufficient skills and experience and were well-informed about the issue with access to relevant information. Additionally, training materials were readily available in the staff's workroom, and there were ample educational pamphlets and banners for passenger use. At the PoE, there was only one medical entomologist conducting entomological surveillance/surveys. In other PoEs, trained health staff undertook entomological surveillance, as there were no entomologists present. The staff's competence in performing entomological tasks, such as collecting eggs from ovitraps or larvae from breeding places, was positively evaluated, demonstrating their knowledge, experience, motivation, and skill. Furthermore, environmental health experts visited the PoE monthly, with a service car available for all health staff attending the PoE. New personnel received necessary training, and refresher and practical courses were provided according to demand. The training was conducted by experts and focused on Medical Entomology, with teaching materials available for the training sessions.

Community mobilization

Community mobilization plays a vital role in the vector control program (Table 5). This study section emphasizes intra- and inter-sectoral collaboration, cross-border cooperation, and Non-governmental organizations (NGOs).

Intra-sectoral collaboration

Collaboration is evident within the health sector and among different programs. Existing documents on training systems, intra-sectoral meetings, joint actions, and field visits demonstrate close relations and cooperation between health education and promotion, environmental health, disease prevention experts, and medical entomologists.

Inter-sectoral collaboration

The collaboration involves various entities such as the municipality, village administration, water and sewage organization, department of environment, customs department, airport management, railway management, cross-border terminal management, military forces, representatives of public institutions, road administration, radio and television in the province, judiciary, and other relevant organizations. At the provincial level, there are meetings between all representatives and officials from all organizations. In these meetings, the responsibilities of each department in preventing and controlling *Aedes*-borne diseases were discussed.

Cross-border cooperation

A cross-border memorandum of cooperation has been established between Iran, Iraq, and Türkiye. The collaboration strongly emphasizes the rapid removal of garbage, used tires, and other materials that act as breeding places for invasive *Aedes*. The number of cross-border collaborations depends on the presence of high-risk areas. There are successful examples of cross-border cooperation with neighboring countries. For instance, there is good cross-border cooperation in cleaning and dredging the Iran-Türkiye channel on the Sero border.

Non-governmental organizations (NGOs)

As per the regulations, non-official responsible persons are not permitted at the PoE, so the involvement of non-governmental organizations (NGOs) in this area is not well defined. There was no specific volunteer partner or NGO involved in the vector surveillance and control program at PoE. Officials and health workers conducted all vector surveillance and control programs.

Materials and equipment

In this section, we assessed the workspace at the border health center, the medical entomology laboratory, and the essential materials, tools, and equipment needed for *Aedes* egg and larvae collection, as well as for vector control. The results are presented in Table 6. According to international health regulations and guidelines, the health center must be designated as the PoE. There is a standardized health center for all PoE in the province. The Medical Entomology Laboratory was established in 2019 and is now operational. The health authorities considered setting up an insectary in 2021, but it faced significant financial challenges due to the COVID-19 pandemic. As a result, the insectary was not operational, and the eggs were raised in non-standard conditions. Although an annual budget was allocated for the insectary, it was insufficient to complete the setup. The PoEs have been provided with the necessary tools for observing or detecting *Aedes* eggs, such as ovitraps, filter papers, yeast, transfer containers, and ice packs. These materials and tools were prepared according to the specifications in the national guidelines. Additionally, the health center has prepared the essential equipment for collecting and monitoring *Aedes* larvae, including a dipper, dropper, bottle with lid, lactophenol solution, transfer container to the laboratory, boots, work clothes, and an entomological tool bag for each PoE. The equipment was provided based on the specifications in the national guidelines. The thermal fogger machine and other required vector control materials and equipment for emergencies were checked to ensure they worked properly. The staff has also been trained in how to use these tools. However, approved insecticides for vector control are currently unavailable. However, national guidelines for the use of insecticides for larval habitats are referenced to be available in case of emergency.

Table 1. Specifications of the international borders surveyed in this investigation in West Azerbaijan Province, Iran, 2019–2023

No	Name of border terminal	Terminal type	Area type	Address	Geographical coordinates and altitude (m) above sea level
1	Shahid Bakeri International Airport	Air	Village	Urmia	45.03 ºE 37.39 ºN 1318
2	Sero	Land	Village	Urmia	44.37 ºE 37.43 ºN 1578
3	Tamarchin	Land	Village	Piranshahr	45.04 ºE 36.39 ºN 1808
4	Bazargan	Land	City	Maku	44.22 ºE 39.24 ºN 1571
5	Poldasht	Land	City	Poldasht	45.04 ºE 39.21 ºN 1581
6	Razi	Land	Village	Khoy	44.18 ºE 38.29 ºN 2055
7	Razi	Railroad	Village	Khoy	44.20 ºE 38.29 ºN 2055
8	Urmia customs warehouses	Land	City	Urmia	45.07 ºE 37.34 ºN 1332

Table 2. Assessment checklist for entomological surveillance and human resources in this study, West Azerbaijan Province, Iran, 2019–2023 (PoE: points of entry)

No.	Key Indicators	Questions	Yes	No
1	Entomological Surveillance	Is there an entomological (*Aedes*) surveillance and reporting policy?		
2	Inter-sectoral collaboration	Is there a unit to provide technical support for the surveillance at the PoE?		
3	Community Mobilization	Are there other partners rather than health workers, involved in entomological surveillance?		
4	Intra-sectoral collaboration	Are the roles and responsibilities of staff clearly defined,		

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Table 2. Continued ...

		including skill and experience requirements?
5	Inter-sectoral collaboration	Is there a space allocated for the health staff at PoE?
6	Human Resources	Is the number of personnel involved in the entomological surveillance sufficient, considering the size of the point of entry, and the number of daily passengers?
7	Human Resources	Is there any entomologist at each PoE?
8	Human Resources	Is there any health staff at each PoE?
9	Human Resources	Are there any transportation facilities available for staff to do entomological surveillance?
10	Human Resources	Is there a system for training new personnel?
11	Human Resources	Have the personnel received the necessary training in the workplace?
12	Human Resources	Is this training reflected in their job descriptions?
13	Human Resources	Does staff have the appropriate skills to perform all the duties required for their tasks?
14	Materials and Equipment	Are there any necessary tools to inspect/surveillance invasive *Aedes* eggs (for example, a sufficient number of ovitrap, filter paper, yeast, and transfer containers)?
15	Entomological Surveillance	Is ovitrapping performed according to national guidelines every 15 days during the mosquito activity season within a radius of 500 meters from the PoE?
16	Materials and Equipment	Is there necessary standard equipment to inspect/surveillance invasive *Aedes* larvae (for example, standard dipper, dropper, bottle with lid, funnel, mesh, lactophenol solution, transfer container to the laboratory, boots, work clothes, entomological tool bag, etc.?
17	Entomological Surveillance	Is the larval survey performed according to the national guidelines every 15 days during the mosquito activity season?
18	Inter-sectoral and Cross-border cooperation	After finding the new larval habitat, is there an immediate intervention to manage the habitat?
19	Community Mobilization	Is entomology surveillance performed in all areas of PoEs (including indoor and outdoor)?
20	Materials and Equipment	Are there a functioning insectary and an entomological laboratory available for such surveillance?
21	Materials and Equipment	Are all the materials for such an insectary and laboratory available?
22	Materials and Equipment	Does the insectary observe any biosafety standards?
23	Materials and Equipment	Is the annual budget allocated for entomological surveillance?
24	Intra-sectoral collaboration	Is there collaboration within the health sector (for example, medical entomology and vector control, health education and promotion, environmental health, disease prevention and control)?
25	Inter-sectoral collaboration	Is there any collaboration with other sectors?
26	Cross-border cooperation	Is there any cross-border collaboration with neighboring countries?
27	Community Mobilization	Do the health professionals provide the basic prevention and control methods for the community?
28	Non-governmental organizations	Are there other partners involved in the surveillance system, for example, nongovernmental organizations or volunteer groups?
29	Materials and Equipment	Are there required materials and tools available in case of emergencies (for example, pesticides and equipment)?

Table 3. Number and type of entomological surveillance in this study, West Azerbaijan Province, Iran, 2019–2023

PoE/ key indicators	Entomological monitoring and reporting			Rearing the eggs			Larvae collection results			Larval source reduction		
	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification
Shahid Bakri International Airport	60	60	adequate	32	32	adequate	0	0	adequate	0	0	adequate
Sero	60	60	adequate	60	60	adequate	0	0	adequate	1	0	inadequate
Tamarchin	60	60	adequate	25	25	adequate	99	99	adequate	0	0	adequate
Bazargan	60	60	adequate	309	309	adequate	175	175	adequate	1	1	adequate
Poldasht	60	60	adequate	399	399	adequate	153	153	adequate	1	1	adequate
Razi (Land)	60	60	adequate	100	100	adequate	0	0	adequate	0	0	adequate
Razi (Railroad)	60	60	adequate	26	26	adequate	79	79	adequate	1	0	inadequate

Table 4. Key elements of human resources at points of entry in this study in West Azerbaijan Province, Iran, 2019–2023

PoE/ key indicators	Skill and experience			Entomologist worker			Environmental health worker			Entomological skills		
	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification
Shahid Bakri International Airport	100	99	adequate	1	1	adequate	1	1	adequate	100	100	adequate
Sero	100	100	adequate	1	0	inadequate	1	1	adequate	100	100	adequate
Tamarchin	100	97	somewhat sufficient, partly adequate	1	0	inadequate	1	1	adequate	100	99	adequate
Bazargan	100	100	adequate	2	0	inadequate	1	1	adequate	100	100	adequate
Poldasht	100	99	adequate	1	0	inadequate	1	1	adequate	100	100	adequate
Razi (Land)	100	99	adequate	1	0	inadequate	1	1	adequate	100	100	adequate
Razi (Railroad)	100	99	adequate	1	0	inadequate	1	1	adequate	100	100	adequate

Table 5. Community mobilization performance studied in this investigation, West Azerbaijan Province, Iran, 2019–2023

PoE/ key indicators	Intra-sectoral collaboration			Inter-sectoral collaboration			Cross-border cooperation			NGO		
	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification
Shahid Bakri International Airport	100	100	adequate	6	6	adequate	0	0	_	100	0	inadequate
Sero	100	94	somewhat sufficient, partly adequate	4	4	adequate	1	1	adequate	100	0	inadequate
Tamarchin	100	100	adequate	3	3	adequate	0	0	_	100	0	inadequate
Bazargan	100	98	adequate	5	5	adequate	0	0	_	100	0	inadequate
Poldasht	100	99	adequate	4	4	adequate	0	0	_	100	0	inadequate
Razi (Land)	100	98	adequate	3	3	adequate	0	0	_	100	0	inadequate
Razi (Railroad)	100	99	adequate	6	6	adequate	0	0	_	100	0	inadequate

Table 6. Vector control program materials and equipment surveyed in this study, West Azerbaijan Province, Iran, 2019–2023

PoE/ key indicators	Workspace in Border Health Center			Medical Entomology Laboratory			Essential materials, tools, and equipment for Aedes egg collection			*Aedes* larvae collection			Vector control materials and equipment		
	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification	Expected	Done	Qualification
Shahid Bakri International Airport	1	1	adequate	0	0	_	100	100	adequate	100	100	adequate	100	50	inadequate
Sero	1	1	adequate	1	1	adequate	100	100	adequate	100	100	adequate	100	50	inadequate
Tamarchin	1	1	adequate	1	0	inadequate	100	100	adequate	100	100	adequate	100	40	inadequate
Bazargan	1	1	adequate	1	0	inadequate	100	100	adequate	100	100	adequate	100	60	inadequate
Poldasht	1	1	adequate	1	0	inadequate	100	100	adequate	100	100	adequate	100	60	inadequate
Razi (Land)	1	1	adequate	1	0	inadequate	100	100	adequate	100	100	adequate	100	50	inadequate
Razi (Railroad)	1	1	adequate	0	0	_	100	100	adequate	100	100	adequate	100	40	inadequate

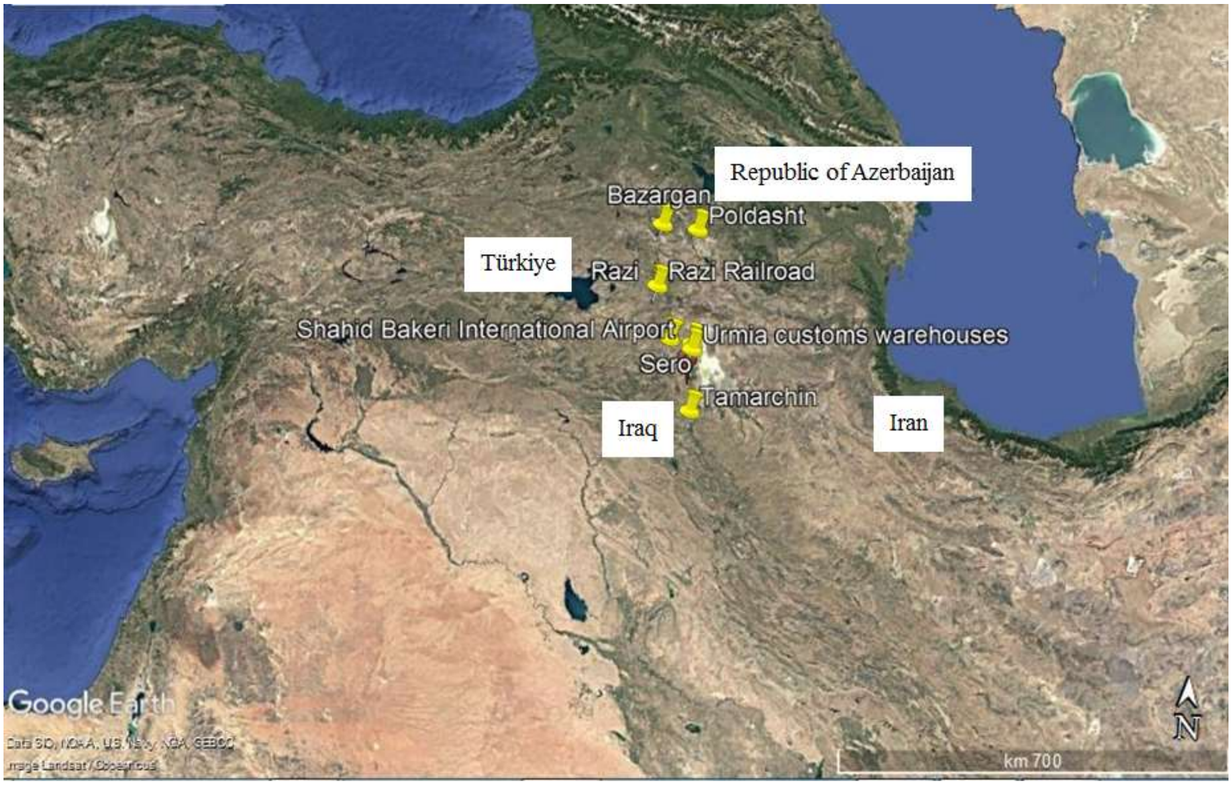

Fig. 1. Map of study locations (international entry points of West Azerbaijan province) from Google Earth

Discussion

The Global Vector Control Response 2017–2030 (GVCR) by the World Health Organization is a critical initiative to combat vector-borne diseases (VBDs) and significantly reduce their devastating impact on global mortality and morbidity. Around 80% of the global population is at risk of these diseases, and over 700,000 people die from them each year (30). Factors such as global warming, rapid urbanization, and increased international trade and travel have contributed to the spread of invasive *Aedes* vectors, particularly *Ae. aegypti* and *Ae. albopictus*. These vectors have recently been introduced and established in various provinces of the country, posing a risk of further spread in the country. One of the key aspects of GVCR is the enhancement of surveillance and vector control efforts, as well as the assessment of interventions (31). Effective entomological surveillance is crucial for the early detection and prevention of *Ae. aegypti* and *Ae. albopictus* in high-risk provinces within the country. It is important to establish entomological surveillance at PoEs such as ports, airports, and ground crossings between countries. In addition, promoting collaboration across different sectors in line with the One Health concept, and setting up a medical entomology laboratory and insectary in high-risk areas are essential considerations. This surveillance can be utilized for operational and research purposes to detect new introductions early, identify changes in the geographical distribution of existing species, monitor and evaluate control programs, obtain relative measurements of the vector population over time, and enable appropriate and timely decision-making regarding interventions (32). Another important pillar of GVCR is the expansion of vector control methods and the incorporation of tools into their management

(33). The larvae were collected from various habitats and identified during this study. Egg sampling was conducted using ovitraps, which are simple and cost-effective tools that have proven to be effective in various studies (34, 35). Larvae and eggs were collected using a current set of tools across the entire country. During this study, no eggs of *Ae. aegypti* or *Ae. albopictus* were found in the ovitraps. However, the presence of eggs from other species (*Ae. caspius*) in the ovitraps indicates that the ovitraps were functioning effectively. Khoshdel-Nezamiha et al. (36) reported the capture of adult *Ae. caspius* from this area in 2013. The eggs of *Ae. caspius* were trapped for the first time using ovitraps in this study. The COVID-19 pandemic has impacted the maintenance of many surveillance and control programs (37), depleting funds and affecting the completion and equipping of insectary and entomological laboratories. It is important to consider that neglecting this issue may result in the failure of this program.

The third pillar (GVCR) involves strengthening collaboration across different sectors and taking cooperative actions (31). Strategies such as intra-sectoral, inter-sectoral, and international cooperation are essential. Sharing best practices and minimizing duplicated efforts will enhance the collective strength of partners and harmonize efforts, ultimately improving the effectiveness and efficiency of disease prevention and control measures (38). This study recognized valuable cooperation, especially in the ongoing efforts to enhance the environment.

To ensure the successful performance of employees, health authorities and managers need to focus on the skills and experience of their staff. Studies have shown that skills and experience have a positive and direct impact on employee performance (39). Holding various training courses can help staff acquire the necessary knowledge and apply it effectively. The source reduction for *Aedes* mosquitoes was done in areas such as Sero, Bazargan, Tamarchin, Urmia Airport, and Poldasht, and it is hoped that these efforts will continue to be implemented. At the Razi border, some locations are suitable for *Aedes* mosquitoes and require more interventions. It is suggested that reducing the sources of larval habitats for *Aedes* mosquitoes is a preventive and vector control measure, rather than using insecticides. The most common side effects of excessive insecticide use are resistance to synthetic insecticides and environmental pollution (40). Several studies have been conducted to develop botanical insecticides and use nanotechnology to prevent environmental pollution and overcome vector resistance (41–47). However, until these plant products are produced on a large scale, environmental management should remain a priority. Imported tires from endemic countries have led to the transfer of invasive *Aedes* eggs to other countries (48). This potential risk has been observed in the customs warehouses and tire storage facilities in West Azerbaijan Province.

Non-governmental organizations can help ensure the proper implementation of the program (49). They can assist in collecting discarded materials (such as tires, food, and drink containers), cleaning drains, removing abandoned vehicles and roadside garbage, and training people to empty and clean water storage containers at weekly intervals. Public participation and community mobilization are the fourth and final pillars of GVCR (31). It is recommended to harness the potential of these individuals in West Azerbaijan Province. One important role of health workers is to teach and encourage individuals to enhance their knowledge of preventing and controlling vector-borne diseases. Distribution of educational materials in the local language can spark the interest of local people and encourage a positive attitude towards improving the program. Similarly, these educational materials covering the subject can be distributed among tourists and travelers. Various studies have found that the distribution of educational materials, in addition to face-to-face training, has been evaluated as useful (50). The results of this study evaluate the current situation of the study area regarding vector control and vector-borne diseases (VBD) and can guide local policies and strategies based on the identified gaps to achieve the goals.

Conclusion

The checklist, designed according to the WHO's recommendations, effectively identified the strengths and weaknesses of the *Aedes* surveillance program. The findings from this study will enable health officials to pinpoint and address the program's weaknesses. It appears that conducting similar research in all provinces of the country could greatly benefit health authorities in making informed decisions to enhance the national program and guidelines.

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Ethical considerations

The study was approved by the Ethical Committee of the National Institute for Medical Research Development (NIMAD), Tehran, Iran, and ethics no. IR.NIMAD.REC.1400.027.

Conflict of Interest

There is no conflict of interest for the authors.

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