Vectors and vector-borne diseases in Qatar: current status, key challenges and future prospects

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RESEARCH ARTICLE

Abstract

Vector-borne diseases (VBDs) have re-emerged worldwide due to urbanisation, increase in travel and climate change, becoming a major and serious threat to global public health. In Qatar, the concern has recently risen because of the attribution of the soccer 2022 FIFA World Cup Qatar™, which necessitates fulfilling requirements in terms of prevention and preparedness for disease transmission, including VBDs. This review presents a general overview about current status of vectors and VBDs in Qatar and addresses key challenges and future prospects of control programmes and strategies. It is based on a vector control situation analysis and needs assessment performed during an expert mission in Qatar, November 2017, organised by the WHO Eastern Mediterranean Regional Office and achieved in collaboration with the Ministry of Public Health of Qatar and other local stakeholders. The situation of vectors and VBDs of public health importance in Qatar was analysed based on a systematic literature review by December 31, 2019. The literature reveals that no locally transmitted VBD cases have been recorded in Qatar, but cases were recorded among expatriate workers and travellers who returned from an endemic country. However, data on VBD cases remain scarce except for malaria. The presence of native arthropod vectors is under-recorded to date. A compilation of literature data revealed reports of 30 vector species, including 20 mosquitoes, 2 fleas, 1 louse, 1 fly, and 6 ticks. Overall, Qatar benefits currently from a good surveillance of some VBDs (malaria) and has some capacities in vector control, but no national plan exists, and vector surveillance is in its infancy. In Qatar, clear needs exist in capacity in epidemiology and vector entomology, as well as on the organisational level, and a number of measures are suggested to mitigate and improve VBD risk assessment and management. There is an urgent need to define sustainable solutions for VBD control, management and prevention, and a number of recommendations are suggested.

Keywords: vector-borne diseases, mosquitoes, ticks, sand flies, flies, lice, Qatar

1. Introduction

In recent years, the importance of vector-borne diseases (VBDs) has increased at global and regional levels (Valenzuela and Aksoy, 2018). Many of these vectors are bloodsucking arthropods that include in particular mosquitoes, sand flies, and ticks. Human population growth,

intensive human and wildlife movement, urbanisation and environmental change including climate change have a significant impact on pathogen transmission (Weaver, 2013). While there is a known increase of incidence of some VBDs such as dengue in the Eastern Mediterranean region (Humphrey *et al.*, 2016), little information is available for the State of Qatar. However in Qatar, structural changes exist

that appear to be risk factors to facilitate VBD local upsurge and pathogen transmission. First, a rapid increase of Qatari population in general is observed due to the arrival of a high number of migrants (mainly from India, Nepal and Sudan) that represent more than 75% of the population ($\times 3.8$ over 15 years)¹. There is also a considerable influx of tourists ($\times 7.5$ over 14 years)¹. Mobility of human populations is known as a source of outbreaks and/or disease persistence (Eder *et al.*, 2018) and migrants and tourists originating from VBD endemic countries may possibly introduce pathogens into Qatar. Second, there is a high proportion and increase of urban population (more than 99%; $\times 4.7$ over 15 years)¹. The urban context has demonstrated to increase the chances of VBD transmission, in particular for those amplified by humans (rather than other non-human hosts) (Eder *et al.*, 2018). Finally, Qatar faces a booming of freight air transport ($\times 24.6$ over 14 years) as well as a huge increase of port traffic (+29% over 14 years) and globally of merchandise import ($\times 10.6$ over 14 years)¹. Here the associated risk is the increase of introduction of vectors, pathogen-infected or not (Tatem *et al.*, 2006).

In VBD non-endemic countries like the State of Qatar, the first step in prevention and control of vector-borne pathogen transmission requires the identification of potential vectors and of the human and animal populations at-risk. Adequate risk assessment, early detection, prevention and control of endemic and emerging VBDs demand approaches other than or in addition to those developed for non-VBDs (Braks *et al.*, 2011). Initial assessment of VBD risk can be estimated from the current presence or absence of the vector at a given location. Unfortunately, the surveillance and control programmes of vectors, in particular those of public health concern, have not been established in Qatar to date. The recent concern has arisen because of the Qatar National Vision 2030, which aims to ‘transform Qatar into an advanced society capable of achieving sustainable development’, and the willingness to fulfil its four pillars, in particular the one on environmental development (GSPD, 2008). Here the impact of climate and environmental changes, in particular urbanisation, requires assessment and mitigation of negative impacts, including of VBDs. In addition, hosting of the 2022 FIFA World Cup Qatar™ necessitates fulfilling a number of requirements for prevention and preparedness for disease transmission, including VBDs. In light of these requirements this review aims to present an overview of the present status of vectors and VBDs in Qatar, and to identify key challenges and future prospects. The work is based on a vector control situation analysis and needs assessment, performed during and following an expert mission in Qatar, November 2017,

organised by the WHO Eastern Mediterranean Regional Office and achieved in collaboration with the Ministry of Public Health of Qatar and other local stakeholders.

2. Materials and methods

Qatar (latitude 24-26°N, longitude 50-51°E) is located on the north-eastern coast of the Arabian Peninsula, Middle East, and is itself a small peninsula that juts in the Persian Gulf. Qatar sizes approximately 11,600 km² and is populated by around 2,750,000 of which a large part of migrants that varies from year to year (75.5% in 2015)¹. The country is divided into eight municipalities. Qatar’s climate is classified as hot desert (Köppen-Geiger category BWh) with annual mean temperature of 27.1 °C and mean rainfall of 72 mm (October-May)². The whole population has access to water supply and sanitation. Water (desalinated) of grade 1 is supplied in the residential areas, whereas water of grade 2 (treated grey water) is supplied for animal farms, agriculture, and gardening (Jasim *et al.*, 2016).

The situation of vectors and VBDs of public health importance in Qatar was analysed based on a systematic literature review with sources up to December 31, 2019 accessed. References were identified through searches on OvidSP (Ovid MEDLINE®, which includes PubMed, 1946 to present), CAB direct (full applied life science database), and Web of Science, any language, any year, by use of the following search string: [(vector* OR mosquito* OR culicid* OR phlebotom* OR tick*).af AND Qatar.ti]. Additional references were identified using reference tracking and grey literature (Figure 1 summarises the PRISMA search flow). A portion of the references obtained were excluded if duplicated or when the content was not relevant to our study and a final list of 29 papers was fully assessed. A limited number of published papers containing precise information

² <https://en.climate-data.org/asia/qatar-183>.

Figure 1. Flow chart of the literature search on vectors and vector-borne diseases in Qatar.

¹ <http://www.indexmundi.com/facts/qatar>.

on vectors or on VBDs in Qatar were found (13 and 6, respectively). However, it is possible that the references on VBDs were underestimated, because the search string focused primarily on vectors (VBDs names were not included, to avoid collecting clinical case descriptions).

3. Results

Importance of vector-borne diseases in Qatar

The literature reveals that no VBD locally transmitted cases have been recorded in Qatar, but cases were recorded among expatriate workers and travellers who returned from an endemic country. The most important VBDs such as malaria, dengue, leishmaniasis are notifiable in Qatar and investigation on case travel history is performed. However, with the exception of malaria, data on VBD cases remain scarce. No active case detection or special surveys among at-risk population have been done in Qatar. Table 1 lists all VBD pathogens that have been observed or are suspected to occur in the State of Qatar.

While there are no reports of locally acquired cases of VBDs in Qatar in the last two decades, numbers of imported VBD cases have been registered, most of them for malaria parasite infection (Figure 2 and 3). As for mosquito-borne arboviruses, a few dengue, chikungunya, and Zika imported cases were reported in 2016 (Figure 3). More human cutaneous leishmaniasis cases exist, with 4 to 11 per year during the period 2000-2011, but evidence of local transmission exist only for infection of local dogs and cats, with 4 out of 199 animals (2.0%) recently found positive for *Leishmania* spp. (Lima *et al.*, 2019).

Malaria

Qatar has been free from local malaria transmission for almost 50 years, with the last local case reported in 1970 (WHO, 2014b). However, influx of migrant workers from malaria-endemic countries in particular during the last two decades, led to a high number of imported cases, representing a major threat for re-introduction of local transmission (Figure 2) (Al-Kuwari, 2009; Farag *et al.*, 2018;

Table 1. List of vector-borne disease pathogens of public health and animal health importance occurring or at risk for Qatar.

Vector-borne disease pathogens		References
Flea-borne	<i>Rickettsia typhi</i> (murine typhus)	AFPMB, 1999
Mosquito-borne	Chikungunya virus	AFPMB, 1999; Haroun <i>et al.</i> , 2017; Khan <i>et al.</i> , 2009
	Dengue virus	
	<i>Plasmodium falciparum</i> and <i>Plasmodium vivax</i>	
	Sindbis virus	
	West Nile virus	
	Zika virus	
Sand fly-borne	<i>Leishmania infantum</i> (visceral leishmaniasis)	AFPMB, 1999; Lima <i>et al.</i> , 2019
	<i>Leishmania major</i> (cutaneous leishmaniasis)	
	<i>Phlebotomus</i> (sand fly fever)	
Tick-borne	<i>Coxiella burnetii</i> (Q fever)	AFPMB, 1999
	Crimean-Congo haemorrhagic fever (CCHF) virus	
Tick-borne pathogens from domestic animals		
In domestic dogs	<i>Anaplasma platys</i>	Alho <i>et al.</i> , 2017; Barradas <i>et al.</i> , 2020; Lima <i>et al.</i> , 2019
	<i>Babesia vogeli</i>	
	<i>Babesia gibsoni</i>	
	<i>Ehrlichia canis</i>	
	<i>Hepatozoon canis</i>	
	<i>Leishmania</i> spp.	
	<i>Mycoplasma</i> spp.	
In domestic cats	<i>Babesia felis</i>	
	<i>Babesia vogeli</i>	
	<i>Ehrlichia canis</i>	
	<i>Leishmania</i> spp.	
	<i>Mycoplasma haemofelis</i>	
	<i>Candidatus Mycoplasma haemominutum</i>	
In ticks infesting tortoises	<i>Rickettsia africae</i>	
	<i>Rickettsia aeschlimannii</i>

Figure 2. Annual numbers of reported (imported) human malaria cases in Qatar, 2000-2019 (based on data from MoPH of Qatar and WHO EMRO).

Figure 3. Number of vector-borne disease cases for pathogens reported to occur or have occurred in Qatar, 2016 (based on data from MoPH of Qatar; ? = not or poorly reported).

Khan *et al.*, 2009). Specifically, *Plasmodium vivax* is the main etiologic agent and most cases occur between August and October, resulting from the importation of infections during summer vacation (Bansal *et al.*, 2017). Furthermore, the presence of malaria vectors e.g. *Anopheles (Cellia) stephensi* Liston, 1901 in Qatar (Kardousha, 2016; Mikhail *et al.*, 2009), emphasises the receptivity for having local malaria transmission (Khan *et al.*, 2009). This situation is similar to that in other countries of the Arabian Peninsula (Simon *et al.*, 2017).

Dengue and chikungunya

The viruses responsible for these two infections are primarily transmitted by *Aedes (Stegomyia) aegypti* (L., 1762) which is reported to occur in Qatar (AFPMB, 1999). Dengue has become endemic in the Eastern Mediterranean region (WHO, 2014a). A recent systematic review of the epidemiology of dengue in the Middle East and neighbouring countries showed a majority of cases being detected along the coastlines of countries bordering the Red and Arabian Seas, and in Pakistan (Humphrey *et al.*, 2016). No data are published for Qatar but a total of 163 dengue cases was reported during 2012-2019 by the Hamad Medical Corporation, Doha, Qatar (unpublished data) and all these cases were imported. Chikungunya infection shows similar clinical presentation to non-severe dengue, which makes its epidemiology uncertain (Kuno, 2015). Recently, many urban outbreaks have occurred in the Indian Ocean region and Latin America (WHO, 2014a), with the largest outbreak in the WHO Eastern Mediterranean Region in Yemen (Malik *et al.*, 2014). However, the current and historical epidemiology of chikungunya in the Arabian Peninsula remains poorly characterised.

Yellow fever

Yellow fever virus is transmitted mainly by *Aedes* mosquitoes (*Ae. aegypti* in the rural/urban cycle) and is endemic to tropical areas of Africa and Latin America, with around 200,000 cases every year (WHO, 2014a). The number of yellow fever cases has increased globally over the past two decades and epidemics occurred in Sudan in recent years (Buliva *et al.*, 2017), but no cases were reported in Qatar during that period.

West Nile (WN) infection and Rift Valley fever (RVF)

These two mosquito-borne zoonotic viral diseases occur in both temperate and tropical regions. West Nile virus is transmitted by various mosquitoes according to the

geographical area, but primarily *Culex* species such as *Culex (Culex) quinquefasciatus* Say, 1823 and *Culex (Culex) tritaeniorhynchus* Giles, 1901 (Eyboosh *et al.*, 2019; Paramasivan *et al.*, 2003). The primary vectors for RVF virus are floodwater *Aedes* species but other species (*Anopheles*, *Culex*) can contribute to transmission during an outbreak (Linthicum *et al.*, 2016). To date, no human cases of WN and RVF have been reported in Qatar. However, recently high seroconversions to WN virus were observed among horses in Qatar, suggesting a possibility that the virus might be endemic in the country and has a potential to pose risk to human health (DeCarlo *et al.*, 2017; Haroun *et al.*, 2017). The fact that Qatar is a peninsula serving as a bridge and land to several migratory avian species, and that there is an increasing activity of importing wild birds in the country calls for attention to WN epidemiology in the state (QBRC, 2016). It can be advised, from veterinary health standpoint, that all horses that visit Qatar for e.g. equestrian festivals should be vaccinated to prevent disease burden in horses.

Tick-borne diseases

For all other VBDs that might be likely to occur in Qatar, there is a clear absence of information. Tick-borne pathogens circulate in Qatar (Table 1), with reports of ten different pathogens of veterinary importance in domestic dogs and cats (Alho *et al.*, 2017). Circulation of other pathogens of animal health and public health importance like Crimean-Congo haemorrhagic fever virus has been reported in the Arabian Peninsula (Wernery, 2014), but no information on tick-borne pathogen presence in humans is available from Qatar to date (Al-Abri *et al.*, 2017).

Knowledge of vectors in Qatar

The review found reports of 29 species of native or introduced arthropods, from families that comprise species recognised to transmit pathogen to human or animal, to occur in Qatar (Table 2). They include 20 mosquito, 2 flea, 1 fly, and 6 tick species (Figure 4). One louse species, *Pediculus humanus capitis* De Geer, 1767, can be added to the list even without reference, since schools do occasionally notify infestations to the Ministry of Public Health (MoPH), and lice eradication campaigns are promoted (<https://www.gulf-times.com/story/367307/Parents-told-to-check-children-s-hair-for-lice>). No sand flies are reported and all other groups except mosquitoes are known by little number of species (1 to 6) only. Most of these species (26 out of 30; 87%) are proven or suspected to transmit at least one pathogen. Only one paper each is reporting fleas and biting flies, while four papers are reporting tick species, and 9 papers are reporting mosquito species occurrences.

4. Discussion

Needs for further investigations on vector occurrence in Qatar

By January 2020, thirty arthropod vector species are reported to occur in Qatar. Although no sand flies are described from Qatar, they certainly occur considering reports of locally acquired *Leishmania* infections (Lima *et al.*, 2019) and reported presence of many species in neighbouring countries with similar environmental conditions (e.g. 22 and 4 species in Saudi Arabia and United Arab Emirates, respectively) (AFPMB, 1999). Similarly for the latter reason, fleas and ticks are most probably more numerous (25 and 41 species, respectively, reported from Saudi Arabia (AFPMB, 1999)). Among these ticks, two species, *Hyalomma aegyptium* (L., 1758) and *Hyalomma rufipes* Koch, 1844 are considered not native from Qatar (Wassef *et al.*, 1997; Barradas *et al.*, 2020). Since they are introduced in the country with their hosts (mammals, birds or reptiles), more studies are needed to collect evidence of their establishment and to determine the species' status in Qatar.

Mosquitoes have been better studied but 7 among the 20 species are reported in single publications, sometimes beyond their previously known natural distribution range (i.e. not known to occur in the Arabic Peninsula, like *Aedes (Ochlerotatus) dorsalis* (Meigen, 1830) which is a cold-climate species), and thus their presence requires confirmation (Table 2). Also two reported taxa, *Culiseta* sp. and *Coquilleltidia* sp., remain to be identified to the species level. And here again, in view of the presence of many other species in neighbouring countries (36 species in Saudi Arabia (AFPMB, 1999)), additional species might occur in Qatar. Only one invasive mosquito species, *Ae. aegypti*, is recorded so far to have established (AFPMB, 1999). However, the Asian tiger mosquito *Aedes (Stegomyia) albopictus* (Skuse, 1895) is another invasive species that is spreading worldwide and already found in Middle East (Iran, Gulf of Oman coast; Doosti *et al.*, 2016). Because of intense international trade (cf. Introduction) and countries' climatic suitability for occurrence (Ducheyne *et al.*, 2018), the species could be introduced and then establish and thus its possible presence should be surveyed. In summary, the presence in Qatar of arthropod vector species looks under-recorded to date and field studies are crucially needed to complete the knowledge of species presence/absence, distribution and abundance as a base for VBD risk assessment (Braks *et al.*, 2011; Sedda *et al.*, 2014; WHO, 2014a).

To date, many of the reported species can be considered as potential vectors, since their confirmed or putative role in transmission of pathogens is well described in the literature (Table 2). The two flea species *Ctenocephalides felis felis*

Table 2. Arthropod vector families and their species reported to occur in Qatar.

Species	Status	First report	Host preference ¹	Larval habitat	Potential vector role ²	References for Qatar
Mosquitoes (Diptera: Culicidae) (n=20 spp.)						
<i>Aedes aegypti</i>	Introduced (during 18 th or 19 th Century)	1999	Human	Container inhabiting	Chikungunya, dengue, and Zika viruses; <i>Dirofilaria immitis</i> filarial worm	AFPMB, 1999
<i>Ae. caspius</i>	Native	2009	Mammals (birds)	Brackish water flooded areas	Rift Valley fever virus	Kardousha, 2015, 2016; Mikhail <i>et al.</i> , 2009
<i>Ae. dorsalis</i>	Presence to be confirmed ³	2015	Mammals (birds)	Brackish water flooded areas	(West Nile virus)	Kardousha, 2016
<i>Anopheles culicifacies</i> s.l.	Native	1999	Human (mammals, birds)	Various standing water bodies, containers	Human malaria	AFPMB, 1999
<i>An. multicolor</i>	Native	1992	Mammals	Fresh and brackish waters	(Human malaria?)	Glick, 1992; Kardousha, 2016; Mikhail <i>et al.</i> , 2009
<i>An. sergentii</i>	Native	1992	Mammals	Fresh waters	(Human malaria)	Glick, 1992
<i>An. stephensi</i>	Native	1999	Mammals, birds	Containers, fresh ground waters	Human malaria	AFPMB, 1999; Kardousha, 2015, 2016; Mikhail <i>et al.</i> , 2009; Rabab, 2015
<i>Culex bitaeniorhynchus</i>	Presence to be confirmed ³	2015	Birds (human)	Fresh ground pools	Filariasis, sindbis virus	Rabab, 2015
<i>Cx. latincinctus</i>	Native	2015	Zoophilic	Containers, fresh ground waters	–	Kardousha, 2015
<i>Cx. mimeticus</i>	Presence to be confirmed ³	2015	Zoophilic (human)	Streams and river bed pools	–	Rabab, 2015
<i>Cx. pipiens</i> s.l. ⁴	Native	1985	Human	Containers and ground waters	West Nile and sindbis viruses, filarial worms	Abdu and Shaumar, 1985; Kardousha, 2015, 2016; Mikhail <i>et al.</i> , 2009
<i>Cx. perexiguus</i>	Presence to be confirmed ³	2015	Birds (mammals)	Containers and ground waters	West Nile and sindbis viruses	Kardousha, 2015
<i>Cx. quinquefasciatus</i>	Native	1988	Human	Containers and ground waters	West Nile virus, filarial worms	AFPMB, 1999; Harbach, 1988; Kardousha, 2015, 2016; Mikhail <i>et al.</i> , 2007, 2009
<i>Cx. sitiens</i>	Native	2015	Birds, pigs (human)	Brackish ground waters, containers	(Japanese encephalitis virus?, filarial worms?)	Kardousha, 2015
<i>Cx. tritaeniorhynchus</i>	Native	2015	Mammals (human)	Various fresh ground waters	Japanese encephalitis, Rift Valley, sindbis and West Nile viruses	Kardousha, 2015, 2016
<i>Cx. univittatus</i>	Native	2009	Birds (mammals)	Fresh waters	West Nile and sindbis viruses	Kardousha, 2015; Mikhail <i>et al.</i> , 2009
<i>Cx. pusillus</i>	Native	2009	Zoophilic	Brackish ground waters	–	Kardousha, 2015; Mikhail <i>et al.</i> , 2009
<i>Cx. vagans</i>	Presence to be confirmed ³	2015	Mammals, human	Containers and ground water	Filarial worms	Rabab, 2015
<i>Cullseta</i> sp.	Presence to be confirmed ³	1985	Birds?, mammals?	Containers	Avian malaria ⁵	Abdu and Shaumar, 1985
<i>Coquillettidia</i> sp.	Presence to be confirmed ³	2015	Mammals?	Permanent fresh water bodies	(West Nile and sindbis viruses)	Rabab, 2015
Sand flies (Diptera: Psychodidae: Phlebotominae)						
No data	Most probably present	–	Birds, mammals, reptiles	Ground with decaying debris	<i>Leishmania</i> spp., phleboviruses	AFPMB, 1999; Cuomo, 2004
Fleas (Siphonaptera)						
<i>Ctenocephalides felis felis</i>	Cosmopolitan	1999	Cat	Host	<i>Rickettsia</i> spp., <i>Bartonella</i> spp.	AFPMB, 1999
<i>Xenopsylla cheopis</i>	Cosmopolitan	1999	Rat	Host	<i>Yersinia pestis</i>	AFPMB, 1999
Lice (Phthiraptera: Pediculidae)						
<i>Pediculus humanus capitis</i>	Cosmopolitan	?	Human	Host	–	6
Biting flies (Diptera: Muscidae)						
<i>Stomoxys calcitrans</i>	Cosmopolitan	1983	Livestock, human	Livestock dung	Mechanical transmission of bacteria and viruses	Abdu and Shaumar, 1985
Hard ticks (Acari: Ixodae)						
<i>Hyalomma aegyptium</i>	Introduced on tortoises	2018	Tortoises, (human)	Host	(<i>Borrelia</i>), (<i>Coxiella burnetii</i>), <i>Hemolivia mauritanica</i> ⁵ , <i>Hepatozoon kisiae</i> ⁵ , (<i>Rickettsia</i>)	Barradas <i>et al.</i> , 2020; Estrada-Peña <i>et al.</i> , 2017
<i>H. anatolicum anatolicum</i>	Native	1997	Livestock, human	Host	<i>Babesia</i> spp., (CCHF virus), <i>Theileria</i> spp., (Thogoto virus)	Estrada-Peña <i>et al.</i> , 2017; Wassef <i>et al.</i> , 1997
<i>H. dromedarii</i>	Native	1997	Camels, cattle	Host	CCHF, Dera Ghasi Khan, Dhori, Kadam, and Sindbis viruses, <i>Coxiella burnetii</i> , <i>Rickettsia</i> spp., <i>Theileria</i> spp.	Estrada-Peña <i>et al.</i> , 2017; Hagras and Khalil, 1988; Wassef <i>et al.</i> , 1997
<i>H. impeltatum</i>	Native	1997	Camels, cattle, sheep	Host	(CCHF and Wallowrie viruses), <i>Rickettsia</i> spp., <i>Theileria</i> spp.	Estrada-Peña <i>et al.</i> , 2017; Wassef <i>et al.</i> , 1997
<i>H. marginatum turanicum</i>	Native	1997	Camels, cattle, sheep	Host	<i>Anaplasma</i> spp., <i>Babesia</i> spp., CCHF virus, <i>Coxiella burnetii</i> , <i>Rickettsia</i> spp., <i>Theileria</i> spp.	Estrada-Peña <i>et al.</i> , 2017; Wassef <i>et al.</i> , 1997
<i>H. rufipes</i>	Introduced?	1997	Birds, livestock	Host	<i>Anaplasma marginale</i> , <i>Babesia occultans</i> , CCHF virus, <i>Rickettsia conorii</i>	Estrada-Peña <i>et al.</i> , 2017; Wassef <i>et al.</i> , 1997

¹ Host given in brackets are bitten occasionally only.
² Only pathogens for which solid suspicion of vector role exists are listed (e.g. infections on the field only or in the lab only are not listed), and pathogens given in brackets are those for which the vector plays a secondary role only.
³ Single observation.
⁴ Includes form *pipiens* and form *molestus*.
⁵ Of veterinary concern only.
⁶ <https://www.gulf-times.com/story/367307/Parents-told-to-check-children-s-hair-for-lice>; '?' = significant suspicion, but not yet evidenced; CCHF = Crimea-Congo haemorrhagic fever.

Figure 4. Numbers of species among arthropod vector families reported to occur in Qatar. Dark grey = potential vector species; light grey = non-vector species; ? = not reported.

(Bouché, 1835) and *Xenopsylla cheopis* (Rothschild, 1903) can transmit pathogens to their animal host (cat and rat, respectively), and the rat flea is the main vector of plague (*Yersinia pestis*) (Bitam *et al.*, 2010). The head louse *P. humanus capitis* is not proven to act as vector (Badiaga and Brouqui, 2012), but the stable fly *Stomoxys calcitrans* (Linnaeus, 1758) can occasionally act as mechanical vector for bacteria and viruses (Baldacchino *et al.*, 2013). Among the reported six tick species (*Hyalomma* spp.), all except *H. aegyptium* are recognised vectors of Crimean-Congo haemorrhagic fever virus, and *H. aegyptium*, *Hyalomma anatolicum anatolicum* Koch, 1844, *Hyalomma marginatum turanicum* Pomerantzev, 1946 and *H. rufipes* can transmit additional pathogens (Barradas *et al.*, 2020; Paştıu *et al.*, 2012; Sajid *et al.*, 2018). Among the 20 reported mosquito species, 16 can be considered as potential vectors, with the most relevant being: *Aedes aegypti* as vector of chikungunya, dengue, and Zika viruses; *Anopheles (Cellia) culicifacies* Giles, 1901, *Anopheles (Cellia) sergentii* (Theobald, 1907) and *Anopheles stephensi* as vector of human malaria; *Aedes (Ochlerotatus) caspius* (Pallas, 1771) as vector of Rift Valley fever virus; *Culex (Culex) pipiens* L., 1758, *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus* and *Culex (Culex) univittatus* Theobald, 1901 as vectors of West Nile virus; *Culex (Culex) sitiens* Wiedemann, 1828 and *Cx. tritaeniorhynchus* as vectors of Japanese encephalitis virus (AFPMB, 1999; Becker *et al.*, 2010; Braack *et al.*, 2018).

Challenges in key prevention and control measures of vector-borne disease in Qatar

Recent years faced a rise in the number of imported malaria cases (Farag *et al.*, 2018) and introduction of at least one non-native *Hyalomma* tick species (Barradas *et al.*, 2020). Thus a programme for surveillance and control of VBD vectors should be urgently implemented. The data on VBD pathogen occurrence in Qatar are scarce

except for malaria. Hence, emphasis should be placed on dengue, chikungunya, Zika, Crimean-Congo haemorrhagic fever, and Rift Valley fever as well as on leishmaniasis. Serological investigations may be implemented within routine surveillance (all suspected cases) or occasional research studies on human (blind surveys) and imported animal hosts (systematic), in particular camels. As conferred above, the knowledge of vector fauna in Qatar is poor. No data are available for phlebotomine sand flies and data are limited for ticks and probably incomplete for mosquitoes. For the latter, also some species reports are incomplete (limited to genus identification) or doubtful and need to be further investigated. Priorities should target mosquito fauna, sand flies and ticks, for their presence, distribution, abundance (main vector mosquitoes), and frequency of introduction (ticks on animal hosts) in Qatar. In a first step, snapshot surveys may be implemented, targeting specific vector families at suitable environments and during the most favourable periods, using various sampling methods. In a second step, cross-sectional and longitudinal studies may be implemented at selected locations and using the most adapted sampling method according to the targeted vector species.

National coordination for VBD risk assessment and management is lacking. Overall, Qatar benefits currently from a good surveillance of some VBD (malaria) but the actual burden of VBDs could be higher than reported here, since there is under-reporting especially from the private facilities and from where many expatriates may seek health care. The state has some capacities in vector control, but no global plan exists, and vector surveillance is in its infancy. Vector control is currently implemented by municipalities to suppress mosquitoes, flies and cockroaches (e.g. applying *Bacillus thuringiensis israelensis* as mosquito larvicide and pyrethroids as insect adulticide) but accurate entomological diagnostic is not always supporting insecticide application. Susceptibility of vector populations to insecticides is occasionally assessed by the municipality pest control unit of Doha, and some differences in susceptibility to organophosphates and pyrethroids are found between *Cx. pipiens* complex populations (Mikhail *et al.*, 2007). This loss of susceptibility appeals for additional and regular assessment to early detect any further loss of mosquito populations' susceptibility and if so to manage insecticide resistance by adjusting treatment methods (IRAC, 2011), together with the promotion of best practices in public health pesticide management (WHO, 2010). The 2022 FIFA World Cup Qatar will occur during winter (November 21st – December 18th), which is the cooler but also the rain period. There are chances to get disturbance with mosquitoes and flies, especially house fly. The fly population is overabundant in the animal farm areas, probably due to poor farm management and improper cleaning and disinfection activity. It will be essential to control fly to avoid fly-borne diseases, such *Escherichia coli* enteritis

or salmonellosis. The major challenges to confront VBD in Qatar are:

- The absence of national strategy for VBD risk assessment and management. Risk plans or strategy definition are usually engaged subsequently to the occurrence of a local outbreak or obvious evidence of VBD threat; this is here not the case to date, but both Qatar National Vision 2030 and 2022 FIFA World Cup Qatar demand it.
- A limited knowledge on the local situation of vectors and vector-transmitted pathogens. This is highlighted above.
- The absence of integrated vector management (IVM) plan and guidelines. Vector management is very limited at this stage; IVM needs to be described for the local context, and to be supported by training and capacity building.
- Inadequate trained human resources for vector surveillance and control. As for IVM, training is crucial to locally build capacity, and competences must be sustained in time.
- Absence of functional intra- and inter-sectoral networking. Local municipalities pest control units do collaborate but more networking is necessary, including with research and health units, private pest control companies and points of entry management agencies (port and airport), to ensure efficient and rational response capacities.
- Absence of international networking. Not all competences are locally available but are accessible through international networking; such networking would also facilitate the information flow on changes in VBD picture.

To take up these major challenges, it appears essential to rapidly develop at central level (ministries) a global strategy for addressing VBDs and coordinating all efforts to be done within an inter-sectoral networking, to achieve a good capacity in VBD management. This needs to define a national plan and priorities, to allocate adequate and sustainable human and financial resources, to adapt policies, and to plan capacity building and collaborations.

A complete VBD risk assessment relies on: (1) a comprehensive picture of presence and abundance of vector species; (2) a comprehensive picture of pathogen circulation; and (3) an estimation of the vectorial capacity of the vector population for a defined pathogen. The latter point is also related to the presence and abundance of susceptible hosts (vector-host ratio and biting rate), and transmission will occur only under favourable environmental and weather conditions that have to be evaluated in regard to both pathogen and vectors. Ideally, competences to address all these factors have to be built locally to be able to rapidly assess a risk once an indicator suggests possible transmission emergence (e.g. a malaria imported case at a place where *Anopheles* mosquitoes are present and active). Research programmes may be designed to adequately support the risk

assessment. Then the risk could be managed by application of mitigation measures (e.g. focal mosquito treatments around the imported case). Additionally, according to the level of risk, vector entomology surveys are suggested to be implemented in Qatar.

5. Conclusions

National commitment is a cornerstone to ensure success and sustainability of any disease surveillance programme. Control of VBDs is the collective responsibility of many partners but not only the Ministry of Public Health. Also controlling of vectors by using larvicides and adulticides, which can have severe and adverse effects on public health and environment has to be properly considered in a sustainability perspective. To date, no approved vaccines are available for malaria, dengue, West Nile virus, but they exist for yellow fever and Japanese encephalitis. Thus complementary and alternative solutions to control, manage and prevent VBDs are needed, and a number of recommendations can be suggested (Box 1) to prevent VBD outbreaks during the 2022 FIFA World Cup Qatar.

Box 1. Recommendations for addressing vector-borne diseases (VBD) risk in Qatar.

A number of recommendations can be given in order to strengthen the integrated surveillance and control of vectors, and to ensure effective VBD outbreak preparedness and response, within a 'One Health' approach, by complying with WHO resolutions as addressed in the Global vector control response endorsed by all WHO Member States in 2017 (WHO, 2017) and in the International Health Regulation 2005 (WHO, 2008):

- Define a national integrated strategy for management of VBDs in Qatar, define an integrated plan for the main VBD at risk for the country, identify all contributors and their tasks, build a coordination unit, and allocate adequate financial resources.
- Build capacities in entomology, to increase knowledge of local vector ecology and competences for vector identification and vector surveillance.
- Build capacities in research infrastructure, including laboratory diagnostic, for both molecular detection of pathogens and identification of vectors.
- Develop coordination and enhance national and international collaborations to build intra- and inter-sectoral networking on vectors and pathogens they transmit.
- Build an integrated surveillance and control system of both vectors and pathogens, based on integrated vector management, with prioritised targets in term of vector species, pathogens, and high-risk areas.
- Develop a national public health pesticide management policy, to tackle weaknesses in pesticide use or management, and solve potential problems of impact on human health and non-target organisms.
- Plan an evaluation and quality check process, to adjust the surveillance system when/where needed.

or any other major local sport event. Qatar has achieved a high rank of developmental rates, and infrastructure construction is going very fast. Accordingly, the population is also increasing by unexpected rates due to the influx of foreign workers originating from various countries, which increases the risk of import of VBD pathogens. This was observed for malaria in 2008-2015 with 99.6% of the cases being reported in non-Qatari people (Frag *et al.*, 2018). Besides, a huge amount of treated wastewater is now produced. Only 40% of the effluent water is utilised for different purposes – mainly landscaping – but the majority is dumped out into the open areas around city premises. These wastewater wetlands may provide larval habitats for various mosquito species and therefore should be surveyed, together with the classical urban and suburban mosquito larval habitats. Finally, there is a regular import of animal hosts (e.g. camels) possibly carrying ectoparasites such as ticks, and a surveillance of these hosts and ticks should be implemented in order to detect introduced pathogens of public health importance.

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Conflict of interest

The authors declare no competing interests.

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