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Climate change and epidemiology of human parasitoses in Saudi Arabia: A review

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ABSTRACT

Climate change is an emerging global problem. It has hazardous effects that vary across different geographic regions and populations. It is anticipated to have significant effects in Saudi Arabia. The present work reviews the future of human parasitoses in Saudi Arabia in response to the expected climate change. The key projections are increased precipitations, flash floods, unstable temperatures, sea-level rise and shoreline retreat. Such environmental changes could strongly influence the epidemiology of fly-borne, mosquito-borne, snail-borne and water-borne human parasitoses in the country.

1. Introduction

Climate change is one of the most serious and rapidly emerging global issues. Such change and its sequels are strongly affected by human activities and not by natural fluctuations[1]. Human activities that depend on fossil fuels as a source of energy result in the production of greenhouse gases like CO_2. Such gases cause temperature-increment in the troposphere. Recent global warming is unusual in the view of the time scale accompanied with natural climate oscillations. Many reports showed the sensitivity of water resources to climate change. The variations in temperature, evaporation, precipitation, the recharge to aquifers and the general hydrologic cycle are all interacting[2]. Climate change is anticipated to have significant consequences on ecosystems and socioeconomic systems[3,4]. Saudi Arabia, like many countries in the world, suffers from severe climate change that will mainly influence peoples' behaviour, health and agriculture. Studies on correlations between climate change and public health in Saudi Arabia are still lacking. It is important to understand how the epidemiology of human parasites may respond to the climate change expected in the country in the next decades. Thus, it is timely and appropriate to make a brief revision on the predicted climate change and its consequences on the epidemiology of human parasitoses in Saudi Arabia.

2. Geography

The largest country on the Arabian Peninsula is Saudi Arabia. It has a total surface area of nearly 2.15 million km^2. It lies in the tropical and subtropical desert area in the intersection of Asia, Europe and Africa (latitude: 16.5° N–32.5° N; longitude: 33.75° E–56.25° E)[5,6]. The country has an arid climate with high temperatures. However, there are great variations in temperature between the different geographical areas and seasons[6]. The mean daily temperature varies from 15 °C in January to 33 °C in July[7]. The country experiences an extreme water scantiness. Rain is the only renewable water source. It comes in a sudden short period with high-intensity storms and is mostly dissipated by evaporation[5,8]. Rainfall depths varies from 0–300 mm/year in the Eastern Desert and the South-Western areas, respectively[7]. The country is characterised by tremendous groundwater reserves which are continuously under increasing demand[9].

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2. Climate change

Recently, some areas of Saudi Arabia were exposed to snowing, heavy rains, flash floods, and unstable temperatures which may be due to climate change[10-14]. During the period 1982–2005, flooding was the most frequent hazard affecting the country with an average annual return period of 7 times and an average annual economic cost of 19 million USD[11]. Climate change significantly affected the global precipitation patterns. Saudi Arabia is anticipated to receive more rainfall and flash flood than before[15]. Flash floods during the period 2000–2010 have caused significant loss of life and property in the lowland areas of Saudi Arabia. Intense rainfall caused flooding of settlements in a number of basins, particularly the Jeddah, Riyadh, Makkah, Tabuk and other areas of the kingdom[16]. On the 25th of November 2009, the city of Jeddah was flooded after more than 90 mm of rain falling within a period of 4 h. The local civil defence authorities described it as the most destructive rainfall during the past 27 years. Unfortunately, more than 100 deaths and about 350 missing persons were reported. The business harms were estimated to about 1 billion Saudi Arabian Riyal[12]. A similar event of more than 110 mm rain falling within a short duration flooded Jeddah again on the 26th of January 2011. There was an enormous loss of property and only a few human deaths[12]. In Saudi Arabia, a general warming was recorded all over the country during the period 1991–2003. It was in the range of 0.15 ˚C to 0.75 ˚C, with an average of 0.40 ˚C[17]. Temperature, precipitation, wind speed, evaporation and runoff were investigated to assess the effect of climate change on water resources in the country. It was found that under A2 scenario, the period from 2071 to 2100 will generally experience warmer weather. The eastern region is expected to register the maximum increase in temperature (4.5 ˚C) and the southern region is anticipated to register the minimum increase of daily temperature (3.9 ˚C). Almost all regions are anticipated to show a significant increase in average daily rainfall (30% or more). The central region is expected to show the maximum increase of average daily precipitation (46%). In contrast, only the northern region is expected to show a 4% decrease in average daily precipitation. There is no expected significant change in the surface wind speeds over most of the country. The eastern and northern regions are anticipated to show a little decrease in the speed of winds. The Empty Quarter is projected to record the maximum increase in wind speeds (8%). The average daily evaporation is unexpected to greatly increase. An increase of 3% or less is anticipated over the eastern, central, western and northern regions. The Empty Quarter is expected to record an increase of 11% and the southern region is expected to show the maximum increase (15%). Runoff is expected to show the greatest change in all other studied parameters. The western region is expected to have a 353% increase of average daily runoff and each of the remaining regions is expected to have more than a 100% increase. This high increase may warn for flash flood events[18]. Climate change is anticipated to stimulate sea level rise and associated coastal flooding that may affect low-lying coastal areas of Saudi Arabia[19]. The most vulnerable coastal areas are the eastern coast of the country along the Gulf especially Khafji, Jubail, Ras Tanura and Dammam. In addition, Jeddah, Rabigh, Yanbu and Jizan have been reported as the most vulnerable western coastal areas along the Red Sea. The main effects will follow at least one of the following mechanisms: inundation along the shoreline, flood risks, direct exposure to the coastal environment and saltwater intrusion and seepage[10,20].

3. Impacts of climate change on human parasitoses in Saudi Arabia

Climate change could strongly affect human parasitic infections transmitted through cold-blooded (ectothermic) animals (insects and snails) in Saudi Arabia (Figure 1). Such intermediate hosts are sensitive to slight temperature, precipitation and humidity changes. Daylight duration, sea level elevation and the wind are also important[21,22]. In addition, many other interacting factors may affect the epidemiology of human parasitoses such as the migration of human and animal populations, the deterioration of public health infrastructure, changes in land-use and the appearance of drug resistance[23].

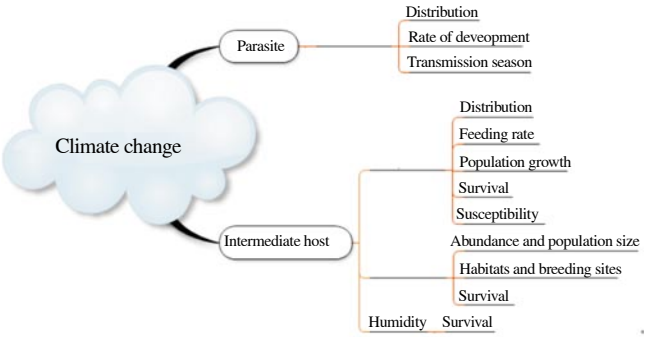

Figure 1. Main impacts of climate change on parasitic infections transmitted to human through insect and snail hosts.

5. Fly-borne diseases

Climate has powerful impacts on natural populations of the different species of flies. Global warming is anticipated to affect survival, generation time, fecundity and dispersal of flies[24].

6. Leishmaniasis

It is a zoonotic disease caused by protozoan parasites of the genus *Leishmania*. Leishmaniasis is endemic in a total of 88 countries distributed throughout Africa, Asia, Europe and the Americas. Leishmaniasis manifests mainly in three forms: cutaneous, mucocutaneous and visceral (kala-azar)[25-27]. There are about 700 species of sandflies of which about 70 are considered to transmit human diseases[28]. *Leishmania* is transmitted by over 30 species of sandflies. Rodents, dogs, wild cats, jackals, foxes, sloths, hyraxes, and other carnivores are the main animal reservoirs in nature. Sandflies of the genus *Phlebotomus* are widespread in North Africa, the Arabian Peninsula, Turkey and Iran[29].

Cutaneous and visceral leishmaniasis are known to be endemic in Saudi Arabia: cutaneous leishmaniasis is the dominant form of the disease and visceral leishmaniasis is less common. Most cases of cutaneous leishmaniasis are infected with *Leishmania major*. In addition, *Leishmania tropica* (*L. tropica*) has been found to be less frequently associated with this form of the disease[30,31]. *Leishmania major* causes zoonotic cutaneous leishmaniasis which is transmitted to human from infected rodents (*Psammomys obesus* and *Meriones libycus*), while *L. tropica* causes anthroponotic cutaneous disease[32]. *L. tropica* typically causes skin lesions without dissemination. Additionally, *L. tropica* may cause mucosal infection (mucocutaneous form)[33]. Also, some cases of viscerotropic infections (visceral form) due to *L. tropica* were reported in some veterans of Operation Desert Storm[34-37]. Field studies revealed the presence of 25 species of sandflies in Saudi Arabia[38,39]. In all the

studied areas, *Phlebotomus papatasi* was the dominant species[40]. Generally, zoonotic cutaneous leishmaniasis is more common in Riyadh and Eastern Province where it is transmitted by the sandfly *Phlebotomus papatasi*, while anthroponotic cutaneous leishmaniasis is more common in the southern region and is transmitted by *Phlebotomus sergenti*[40-42]. Species of the *Leishmania donovani* (*L. donovani*) complex, *L. donovani* and *Leishmania infantum* (synonym *Leishmania chagasi*) are the typical causes of visceral leishmaniasis. In Saudi Arabia, both species are present. The black rat, *Rattus rattus*, is a reservoir host of *L. donovani* which is the main cause of visceral leishmaniasis in the country[43-46]. Dogs have been found infected with *Leishmania infantum* which occasionally infects human in Saudi Arabia[44,45,47]. The disease has been reported on several occasions and the first case was in 1955 at Dhahran Hospital ARAMCO in the Eastern Province[48]. Human infections are sporadic and mostly found in the southwest of the country[43-46,49-52]. Both *Phlebotomus alexandri* and *Phlebotomus orientalis* are incriminated in the transmission of visceral leishmaniasis in the southwest of the country[47].

Concerning the number of cases reported yearly in Saudi Arabia, a total of 5 687 cases of cutaneous leishmaniasis were recorded in 1999. Since then, there was a general decrease in the number of cases with 2 549 cases being reported in 2009. The same condition was observed in visceral leishmaniasis as 63 cases were reported in 1999 *vs*. 17 cases in 2009[53].

Global warming affects indirectly the distribution of leishmaniasis through its effects on the range of the intermediate and reservoir hosts[54]. For example, leishmaniasis is endemic in Mexico and Texas. Recently, the disease has begun to expand its range into northward. Moreover, it is expected that climate warming may increase the risk of human exposure to the infection in areas outside its present range in the United States and probably Canada[55]. The same scenario is expected for the expansion of visceral leishmaniasis from its foci in southern areas of Saudi Arabia.

7. Onchocerciasis

This is an eye and skin disease caused by a filarial worm known as *Onchocerca volvulus*. The infection is transmitted to humans through the bite of an infected blackfly that belongs to the genus *Simulium*. Blackflies are found in areas of dense vegetation and forests. Their eggs are deposited on vegetation or near fast-flowing rivers and streams, thus the disease is commonly known as river blindness. Inside the human body, the adult female worm produces thousands of larvae (microfilariae) that wander through the skin and the eye where it can survive for 2–3 years. However, dead and dying microfilariae are very toxic to the skin and the eye. It causes severe itching and various eye manifestations. After repeated exposure, these lesions may lead to irreversible blindness and skin disease sometimes named leopard or lizard skin. The geographical distribution of the disease is linked to the habitat of its vector in the inter-tropical zones. It is estimated that about 90% of the infected cases occur in Africa. In addition, onchocerciasis was reported from six countries in Latin America and in Yemen[56,57].

In 2003, three human cases of *Onchocerca volvulus* were reported from Assir in Saudi Arabia[58]. In 2008, a human infection of a Kuwaiti woman with *Onchocerca* sp. was reported. The infection was suspected to be contracted in Saudi Arabia. About 3 months earlier, the patient had visited Najran (a Saudi city) on the border with Yemen, where she had stayed for about 2 months[59]. The recent appearance of the parasite in Saudi Arabia could be explained by the climate change which resulted in the northern expansion of the blackfly from Yemen. The northern expansion of insects as a response to global warming is a well-documented phenomenon[60,61].

8. Mechanically transmitted parasitic infections

The housefly, *Musca domestica*, is a cosmopolitan insect which occurs on all inhabited continents of the world. It is common in different climate zones from tropical to temperate and in both rural and urban environments. However, it is more adapted to warm regions of the world. The housefly is usually associated with faeces. Also, it has adapted well to feeding on garbage. Thus, it is generally found in association with humans[62,63]. The housefly is an efficient mechanical carrier of pathogens including many human parasites. Protozoan cysts and helminth eggs can be mechanically carried on wings, legs and body hairs of the fly and transmitted to human mostly through food and drinks[64]. Climate change is anticipated to have serious effects on houseflies worldwide. Climate change models have predicted that housefly population could increase substantially, up to 244% by 2080. In view of the predicted increase in numbers of houseflies, their role as mechanical carriers of parasites and other pathogenic organisms is likely to take on more significance[65].

9. Mosquito-borne diseases

The most often climate change factors noted for their influence on mosquitoes are rainfall, temperature and humidity. Also, other factors such as atmospheric particle pollution and wind may have an impact. Changes in such variables can alter the bionomics of mosquitos and therefore the rates of transmission of diseases caused by mosquitoes[66-68]. In Saudi Arabia, the known mosquito-borne parasitic diseases are filariasis and malaria[69-71].

10. Lymphatic filariasis

Lymphatic (bancroftian) filariasis or elephantiasis affects over 120 million people in 73 countries around the world. Endemic foci of the disease are present mainly in Egypt, sub-Saharan Africa, Southern Asia, the Western Pacific Islands, the north-eastern coast of Brazil, Guyana, Haiti and the Dominican Republic. Most cases experience asymptomatic infection and many infections go unrecognized. The nematode parasite *Wuchereria bancrofti* is incriminated in causing the disease in 90% of the cases. In addition, a related species, *Brugia malayi*, is incriminated in causing the disease in most of the remainder of the cases. *Brugia timori* was also reported to cause lymphatic filariasis[72]. The parasite is transmitted by some species of mosquitoes belonging to the genera *Anopheles, Culex, Aedes, Mansonia, Coquillettidia* and *Ochlerotatus*[73]. However, *Culex* mosquitoes, mainly *Culex pipiens* and *Culex quinquefasciatus*, are the main vectors of the parasite in many countries of the world including the Eastern Mediterranean countries[74]. Lymphatic filariasis has been reported from the southwestern region of Saudi Arabia where foreign labour constitutes the majority of cases[75-77]. In 2002, three autochthonous Saudi cases of lymphatic filariasis were reported in Riyadh[78]. *Culex pipiens* is a potential vector of introduced lymphatic filariasis in the country[75]. Climate change greatly influence transmission of the disease, as the increase of temperature and rainfall play an important role in propagating the vectors[79]. In Africa, a broad geographic distribution of

lymphatic filariasis, extending from the west to the east across the middle region of the continent, is predicted in responses to climate change[80].

11. Zoonotic filariasis

Dirofilaria repens is a filarial nematode parasite which infects dogs and other carnivores. Different species of the genera *Aedes* and *Culex* are the main vectors of zoonotic filariasis (dirofilariasis). Humans are considered as aberrant hosts, where the worms fail to reach maturity in the human body. The immature worms die in subcutaneous sites and provokes immune reactions in the surrounding host tissues. This filarial nematode is usually found in the Mediterranean basin, sub-Saharan Africa and Southern Asia[81,82]. Nowadays, there is a strong evidence that *Dirofilaria* infections are spreading among animal populations in Europe, most probably due to climate change especially global warming[83-86]. The parasite was reported in three dogs from Western Saudi Arabia[87]. A 60-year-old male infected with *Dirofilaria repens* was reported from Al-Hassa region in Saudi Arabia's Eastern Province[88].

12. Malaria

Malaria is the most important vector-borne parasitic infection in the world. It is one of the biggest contributors to the global burden of diseases in terms of suffering and death. Malaria is caused by some species of the genus *Plasmodium* which are transmitted to humans through the bites of mosquitoes of the genus *Anopheles*. Worldwide, four species belonging to the genus *Plasmodium* are highly pathogenic to humans [*Plasmodium falciparum* (*P. falciparum)*, *Plasmodium malariae*, *Plasmodium vivax* and *Plasmodium ovale*]. In tropical areas, *P. falciparum* is the most common and the most pathogenic species in the genus[89,90].

In Saudi Arabia, cases of malaria are reported from the north and west of the country. The disease is especially endemic in the lowlands of Assir region in the southwest of the country. The existence of malaria is maintained there by continuous importation from Yemen[70,91-96]. In addition, there was a high risk of introducing malaria to non-endemic areas of the country by expatriates, or pilgrims at Hajj and Umrah[97,98]. *P. falciparum* is the predominant species, accounting for more than 90% of cases in the country, and 35% of cases in the northwestern region. *Plasmodium vivax* is a predominant species in the northwest, accounting for more than 50% of the cases there. *Plasmodium malariae* is a rare species, accounting for 1%–2% of cases in the country. Most infections occur mainly between October and April and synchronize with the rainy season. During summer, there is a decrease in the incidence of the disease. Breeding of the anopheline vector usually occurs in permanent springs in the central and eastern regions and streams that traverse the coastal mountainous range along the Red Sea[99].

Saudi Arabia can be divided into four geographical categories based on malaria endemicity. First, non-malarious areas in the central part of the country where low density of *Anopheles sergenti* (*A. sergenti*) is present and only imported cases are reported occasionally. Second, areas of malaria transmission has been ceased by effective control measures. They are located in the eastern and northern parts of the country. In such areas, *Anopheles superpictus* and *Anopheles stephensi* are present. Third, areas with low malaria incidence rates (1–3/1000/year), these areas include foci in remote areas in the western parts of the country where *Anopheles superpictus* and *A. sergenti* are present and they also include some foci in the southern parts of the country where *Anopheles arabiensis* (*Anopheles gambiae* sensu lato or complex) is present. Finally, areas with medium or high malaria incidence rates (> 3/1 000/year)include Tihama foothills and lowlands and the coastal plain along the Red Sea in the southern and southwestern parts of the country down to the border with Yemen. In such foci, *A. arabiensis* and *A. sergenti* are present[99,100].

Concerning the number of cases reported yearly in Saudi Arabia, in 1998, an outbreak of autochthonous malaria cases occurred, and the total number of confirmed cases reached 36 139. This outbreak increased the incidence rate of the disease in the country to 1.87/1 000 compared to 0.92/1 000 in the previous year. This outbreak provoked a national control campaign which resulted in a general decline in autochthonous cases. In 2010, autochthonous cases of malaria were reported in Assir (incidence rate of 0.001/1 000) and Jazan (incidence rate of 0.013/1 000). In 2011, two deaths due to autochthonous malaria transmission were recorded[101]. Currently, malaria incidence is very low. However, imported cases will continue as a potential for autochthonous transmission[102].

The expected climate change in Saudi Arabia may dramatically affect the epidemiology of malaria in the country. It was observed that in the southwestern part of the country, disease transmission occurs throughout the year. However, transmission peaks are usually associated with the rainy season and hot summers[103]. In Yemen, strong associations were recorded between the incidence of malaria and favourable climate factors like rainfall volume, relative humidity, temperature and wind speed[104]. In Egypt, climate factors such as temperature and relative humidity were found associated with elongation of the transmission season to 8 months in Fayoum Governorate[105,106]. In Europe, climatic factors are projected to favour autochthonous transmission of malaria[107,108]. However, other factors like socioeconomic standard, land use, building regulations, treatment, *etc*. may counteract the likelihood of climate-related re-emergence of the disease there[109].

13. Snail-borne parasitic infections

The development of the parasites and their snail intermediate hosts are dependent on temperature. However, other environmental factors like precipitation and potential evapotranspiration may contribute to the delimitation of their spatial distribution[110]. Climate change in Saudi Arabia may seriously affect snail-borne parasitic infections, especially dicrocoeliasis, fascioliasis and schistosomiasis. Precipitation may have a special importance because it will offer new habitats for freshwater and land snails in the arid country.

14. Dicrocoeliasis

Dicrocoelium dendriticum (*D. dendriticum*) is a parasite of herbivores, such as sheep, goat and cattle in many countries of the world including Saudi Arabia. The parasite has a complex life cycle that involves two intermediate hosts (the first is a land snail and the second is an ant)[111]. Worldwide, about 100 land snail species have been quoted as natural and experimental intermediate hosts of *D. dendriticum* by different authors. Likewise, at least 21 species of ants, mainly of the genus *Formica* (family Formicidae), have been reported susceptible to *D. dendriticum* in different countries[112]. The parasite is prevalent in pastures with woody vegetation[113]. Thus, the predicted climate change in Saudi Arabia may positively

support the development and transmission of the parasite. Human dicrocoeliasis is generally rare due to the highly specific nature of this parasite's life cycle[114]. Sporadic cases of human dicrocoeliasis were reported in Saudi Arabia[111,115-120]. However, in most of the cases, the infection is spurious, *i.e.* the presence of the parasite eggs in human faeces is due to the ingestion of liver of infected animals. For example, in a study in Saudi Arabia, eggs of the parasite were detected in 208 patients, but only seven of them were confirmed as having a genuine infection[115]. In a different study, also in Saudi Arabia, genuine dicrocoeliasis was confirmed only in 32 out of 1 196 patients by re-examination after being kept on a liver-free diet for 3 days[117].

15. Fascioliasis

Infection with *Fasciola* spp. is an important parasitic disease affecting livestock in Saudi Arabia. *Fasciola hepatica* and *Fasciola gigantica* are present in the country[121]. These digeneans are transmitted by lymnaeid snails. *Radix natalensis* (synonym *Lymnaea arabica*) and *Stagnicola palustris* (synonym *Lymnaea palustris*) were reported from the country[122]. The total infection rate among local breeds of ruminants was as much as 21.9% in Riyadh abattoir[123]. Probably *Fasciola hepatica* is the species incriminated in the human disease as it is the species more adapted to human infection[124]. Sporadic cases of human fascioliasis were detected in the country especially among expatriate workers from endemic areas[120,121,125,126]. It is anticipated that climate change including the warming trend will, directly and indirectly, enhance the transmission of fascioliasis in different countries of the world[110].

16. Schistosomiasis

Two species of schistosomes, *Schistosoma mansoni* (*S. mansoni*) and *Schistosoma haematobium* (*S. haematobium*), are endemic in Saudi Arabia. They are transmitted by certain species of freshwater snails[127-130]. There are four species of freshwater snails which can transmit human schistosomes in Saudi Arabia. *Biomphalaria pfeifferi* which is the only snail host of *S. mansoni* in the country. *Bulinus beccarii*, *Bulinus truncates* and *Bulinus wright* are the snail hosts of *S. haematobium* in endemic Saudi foci[131]. Infection with *Schistosoma japonicum* was diagnosed in some non-Saudi residents, but the schistosome did not complete its life cycle in the country because of the absence of a suitable snail host[132]. Autochthonous human cases of schistosomiasis have been detected in all provinces except the Eastern Province, Qassim and Empty Quarter Provinces[129,131]. Human infections of *S. mansoni* were found mainly in the highlands of the western areas and some parts of the central and northern regions. Cases infected with *S. haematobium* were diagnosed mainly in Tihama Assir and the lowland coastal plain in the southern areas[131,133]. In 2005, an ambitious national programme for the eradication of schistosomiasis in Saudi Arabia was initiated in all the known disease foci. In 2007, the areas of Madinah, Riyadh, Hail, Tabuk, Jouf, and Najran were reported as disease-free areas[134]. Since 2010, heterochthonous cases progressively outnumbered the autochthonous ones. Recent reports indicated that regions of Saudi Arabia can be classified into three categories: disease-free, transmission interrupted and low transmission (general prevalence < 1%)[135].

The epidemiology of schistosomiasis worldwide is affected by many environmental factors[136]. It is predicted that climate change will enhance the transmission of schistosomiasis in the endemic foci[110,137-139].

17. Water-borne parasitic infections

Human exposure to water-borne parasitoses occurs through drinking water, recreational water or food. Water contamination may result from either human actions or natural events. Rainfall can influence the propagation of the infective stage of this group of parasites while temperature affects their growth and survival in the external environment. Outbreaks of water-borne parasitoses often occur after severe precipitation events. Heavy precipitation and its subsequent runoff have been assumed to be a major factor in the transmission of water-borne parasitic infections[140]. Many parasites can be transmitted via contaminated water, but only *Cryptosporidium, Cyclospora, Giardia* and *Toxoplasma* are difficult to be destroyed in drinking water by conventional disinfection methods[141-144]. Rainfall and runoff have been incriminated in many outbreaks of water-borne parasitoses in the UK and the US[145-150].

Because climate change is anticipated to enhance the severity and frequency of some major precipitation events in Saudi Arabia, the country could be faced with the elevated burden of water-borne diseases. Unfortunately, cryptosporidiasis, cyclosporiasis, giardiasis and toxoplasmosis are not uncommon in Saudi Arabia and the water-borne transmission of these diseases through drinking water is possible[119,151-156].

18. Conclusion

The Kingdom of Saudi Arabia is mostly a desert nation. Climate change is anticipated to have significant impacts on the country. The key projections are increased precipitations, flash floods, unstable temperatures, sea-level rise and shoreline retreat. Such environmental changes could strongly affect human parasitic infections transmitted through insects and snails. The fly-borne diseases in Saudi Arabia are leishmaniasis and onchocerciasis, and mechanically transmitted by parasitic infections. The mosquito-borne parasitic diseases are filariasis (either lymphatic or zoonotic) and malaria. The snail-borne parasitic infections are dicrocoeliasis, fascioliasis and schistosomiasis. In addition, flaring-up of the water-borne transmission of cryptosporidiasis, cyclosporiasis, giardiasis, and toxoplasmosis in drinking water is possible as a result of increased rainfall and runoff.

Conflict of interest statement

We declare that we have no conflict of interest.

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