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Impacts of flood on health of Iranian population: Infectious diseases with an emphasis on parasitic infections

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A B S T R A C T

Background: Outbreaks of infectious diseases are the major concern after flooding. Flood makes people displacement which would be more complicated with inadequate sanitation. Settling in crowded shelters in absence of clean water and inaccessibility to health care services makes people more vulnerable to get infection. This review aimed to discuss about potential undesirable outcomes of flooding occurred in 2019 in Iran.

Methods: A comprehensive search was carried out in databases including PubMed, Google scholar, Scopus, Science Direct, Iran medex, Magiran and SID (Scientific information database) from 2000 to 2019. All original descriptive articles on flood were concerned. Related articles on flood disturbance were considered. Also, publication of red cross society was considered as only reliable reference in evaluation of consequences of flood occurred in 2019 in Iran.

Results: Flooding in Iran, was started in March 2019 and lasted to April 2019. Flood affected 31 provinces and 140 rivers burst their banks, and southwestern Iran being hit most severely. According the reports of international federation of red cross society, 3800 cities and villages were affected by the floods with 65,000 destroyed houses and 114,000 houses partially damaged. Also 70 hospitals or health care centers with 1200 schools were damaged along with many infrastructures including 159 main roads and 700 bridges.

Conclusions: Considering 365,000 displaced persons and estimation of mentioned damages, it was one of the greatest natural disaster during the last 20 years. Various risk factors in favor of infectious diseases such as overcrowding, disruption of sewage disposal, poor standards of hygiene, poor nutrition, negligible sanitation and human contact among refugees provide suitable conditions for increased incidence of infectious diseases after flooding and also cause epidemics.

More attention is needed to provide hygienic situation for people after natural disasters including flood.

Contents

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1. Introduction

Natural disasters often cause disorders in the ecosystem and pose multiple dangers to human and animal health. Floods are the most common and widespread geo environmental disasters all around the world, which mostly occur in Asia (Okaka and Odhiambo, 2018; Paterson et al., 2018; Bich et al., 2011; Cousins, 2017). Floods with several reasons lead to mortality and morbidity (Brown and Murray, 2013; Alderman et al., 2012).

Flooding, as one of the major environmental challenge, has been caused by many factors. Heavy rains, river and coastal floods, and human interferences (e.g. deforestation, urbanization, poor urban drainage) are examples of flooding causes (Okaka and Odhiambo, 2018). In the twenty-first century, flood hazard due to climate change and global warming has attracted significant concern and international attention (Okaka and Odhiambo, 2018; Paterson et al., 2018; Lin et al., 2015). In 19th March 2019, the heavy raining was started in Iran and lasted to April 2019, which resulted in flooding in 31 provinces. The flood initially started in northeast Iran including the cities of Gorgan, Bandar Turkman, Azad Shahr, Aq Ghala, Gonbad-e Kavus, bandar-e Gaz, Ali Abad, Kalaleh, Kordkuy, and Minodaasht (www.ifrc.org). UN Office for the Coordination of Humanitarian Affairs reported that about 140 rivers inundated and the provinces of Golestan, Ilam, Lorestan and Khuzestan (all southwestern Iran) were damaged most severely. On 26 April a flood gate was broken and city of Aqqala (Golestan province) was inundated and about 700 families were left their homes. The vast destruction affected 10 million people (about one in eight citizens of Iran), leaving 2 million in need of humanitarian assistance (including 500,000 women in reproductive age, thereof about 7100 pregnant). It is reported that 78 persons lost their lives and 1137 persons were injured. According the reports of international federation of red cross and red crescent societies, 3800 cities and villages were affected by the floods, 65,000 houses were destroyed and 114,000 houses were partially damaged. Also, 70 hospitals or health care centers and 1200 schools were damaged. The flood damaged many infrastructures including 159 main roads and 700 bridges. About 365,000 people were temporarily displaced, staying in emergency/temporary shelters or with relatives. Considering the damages, it was one of the greatest natural disaster during the last 20 years.

Agricultural areas were heavily damaged, 1 million hectares of farmland were flooded, with crops ahead of harvest and livestock were lost.

After stabilization of weather conditions waters in the Northeast of the country have widely receded, while the vast regions of country in south-west in Khuzestan province (delta-region for some of Iran's main rivers) remained flooded with heavy agricultural damages. During the flood in Iran, water and sewage infrastructures were damaged extensively and although clean water was prepared by the Ministry of Energy and Water with water tanks and water containers, but it was not easily accessible in some isolated regions (www.ifrc.org). Major flood related consequences which can affect the population health including drowning, injuries, poisoning, animal attacks, poor mental health issues, chronic diseases, contagious diseases and infections are the main public concerns (Okaka and Odhiambo, 2018; Paterson et al., 2018; Alderman et al., 2012).

Various risk factors in favor of infectious diseases such as overcrowding, disruption of sewage disposal, poor standards of hygiene, poor nutrition, negligible sanitation and human contact among refugees provide suitable conditions for increasing the incidence of such diseases after flooding and can cause epidemics (Okaka and Odhiambo, 2018; Huang et al., 2016). Furthermore, floods may lead to severe changes in the equilibrium of the environment and provides an ideal breeding ground for pathogens, vectors and zoonotic reservoirs (Okaka and Odhiambo, 2018; Brown and Murray, 2013). As a result, flooding phenomenon facilitates the transmission of the subsequent infectious diseases including water-borne, vector-borne and rodent-borne diseases, likewise cutaneous and respiratory infections (Okaka and Odhiambo, 2018; Paterson et al., 2018; Brown and Murray, 2013). Moreover, in areas where many infectious diseases are endemic or there have been some reports of occurrence, an association between the displacement of people and dramatic increase of human exposure to vectors and pathogens is expected (Paterson et al., 2018; Brown and Murray, 2013; Lin et al., 2015). In addition, flooding affects the availability and access to the crucial health services and may be lead to a wider spread of infectious disease (Okaka and Odhiambo, 2018; Brown and Murray, 2013). Although, no long-term impact of the 1934 floods in Tabriz had been observed (Melville, 1983), from mid-March to April 2019, Iran experienced unprecedented floods (www.nbcnews.com).

Some of the past significant floods in different parts of the world such as India, Nepal, Kenya, China, Bangladesh, Italy, Taiwan, Vietnam, Canada, England, United States, Germany, Indonesia, The Philippines, Australia, Austria, Mexico, France, Czech Republic, Pakistan and other communities had caused considerable economic and human lives losses (Okaka and Odhiambo, 2018; Paterson et al., 2018; Bich et al., 2011; Brown and Murray, 2013; Huang et al., 2016; Ni et al., 2014; Ahmed et al., 2011). Flooding can pose a range of devastating impacts in both industrialized and developing countries (Paterson et al., 2018; Huang et al., 2016). There are several literatures that have indicated the incidence of human illness following the floods (Lin et al., 2015; Huang et al., 2016; Ivers and Ryan, 2006). (Tables 1,2). In this paper, we focus solely on some of infectious disease expected in regard to recent flooding in Iran.

2. Methods

A comprehensive search was carried out in databases including PubMed, Google scholar, Scopus, Science Direct, Iran medex, Magiran and SID (Scientific information database) from 2000 to 2019 with both English and Persian languages. All original descriptive articles on flood were concerned. A combination of Iran or Iranian with terms like: flooding, flood, infectious, helminth, respiratory, vector-born, leishmania, plasmodium or the name of diseases caused by parasites (e.g. leishamnisis, malaria) or a more general terms linked to flooding (e.g. natural disaster, post flooding, helminthic infection) was searched.

Related articles on flood disturbance were considered. Also, publication of red cross society was considered as only reliable reference in evaluation of consequences of flood occurred in 2019 in Iran. Our focus was on the infectious diseases as a consequence of flooding and also, we decided to emphasize the outcomes of flood in Iran in 2019 which was notably destructive during the last 20 years in Iran. We considered to write a review about infectious diseases after flooding and recommended more attentions to parasitic diseases after natural disasters including the flood.

3. Infections

Flood-associated wet lands and humidity, as well as extreme ambient temperatures fluctuations, provide opportunities for outbreaks of infectious disease (Paterson et al., 2018; Ni et al., 2014). Unavailability to clean water and food in displaced people, crowded shelters, unsanitary living conditions and frequency of arthropod vectors in temperate regions make the situation in favor of wide range of infectious diseases. Also dead bodies and animal corpse are one of the most important sources of infection after flooding (Okaka and Odhiambo, 2018; Paterson et al., 2018; Brown and Murray, 2013; Lin et al., 2015; Ivers and Ryan, 2006). Herein, we summarize some of them occur more frequently after prolonged flooding rains (Tables 1, 2).

3.1. Diarrhea and water-borne diseases

Diarrheal diseases are one of the most problematic after flooding, particularly in areas with the lack of hygienic facilities. Outbreaks of diarrheal diseases (e.g. cholera, nonspecific diarrhea, cryptosporidiosis, rotavirus, typhoid and paratyphoid) have been frequently reported in weeks or months after flooding (Okaka and Odhiambo, 2018; Paterson et al., 2018; Ni et al., 2014; Ghozy et al., n.d.). In studies carried out in (1998–2004) by Schwartz et al., the main cause of diarrhea was cholera in Daka, Bangladesh. Also, in other study in Indonesia in 1992–1993, the predominant cause of diarrheal disease was *Salmonella enterica* serotype *Paratyphi A* (paratyphoid fever). Gastroenteritis is the other complication post flooding and has been reported in Lewes, England in 2000 through a study carried out by Reacher et al. (Ni et al., 2014).

Disruption of sewage systems and contamination of drinking water may contribute in food- borne or water related infectious diseases (Badparva et al., 2017). Consuming of crops which were grown in soils that were contaminated with sewage during the flood is another potential source of gastrointestinal diseases. Crops can be contaminated with bacterial and parasitic agents during the grow. It is like that soils were fertilized by animal and human feces (Alderman et al., 2012). Poor sanitation facilities along with overcrowding can increase fecal-oral transmission of different pathogens (Paterson et al., 2018). Flood water scan transport microbial agents into the aquatic environment and clean water supplies, resulting to increased incidence of waterborne diseases and post flood epidemics. However, a considerable population displacement may lead to difficult access to clean water sources (Okaka and Odhiambo, 2018; Paterson et al., 2018). Contact with flood water is reported as an increased risk of gastrointestinal diseases during the 2002 floods in Germany (Alderman et al., 2012). The most common identified pathogen bacterial post flooding was *Vibrio cholerae* and enterotoxigenic *Escherichia coli* (Paterson et al., 2018; Ni et al., 2014). Also, the increased

Table 1
Health risks of flooding, stratified by time after event (Paterson et al., 2018).

Immediate	Early (<10 d after event)	Late (>10 d after event)
Drowning	Cutaneous infection	Leptospirosis
Trauma	Aspiration pneumonitis/pneumonia	Mosquito-borne illnesses
Hypothermia	Viral respiratory infections	Cutaneous infection from atypical organisms (fungi, mycobacteria)
Electrocution	Gastroenteritis	Hepatitis A or E virus infection
Carbon monoxide poisoning	Cutaneous infection	Mental health disorders, including posttraumatic stress disorder and depression
		Management of chronic disease
		Leptospirosis

Table 2
Summary of studies assessing infectious disease transmission following flood events (Brown and Murray, 2013).

Country	Studied year(s)	Infectious disease(s)
Australia	1998–2001, 2011	Leptospirosis, Ross River virus
Austria	2010	Leptospirosis
Bangladesh	1983–2007	Cholera, rotavirus, acute respiratory infection
Canada	1975–2001	Diarrhea
China	1979–2000	Schistosomiasis
Czech Republic	1997, 2002	Leptospirosis, Tahyna virus
England	2000	Diarrhea
France	2009	Leptospirosis
Germany	2005, 2007	Norovirus, leptospirosis
Guyana	2005	Leptospirosis
Italy	1993–2010	Hepatitis A, salmonellosis, diarrhea, leptospirosis, leishmaniasis, legionellosis
India	2001–2006	Leptospirosis
Indonesia	2001–2003	Paratyphoid fever
Mexico	2007, 2010	Leptospirosis, dengue fever
Pakistan	2010	Diarrhea, skin and soft tissue infection, conjunctivitis, respiratory tract infection, suspected malaria
the Philippines	2009	Leptospirosis
Sudan	2007	Rift Valley fever
Taiwan	1994–2009	Leptospirosis, melioidosis, enteroviruses, dengue fever, bacillary dysentery, Japanese encephalitis
Thailand	2012	Melioidosis
United States	2001, 2004	Diarrhea, leptospirosis
Vietnam	2008	Conjunctivitis, dermatitis
Australia	1998–2001, 2011	

numbers of dysentery cases due to shigellosis, salmonellosis giardiosis, cryptosporidiosis, infection with *Entaemoeba histolytica* and enteric fever cases have been reported in the resident of flood-affected communities (Paterson et al., 2018; Ghozy et al., n.d.).

Based on the results of several review studies in Iran, prevalence of three intestinal parasitic diseases including amoebiasis, cryptosporidiosis and blastocystosis have been reported 1%, 3% and 3%, respectively (Badparva et al., 2017; Berahmat et al., 2017; Haghighi et al., 2018). The above mentioned species are the most abundant pathogens for gastroenteritis that occur post-flooding (Paterson et al., 2018), so an upswing in the reappearance of these infections in relation with recent flood in the future is predicted.

The importance of dysentery including amoebic or bacillary dysentery is more bolded in summer season floods. A high incidence of diarrheal disease has reported from Ethiopia in 2009. The other flood in 2008 in Mozambique resulted to an outbreak of cholera (Alderman et al., 2012). *Norovirus* has been reported as the superior and *rotavirus* as the most common pathogen which have characterized in some epidemics of diarrheal diseases (Okaka and Odhiambo, 2018; Paterson et al., 2018). Post flood gastrointestinal problems risk is lower in countries with high income, although the risk is depended with the depth of flooding. Another outbreak of non-viral based gastrointestinal diseases has been reported during Katrina in about 4% of sheltered evacuees which was associated with over-crowding, poor sanitation and compromised health levels among them (Alderman et al., 2012). Outbreaks of other viruses, such as hepatitis A and E, with fecal-oral transmission is associated with flooding and is attributed with contaminated water and food (Ni et al., 2014; Ghozy et al., n.d.). Outbreaks of hepatitis E have frequently been reported in endemic areas and are in association with water contamination (person to person transmission only causes 2.2% of all new cases). This type of hepatitis occurs in large scale and affects great populations including pregnant women. An outbreak of hepatitis E in Kaupur, India in 1991 resulted to 48 deaths which 13 of them were pregnant women (Alderman et al., 2012).

3.2. Respiratory infections

Acute respiratory infections are the major health concern after flooding in displaced populations. Reports from south Asia and United States indicate that upper respiratory infections are the most common infectious diseases post flooding. Destruction of homes and overcrowding increases the risk of transmission respiratory viral pathogens. Immersion in flood water or aspiration of contaminated water can inoculate pathogens (often polymicrobial) to lower respiratory tract. Flulike and upper respiratory tract symptoms including cough, sore throat, rhinitis have been frequently observed among refugees due to exposure to allergens or viral pathogens (Paterson et al., 2018; Alderman et al., 2012; Baqir et al., 2012). Aspiration of flood water can conduce pneumonia and be worsen with abscess formation, empyema and pulmonary necrosis. After tsunami disaster in 2004 in Sri Lanka, about 30% of displaced people were complaining of respiratory problems which probably related to post aspiration pneumonia (Ivers and Ryan, 2006).

Chronic cough syndrome with unknown cause is another complications of natural disasters like flooding (Alderman et al., 2012; Ivers and Ryan, 2006; Baqir et al., 2012). Tuberculosis post flooding is another concern in communities with high prevalence of disease and poor resource. In countries with low incidence of tuberculosis and abundance of resources, the frequency of disease after disasters like flooding is not common (Ivers and Ryan, 2006). Studies have revealed a significant growth rate of molds after flooding. The spores of molds can be spread indoor/outdoor with different impact of human health through direct respiration but the exact role of flood in spreading spores is not well understood (Alderman et al., 2012).

3.3. Cutaneous infection

The risk of skin diseases is increasing after flooding and skin infections are considerable in these situations. These diseases are categorized as inflammatory skin diseases, traumatic skin diseases, wound infections and other miscellaneous skin diseases (Huang et al., 2016; Tempark et al., 2013). Skin injuries are frequently occurred after natural disasters and may be resulted from glass/metal pieces under water or falling debris of buildings or trees. Wound contamination can occur through contact with contaminated water, soil, metal, wood and other debris. The destruction of infrastructures and unavailable clean water for washing the wounds, limited facilities to medical treatments and poor hygiene may lead to sever infection even with initial minor trauma. The most dangerous outcome of wound contamination with soil is tetanus and gas gangrene which are caused with (*Clostridium tetani*) and (*Clostridium perfringens*) respectively (Ivers and Ryan, 2006). Other frequent bacteria which are responsible for skin and soft-tissue infections are *Staphylococcus aureus, Streptococcus pyogenes, Aeromonas Spp., Vibrio spp., Shewanella spp., Leclerciaadecarboxylata, Chromobacterium violaceum* and *Burkholderia* (Paterson et al., 2018). However, bacteria are the most cause of skin infections post flooding but infections with fungal pathogens or poly microbial infections may occur (Paterson et al., 2018; Tempark et al., 2013). Anaerobic infection, mucormycosis and melioidosis and cases of disseminated *Scedosporium apiospermum* and *Mycobaceterium chelonae* resulted from inoculation of soil pathogens can be considered a threat for wounds (Ivers and Ryan, 2006).

3.4. Vector-Borne diseases

Vector-borne diseases are transmitted by vectors and epidemics of these diseases are expected to occur following massive flooding (Okaka and Odhiambo, 2018; Paterson et al., 2018). Weather changes have a great impact on vector-borne diseases and insect population. Previous studies have shown the association of monsoon rains and floods with outbreaks of dengue fever in India and Thailand (Ivers and Ryan, 2006).

Initial heavy flooding can destruct vector breeding habitats and reduce their populations, so it would be even beneficial and reduce the transmission. In contrast, vector-borne diseases are a problem some days after flooding, because stagnant water provides an ideal breeding site for arthropod vectors such as mosquitos (Brown and Murray, 2013). Therefore, an increase in outbreaks of mosquito-borne diseases for instance Rift Valley fever, malaria, dengue fever, and West Nile fever in endemic areas may occur (Okaka and Odhiambo, 2018; Brown and Murray, 2013; Baqir et al., 2012).

Leishmniasisas one of the most important neglected tropical diseases, is caused by several species of the genus *Leishmania* and transmitted by the bite of female sandflies. These zooanthroponoses are mainly classified into cutaneous, visceral and mucocutaneous forms (Azizi et al., 2016). In Iran, cutaneous leishmaniasisis endemic and annually 20,000 new cases have been reported (Mohebali, 2013; Norouzinezhad et al., 2016) (Tables 3-6), but the visceral form with about 100–300 new cases annually, has been reported sporadically, but the disease is endemic in northwestern (Ardabil and East Azerbaijan provinces) and southern (Fars and khuzestan provinces) Iran (Mohebali, 2013; Mohebali, 2012; Sharifi et al., 2017) (Table 6). Increased transmission of leishmaniasis after flood has been reported from Pakistan and Bangladesh (Baqir et al., 2012; Emch, 2000). Inadequate sanitation and malnutrition lead to poor health condition of survivors and also prepares habitat for vectors breeding. These conditions make population more susceptible and help to spread disease (Paterson et al., 2018; Baqir et al., 2012). Leishmaniasis is common in displaced individuals who are living in overcrowded shelters where the risk of sand fly bite and transmission is increased (Baqir et al., 2012; Abaker et al., 2015). Based on previous reports of the disease from different parts of country especially in flood-affected areas like Fars province which vastly affected by recent flood, (Azizi et al., 2016; Mohebali, 2013; Norouzinezhad et al., 2016; Mohebali, 2012; Sharifi et al., 2017; Alborzi et al., 2007) an upsurge of infection in future is predictable.

3.5. Rodent-borne diseases

Rodent control is another health concern during and after flooding. The important point is identifying the local species and their behaviors. The water and food storage container should be protected from rodents and wastes should be properly disposed. As survivors may be settled in tent or campus for a while, improvement of environment sanitation should be considered.

Rodent borne diseases may increase during excessive rainfall and flood because the patterns of human- pathogen- rodent contact is altered (Okaka and Odhiambo, 2018; Brown and Murray, 2013). There are numerous reports about outbreaks of leptospirosis after flooding from different countries all around the world (Brown and Murray, 2013) (Table 2). Leptospirosis is a zoonotic disease and animals, particularly rodents are known as reservoirs. Human infection occurs directly in contact with urine of an

Table 3
Sero-prevalence of human visceral Leishmania infection by geographical zones and active case detection during 2002–2012 (Mohebali, 2013).

Zones	No. of tested	Sero-prevalence (95% CI)	No. of patients with clinical signs
North & north-west	4158	2.9 (2.3–3.3)	30
West	1800	0.3 (0.07–0.59)	4
North-east	3798	0.8(0.53–1.09	5
Central	1432	8.8 (7.25–10.15)	10
South & south-east	6847	3.1(2.69–3.51)	8
Total	18,035	2.8 (2.47–2.93)	57

Table 4
Serological positivity in 18,035 serum samples tested for human visceral by direct agglutination test (DAT) in patients referred to remote laboratories by geographical zones during 2002–2012 (Mohebali, 2013).

Zones	No. of tested	No. of DAT+	Sero-prevalence (95% CI)
North-west	12,574	638	5.1
North-east	562	21	3.7
Central[a]	4593	396	8.6
South[a]	317	146	46.1
Total	18,046	1201	6.6

[a] Majority of samples were only prepared from hospitalized patients.

infected animal or indirectly through contaminated water and soil (Blasdell et al., 2019) (Tables 7-9). Another zoonotic viral disease after heavy rainfall and flooding is hantavirus pulmonary syndrome (HPS) with rodent reservoirs (Abaker et al., 2015). However, this rodent- borne diseases not yet reported in Iran (Diaz, 2015). Another flood-related rodent-born disease is hemorrhagic fever with renal syndrome (HFRS) which was reported once in Iran, in man from Isfahan (Diaz, 2015). Post flooding, risk factors such as increasing rodent population, inadequate sanitation, overcrowdings, rising temperatures, poor health care quality, and poverty increases the risk of leptospirosis outbreaks. (Ghozy et al., n.d.; Blasdell et al., 2019; Diaz, 2014; Diaz, 2015). Several outbreaks of leptospirosis have been reported after flooding among survivors in a number of countries all around the world (Okaka and Odhiambo, 2018; Paterson et al., 2018) (Table 2). According to different reports from various regions of Iran, the number of leptospirosis cases in human and livestock has been increased especially in northern provinces close to Caspian Sea (Sakhaee and Farahani, 2014; Zakeri et al., 2010; Rabiee et al., 2018; Faraji et al., 2016; Esfandiari et al., 2015) (Table 7). Therefore, awareness of the potential risk of disease and prevention of transmission after flooding, management and urgent care of survivors are needed. Destroying the breeding sites post flooding is an effective protection procedure. Using repellents in biting hours and screens in doors and windows can protect individuals from mosquito bites. These prevention program can reduce human infection and risk of disease in flooding emergency (Brown and Murray, 2013). (See Table 10.)

3.6. Helminth infections

Neglected intestinal helminthic infection is a major health concern worldwide. Soil-transmitted helminth (STH) infections have affected about 24% of world population in 2016 and are more prevalent in developing countries (Faraji et al., 2016) and transition occurs through contaminated water or food or via skin. The infection is associated with multiple factors including low-income, poor sanitation of food, food habits and close relationship with animal reservoirs (Masaku et al., 2017; Han et al., 2019). The most important helminths are *Ascaris lumbricoides*, *Trichuris trichiura*, *Necator americanus*, *Ancylostoma duodenale, Enterobius vermicularis, Strongyloides stercoralis* (World Health Organization, 2016). It seems that intestinal helminthiases have been decreased in last decade in Iran. For example, the prevalence rate of ascariasis and Strongyloidiasis was estimated to be 0.1% and 0.3%, and the infection rate with hookworms is <1% in population while infection with *Hymenolepis* and *Enterobius* is relatively common (Rokni, 2008). Humid and muddy soil after flooding, could form a favorable environment for the helminth development. Free-living stages of some soil transmitted helminths are highly resistant which leads to persistence in the soil for years and possible outbreaks of infections are expected. It is known that developmental stages of helminths in the environment before infecting the host mainly depend on humidity (Han et al., 2019).

3.7. Dead bodies and the risk of communicable diseases

The important point in this topic is reminding some of neglected matters after natural disasters including the flood. It should be assessed who is most at risk of contamination with dead bodies? How safe dispose of these bodies should be performed? And how can people be protected from infection? It is a great concern after flooding that unburied dead human or animal bodies are potential sources of viruses and microbial agents which can easily contaminate water and soil. An important concern post flooding is the infections among survived populations through contaminated water and soil. The route of contamination is inappropriate burial of dead victims The risk of infection associated with dead bodies and population most at risk is unclear. It is clear that volunteers, rescue team and military personnel are most likely to be infected through exposure with infective agents (Morgan, 2004). The transmission of pathogens from person to the environment does not occur immediately after passing away. Infection with

Table 5
Sero-prevalence of canine visceral *Leishmania* infection by direct agglutination test (DAT) with anti-*Leishmania infantum* antibodies by geographical zones during 2002–2012 (Mohebali, 2013).

Zones	No. of tested	No. of DAT+	Sero-prevalence (95% CI)	Leishmania species
north-west	3308	608	18.4 (16.9–19.6)	*L. infantum L. tropica*
North-east	507	40	7.9 (5.4–10.1)	*L. infantum*
Central	2525	164	6.5 (5.4–7.3)	*L. infantum L. tropica*
South-west	864	67	7.7 (5.9–9.4)	*L. infantum L. tropica*
Total	7204	879	12.2(9.6–14.7)	*L. infantum L. tropica*

Table 6
Proven/probable vectors of VL in Iran by geographical zones, infection rate, *Leishmania*species and method used for *Leishmania* detection (1992–2013) (Mohebali, 2013).

Zone	Province	District	Phlebotomus Spp.	Infection rate (%)	Leishmania species	Method of isolation	Investigator(s)
North-west	Ardabil	Meshkin-Shahr	*Ph.(Lar.) kandelakii*	0.3	*L.infantum*	Parasitolo-gy[a]	Nadim et al. 1992
North-west	Ardabil	Meshkin-Shahr	*Ph.(Lar.) kandelakii*	1.1	*L.infantum*	Nested-PCR	Rassi et al. 2005
North-west	Ardabil	Germi	*Ph.(Lar.) perfiliewi*	0.9	*L.infantum*	Parasitolo-gy[a]	Nadim et al. 1992
North-west	Ardabil	Germi	*Ph.(Lar.) perfiliewi*	1.1	*L.infantum*	PCR	Rassi et al. 2009
North-west	Ardabil	Bilesavar	*Ph.(Lar.) Perfiliewi*	1.5	*L.infantum*	PCR-RFLP	SaneiDehkordi et al. 2011
North-west	Ardabil	Germi	*Ph.(Lar.) Perfiliewi*	0.94	*L.infantum/L. donovani*	Semi-nested PCR	Oshaghi et al. 2009
North-west	East Azer-baijan	Kalibar	*Ph.(Lar.) perfiliewi*	2.85	*L.infantum*	Nested- PCR	Parvizi et al. 2008
Nort-west	East Azer-baijan	Azar-Shahr	*Ph.(Lar.) tobbi*	25[c]	*L.infantum*	PCR-RFLP	Oshaghi et al. 2013
South	Fars	Ghir-Karzin	*Ph.(Lar.) keshishiani*	1.1	*L.infantum*	Parasitolo-gy[a]	Seyedi-Rashti et al. 1995
South	Fars	Ghir-Karzin	*Ph.(Lar.) major* S.l.	3–5	*L.infantum*	Parasitolo-gy[b]	Sahabi et al. 1992
South	Fars	Ghir-Karzin	*Ph.(Lar.) major* S.l.	8.3	*L.infantum*	Nested-PCR	Azizi et al. 2008
South	Khuzestan	*Ph(Par.) alexandri*		1.7	*Leishmania spp.*	Parasitolo-gy[b]	Javadian et al. 1997
South	Fars	NourabadMamasani	*Ph(Par.) alexandri*	4.2	*L.infantum*	Parasitology[b] Semi-nested PCR	Azizi et al. 2006

[a] Leishmania sp. was inoculated into golden hamsters intraperitoneally and produced VL infection that con-firmed by microscopy.
[b] Natural promastigote infection was found.
[c] Of 8 female Ph. tobbi, 2 (25%) were found naturally infected with L. infantum.

Table 7
Bacterial rodent-borne diseases reported in Iran (Rabiee et al., 2018).

Disease	Agent	Reports in Iran human report		Rodent report		
		Number	Province	Number	Species	Province
E. coli enteritis	*E. coli*	>10	Golestan, Tehran, Fars, Khuzestan, Hamadan, Sistan-Baluchestan, Yazd, Ardebil	2	*Rattusrattus, R. norvegicus*	Tehran, Gilan
Salmonellosis	*Salmonella spp.*	>10	Goletan, Fars, Tehran, Mazandaran, Yazd, Ardebil, Khorasan, Khuzestan	4	*Mus musculus, R. rattus, R. norvegicus*	Tehran, Gilan
Plague	*Yersinia pestis*	>10	Kurdistan, East Azerbaijan	>10	*Merionespersicus,M. libycus, Merionesvinogradovi, Merionestristrami*	Kurdistan, Hamadan
Yersiniosis	*Y. pseudotuberculosis, Y. enterocolitica*	2	Tehran, Golestan	1	*Rattusrattus, R. norvegicus*	Gilan
Leptospirosis	*Leptospirainterrogans*	>10	Gilan Mazandaran, Golestan, Sistan-Baluchetsan Kerman, Tehran, Fars, Chaharmahal, Khuzestan, West Azerbaijan			
Campylobacteriosis	*Campylobacter spp*	>10	Mazandaran, Golestan, Tehran, East Azerbaijan, Fars, Khuzestan, Lorestan, Kermanshah, Khorasan	1	*Sciurusanomalus*	Chaharmahal, Isfahan
Tularemia	*Francisellatularensis*	3	Kurdistan, Sistan-Baluchestan	2	*Microtus paradoxus, Tatera indica*	Golestan, Sistan-Baluchestan
Tick-borne relapsing fever	*Borrelia spp.*	>10	Ardebil, Hamadan, Zanjan, Kurdistan, Qazvin, Fars, Hormozgan	1	*Rattusnorvegicus*	Hormozgan
Tuberculosis	*Mycobacterium tuberculosis complex*	>10	AP	2	*Mus musculus*	Hamadan
Listeriosis	*Listeria spp.*	2	Tehran, Fars	0	–	–
Lyme disease	*Borreliaburgdorferi*	5	Tehran, Mazandaran	0	–	–
Q fever	*Coxiellaburnetii*	>10	Mazandaran, Khuzestan, Khorasan, Semnan, Kerman, Fars, Kurdistan, Tehran	0	–	–

Abbreviation: AP, All Provinces.

Table 8
Viral rodent-borne diseases reported in Iran (Rabiee et al., 2018).

Disease	Agent	Report in Iran			
		Human report		Rodent report	
		Number	Province	Number	Species
Hepatitis E	Hepatitis E virus	>10	Kermanshah, Hamadan, East Azerbaijan, Isfahan, Khuzestan, Chaharmahal	0	–
Rabies	Rabies virus	>10	AP	0	–
Crimean-Congo hemorrhagic fever	Nairovirus	>10	AP	2	*Allactagawilliamsi,Mus musculus, Meriones crassus*
HFRS	Hantaan virus, Puumala virus, Dobrava virus, Seoul virus	1	Isfahan	0	–

Abbreviations: AP, All Provinces; HRFS, hemorrhagic fever with renal syndrome.

Table 9
Parasitic rodent-borne diseases reported in Iran (Rabiee et al., 2018).

Disease	Agent	Report in Iran				
		Human report		Rodent report		
		Number	Province	Number	Species	Province
Cryptosporidiosis	*Cryptosporidium spp.*	>10	AP	4	*Mus norvegicus, R. rattus, Mus musculus*	Hormozgan, Tehran, Khuzestan
Toxoplasmosis	*Toxoplasma gondii*	>10	AP	5	*Rattusrattus, R. norvegicus*	Gilan, Khuzestan, Tehran, Kohgiluyeh- Boyerahmad
Leishmaniasis	*Leishmaniainfantom, Leishmania major, Leishmaniatropica, Leishmaniadonovani*	>10	AP	>10	*Merionespersicus, Cricetulus migratorius, M. libycus, Rhombomysopimus, Tatera indica, Nesokiaindica, Gerbillus sp., M. hurrianae, Mesocricetusbrandti, Rattus rattus, Mus musculus, R. norvegicus*	Ardebil, Isfahan, Semnan, Yazd, Fars, Golestan, Sistan-Baluchestan, Hormozgan
Hepaticcapillariasis	*Capilaria hepatica*	1	Tehran	3	*Merionespersicus,Mus musculus, Rattusrattus, R. norvegicus, Cricetulus migratorius*	Ardebil, Kermanshah
Trichinellosis	*Trichinella spp.*	2	Tehran	1	*Merionespersicus*	Isfahan
Hymenolepiasis (Rodentolepiasi-s)	*Rodentolepis nana, Rodentolepisdiminuta*	>10	AP	>10	*Rattusrattus, R. norvegicus, Mus musculus, Rhombomys opimus, Tateraindica, Apodemus spp., Meriones persicus, Microtussocialis, Cricetulusmigratorius*	Mazandaran, East Azerbaijan, Golestan, Sistan-Baluchestan, Hamadan, Isfahan, Khuzestan, Ardebil, Tehran, Kermanshah, Khorasan
Taeniasis	*Taenia spp.*	>10	Ardebil, Tehran, Arak, Mazandaran, Hamadan, Kermanshah	5	*Rattusnorvegicus, R. rattus, Mus musculus, Apodemusspp*	Mazandaran, East Azerbaijan, Hamadan, Kermanshah, Ardebil
Alveolar echinococcosis	*Echinococcus multilocularis*	2	Ardebil, Khorasan	1	*Microtus transcaspicus, Ochotona rufescens, Mus musculus, Crociduragmelini, Apodemus spp.*	Khorasan
Moniliformiasis	*Moniliformis moniliformis*	4	Sistan-Baluchestan, Isfahan, Khorasan, Khuzestan	5	*Mus musculus, Rattusrattus, R. norvegicus, Meriones persicus*	East Azerbaijan, Khuzestan, Ardebil, Kerman
Trichuriasis	*Trichuris spp.*	3	Khuzestan, Ardebil	6	*Mus musculus, Rattus, norvegicus, R. rattusTatera indica*	Kermanshah, Kerman, Hamadan, Golestan, Ardebil, Mazandaran
Gongylonemiasis	*Gongylonema spp.*	1	NS	3	*Rattusnorvegicus, R. rattus*	Khuzestan, East Azerbaijan
Babesiosis	*Babesia spp.*	0	–	3	*Merionespersicus, Rattus norvegicus,Musmusculus*	Ardebil, Hormozgan, East Azerbaijan
Toxocariasis	*Toxaocara spp.*	>10	Gilan, Tehran, Hamadan, Khuzestan, Zanjan, Mazandaran, Fars, Kermanshah	0	–	–
Schistosomiasis	*Schistosoma spp.*	>10	Khuzestan	0	–	–
Giardiasis	*Giardia lamblia (G. duodenalis)*	>10	AP	0	–	–
Fasciolosis	*Fasciola hepatica, F. Gigantica*	>10	Gilan, Mazandaran, Kermanshah, Kohgiluyeh-Boyerahmad, Ardebil	0	–	–

Table 10
Geographical distribution of Giardia lamblia in Iran (Heydari et al., 2018).

Region	No. of studies	Prevalence, %	95% CI, %	Weight
East	1	35.5	32.3–38.8	2.29
Centre	14	16.9	13.0–20.8	32.83
South	4	14.9	6.8–23.0	9.26
North	8	13.2	6.5–19.9	18.8
West	16	12.2	9.3–15.1	36.84
Total	43	14.7	12.8–16.6	100.0

pathogens including tuberculosis, group A streptococcal infection hepatitis B, hepatitis C, HIV infection, gastroenteritis and probably meningitis is a great threat for whom carrying cadavers (Healing et al., 1995). Usually flood victims die from trauma and drowning and are less likely to have acute infections or rare diseases (e.g., Creutzfeldt-Jakob disease). In contrast, more probably, infections like tuberculosis, viral hepatitis and enteric pathogens spread from an ill person to the others (Noji, 2000). In cases that dead bodies contaminate the water supplies, the most notable problem will be gastroenteritis (Morgan, 2004). Disposal of dead bodies after flooding is a great concern as the putrefaction starts soon after death (Vass et al., 2002). Concerns about contagious diseases may lead to unplanned disposal of dead bodies and sometimes unnecessary precautions such as burring corpses in common graves and adding lime for disinfection. Finding new burial sites after flooding is a big challenge because the flood leaves huge mas of mud or saturated soil. Also, for protection of water supplies, the distance of at least 30 m from springs or watercourse and 250 m from well or any source of drinking water with burial sites should be considered. However, distance must be chosen based on local hydrogeological conditions. The most important hazards for whom carrying the dead bodies are blood-borne viruses, gastrointestinal infections, and tuberculosis. Basic hygiene and using gloves, mask and body bags can be useful in protecting dead body managers. Precautions to volunteers for preventing from infection are necessary. In lack of enough sites for burial or difficulty in identification of dead bodies, mass grave is used (Morgan, 2004). Same precautions are needed for animal dead bodies. Animal dead bodies are potential sources of zoonotic infections and in some cases dangerous bacterial infections (e.g. *Anthrax*) and also they can contaminate water with feces (e.g. *Cryptosporidia*) and discharge from lesions (*Listeria*, *Campylobacter*) but only when dead bodies are in water as these microorganisms cannot survive long time if the animal body is put in dry land. Therefore, proper disposal of animals is important after natural disasters including flood (PAHO Cataloguing in Publication).

4. Diseases associated with crowding

4.1. Measles

The risk of transmission is depending on vaccination coverage rate among flood affected population especially in children under 15 years old. Overcrowdings in displaced people facilitate the transmission and especial attention is needed to prevent outbreaks. An outbreak occurred in Philippines in 1991 involved 18,000 cases (Surmieda et al., n.d.). Other outbreaks of measles have reported after natural disasters from Pakistan and Aceh Utara district.

4.2. Meningitis

Is another person to person transmittable infection with the high risk of transmission in crowded displaced populations. Several reports about cases and deaths have been reported in the world (WHO, 2016).

4.3. Acute respiratory infections (ARI)

Acute respiratory infections (ARI) are important infections in population affected by natural disasters with high incidence of morbidity and mortality particularly in children under 5 years old. The risk of mortality is high due to unavailability to health care services and antibiotics for treatment (Ivers and Ryan, 2006). Exposure with indoor cooking, poor nutrition and overcrowding are main risk factors in displaced people. The report of ARI incidence in a Hurricane Mitch in 1998, indicated the increased incidence of four-fold in Nicaragua (WHO, 2016).

5. Post flooding prevention programs for communicable diseases

The following programs are critical for prevention and reducing the impact of communicable diseases:

1. Safe water, sanitation, site planning:

Providing safe drinking-water is the most important preventive measure. An available, inexpensive agent which is effective against nearly all waterborne pathogens is Chlorine and can be used post flooding. Also, adequate plans for access to clean water and sanitation should be considered.

2. Health care services:

Primary health care services are critical to prevention program. Early diagnosis and treatment can reduce the burden of communicable diseases such as ARI, diarrhea, vector borne disease, etc.

2.1. Immunization

Measles mass immunization along with vitamin A supplement is an initial step in flooding and natural disasters particularly in areas with inadequate vaccination coverage. Measles mass vaccination is critical when baseline coverage rate is below 90% among people under 15 years old and should be done as soon as possible with priority of age group 6 months to 5 years.

3. Prevention of malaria, leishmaniasis, dengu fever:

Specific attention in endemic area for prevention of malaria should be paid. According to the geographic situation of flood affected regions, presence of vector and endemicity for parasite, preventive interventions must be done. Delay in program leads to increase the mosquito numbers and preventive measures including indoor residual spraying, destroying nets with insecticides with long-lasting insecticidal nets (LLIN) are recommended. Early detection and treatment of malaria and leishmania cases is useful for controlling diseases. Particular attention for vector control is necessary in prevention of dengue (Heydari et al., 2018). For this purpose it is emphasized to eliminate vector breeding sites as much as possible by:

- continuous covering of all stored water containers
- removal or destruction of solid debris where water can collect (bottles, tires, etc.) (WHO, 2016).

6. Conclusions

Events like flooding can increase the risk of vector-borne, viral respiratory, gastrointestinal and soft tissue diseases. Some of the problems are resulted from direct contact with pathogenic organisms (wound infection, tetanus, pneumonia). Overcrowded survival shelters results to infections like measles, meningitis, tuberculosis and influenza. Absence of clean water supplies leads to intestinal complications (shigellosis, cholera). Buried dead bodies are potential reservoirs for dangerous diseases (anthrax). Also increasing stagnate water results to increasing the number of mosquitoes and vector- borne diseases (malaria, leishmaniasis). These problems can affect hundreds of lives in destructed areas and need critical attention in order to limit the consequences. In this review we discussed some aspects of devastating flood. Such natural disasters can pose long lasting effects on public health and will have more consequences in future which may not be predictable. More attentions are needed to protect forests and herbaceous coverage all around the world in order to prevent such disasters.

Declaration of competing interest

The authors declare that there is no conflict of interests in relation to this work.

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Authors' contributions

Azar Shokri conceived and designed the current study and, with Seyed Ahmad Hashemi, guided the work. Sadaf Sabzevari drafted the manuscript. All authors contributed to the writing of the manuscript and read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Medical Ethics Committee of the North Khorasan University of Medical Sciences. (Ethic ID: IR.NKUMS.REC.1398.027).

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The data that support the findings of this study are available online from the references that have been cited in this study.

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