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REVIEW

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Bacterial infection during wars, conflicts and post-natural disasters in Asia and the Middle East: a narrative review

Tania Nawfal Dagher[a,b], Charbel Al-Bayssari[c], Seydina M. Diene[a], Eid Azar[b] and Jean-Marc Rolain[a]

[a]Faculté de Médecine et de Pharmacie, Aix Marseille Univ, IRD, APHM, MEPHI, IHU-Méditerranée Infection, Marseille, France; [b]Saint George Hospital University Medical Center, University of Balamand, Beirut, Lebanon; [c]Faculty of Sciences 3, Lebanese University, Michel Slayman Tripoli Campus, Ras Maska, Lebanon

ABSTRACT

Introduction: Bacterial infections resulting from wars and natural disasters represent a major public health problem. Over the past 50 years, Asia and the Middle East have suffered several wars. Moreover, East-Asian countries are considered the most natural disaster-prone countries in the world.

Areas covered: This review focuses on bacterial infection occurring during wars and after natural disasters, among refugees, wounded citizens and soldiers as well as the prevention and control measures that must be taken.

Expert opinion: During wars, refugees and soldiers represent the two main sources of bacterial infections. Refugees coming from countries with a high prevalence of antimicrobial resistance can spread these pathogens to their final destination. In addition, these refugees living in inadequate shelters can contribute to the spread of bacterial infections. Moreover, some factors including the presence of fixed imported fragments; environmental contamination and nosocomial transmissions, play a key role in the dissemination of bacteria among soldiers. As for natural disasters, several factors are associated with increased bacterial transmissions such as the displacement of large numbers of people into over-crowded shelters, high exposure to disease vectors, lack of water and sanitation. Here, we carry out a systematic review of the bacterial infections that follow these two phenomena.

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1. Introduction

Over the past 50 years, wars, conflicts and natural disasters around the world have led to massive population displacements and forced displacements of large numbers of people from their homes, and have posed a major threat, namely the spread of infectious diseases [1]. Historically, the majority of wartime deaths have been associated with diseases such as typhoid, typhus, cholera, and plague. During the wars, mortality from infectious diseases has changed considerably over the past century due to improved sanitation and understanding of ways to prevent infections, such as the reduction in the mortality rate from 1:8 in 1898 during the Spanish-American war to 1:01 during the first Gulf War [2]. On the other hand, the development of the world population, as well as displacement and poverty, as well as displacement and poverty have increased the number of people living in regions vulnerable to natural disasters, multiplying the impacts of their public health [3]. Over the last period, the number of natural disasters that have hit the world, such as floods, tsunamis, typhoons, and earthquakes, increased threefold between 2000 and 2009, compared to 1980–1989, according to some sources [4]. Several factors contribute to increasing the transmission of infectious diseases after natural disasters. These factors include the displacement of a large number of people into over-crowded shelters with limited supplies [5], high exposure and proliferation of disease transmission vectors [3], poor water quality, poor sanitation, and sewerage systems [6], decreased immunity to the vaccine that prevents disease or insufficient immunization coverage, and limited access to care [3]. The emergence and transmission of these post-disaster infectious diseases were due to changes in the human situation, the environment, and the pathogen ecosystem.

This review aims to describe the potential infectious diseases occurring during wars and after reported natural disasters in Asia and the Middle East. In addition, we summarize the prevention and control measures to be considered in addressing the challenges arising from these two phenomena.

2. Bacterial Infections during wars

The injuries resulting from wars are not limited to military personnel. Since 1945, more than 100 million civilian people, with 25 million deaths, have been described globally in military conflicts [7]. The harms caused by war are many and complex. Death, displacement, and injury are the most obvious, in addition to infection, which is closely associated with conflict and war.

Bacterial infections, especially the multidrug-resistant (MDR) bacteria, have become a global public health problem over the past few years and is causing a serious challenge to global healthcare [8]. In Asia and the Middle East, infection

CONTACT Jean-Marc Rolain jean-marc.rolain@univ-amu.fr Faculté de Médecine et de Pharmacie, Aix Marseille Univ, IRD, APHM, MEPHI, IHU-Méditerranée Infection, 19-21 Boulevard Jean Moulin, 13385, Marseille CEDEX 05, France

Article highlights

- Bacterial infections, particularly the multidrug-resistant (MDR) bacteria, have become a serious challenge to global healthcare.
- Wars and natural disasters have led to a large human movement and made an enormous number of individuals' displacements from their homes, and a serious threat, which is the dissemination of infectious diseases.
- Outbreaks of infections have been a direct result of wars, which cause huge damage to health services and medical organizations. In addition, conflict-related traumatic injuries have worsened the case.
- Several diseases can also be spread during the war as a direct effect of the mass movement of refugees living in poor hygiene conditions.
- In recent decades, the frequency of natural disasters has increased worldwide resulting in large economic damage affecting and killing millions of people.
- Outbreaks of diseases following this phenomenon are primarily related to the displacement of people into the overcrowded shelter where supplies are limited.
- Moreover, during a water-related disaster, contaminated water, waste and sharp objects may play a major role in the dissemination of bacterial infections.
- Prevention and control measures must be taken in addressing the challenges resulting from these two phenomena.

outbreaks have arisen as a direct outcome of the war, worsened by the lack of food and water, destruction of the infrastructure and health centers and the displacement of a large number of refugees, as described in the Syrian war [9]. This massive movement of refugees can be responsible for the transmission of a variety of bacterial species from one geographical location to another, leading to an increase in the spread of many infectious agents internationally, such as antimicrobial-resistant bacteria. During wars, migration is one of the leading factors responsible for the spread of infectious diseases and MDR pathogens. Refugees coming from countries with a high rate of antimicrobial resistance in the community can transmit these pathogens on their way to their final destination and can catch such pathogens from other refugees leaving in crowded refugee camps suffering from poor hygiene conditions. The MDR pathogens that can be spread include mostly the extended-spectrum-β-lactamase and carbapenemase-producing *Enterobacteriaceae*, MDR *Acinetobacter baumannii*, methicillin-resistant *S. aureus* (MRSA), and MDR tuberculosis (MDR-TB) [10].

In addition to infections caused by war refugees, conflict-related traumatic injuries have been a defining feature of war history, and the types of traumatic injuries have been altered by changes in the weapons of conflict and the modalities of injury [11]. The majority of wounds (65%) results from traumatic injuries, such as high-velocity projectiles (shrapnel and gunshot), blast injuries (mines, mortars and improvised explosive devices) and burns, followed by 15% of wounds of head and neck, 10% of thoracic wounds and 7% of abdominal wounds. There were distinctive characteristics of traumatic wounds that improve the development of infections. Factors that influence this situation include the type of wound and its severity, the existence of devitalized tissue and the fixation of foreign objects, environmental contamination, a collection of clots and fluid, time to access care, the onset of antimicrobial agents, the presence of nosocomial pathogens [12,13].

It has been shown that with advances in the treatment of conflict-related traumatic injuries, the bacteriology of war wounds has developed successfully over time. Fleming was one of the first scientists to describe war wound bacteriology back in 1919 [14]. The experiences of the First World War led to initial descriptions of the evolution of pathogens that lead to wound infections in three phases. The initial phase is infection with sporulating anaerobes (such as *Clostridium* species) and *Streptococci* that have changed after about 7 days to non-sporulating bacteria of fecal origin (such as *Escherichia coli* and *Klebsiella* species) in the second phase and then transformed during the third phase to pyogenic organisms after approximately 20 days (such as *Staphylococcus* species and *Streptococcus pyogenes*) [13,14]. During the First World War, the use of violent surgical debridement led to the extinction of clostridial gas gangrene and during the Second World War, the use of penicillin contributed to the reduction of wound infections produced by *S. pyogenes* [15]. At the same time, the larger spectra and increased use of antimicrobial agents have led to an increase in bacterial resistance [16,17]. Since the Vietnam War, microorganisms associated with combat-related traumatic injuries include *S. aureus, S. pyogenes* and Gram-negative bacteria such as *Enterobacter* spp., *E. coli, Pseudomonas aeruginosa*, and *Klebsiella* spp. [18]. During wars, wounds infections continuously have a major influence on morbidity and mortality in both military and civilian populations [12,19,20]. The infectious diseases outbreaks that occur following wars are summarized in Table 1.

2.1. Wars in the Middle East

The Middle East region suffered from repeated armed conflicts that affect both civilians and soldiers. The Arab-Israeli wars and recent uprisings (Syria and Yemen) are very good examples.

2.1.1. Syria

The Syrian civil war is considered to be one of the perfect examples of a military conflict that affects both civilians and soldiers. Now in its seventh year, this war has left more than 200,000 people dead, 500,000 wounded and more than 9 million refugees [19,21]. Before the emergency, the Syrian health system was almost identical to that of other neighboring countries. By 2016, health infrastructure was significantly reduced in all areas of the country due to the destruction of hospitals and health centers, the reduction in the number of medical staff and the lack of therapeutic supplies [19].

In 2014, a study conducted by Doctors Without Borders on 61 orthopedic Syrian patients with assumed infections, showed that 74% of these patients had a minimum of one positive wound culture and 13% had polymicrobial results. Gram-negative organisms represented 56% of cultures with *P. aeruginosa* is the major bacteria (56%), followed by *E. coli* (19%) and *A. baumannii* (14%). On the other hand, the Gram-positive bacteria, such as MRSA, represented 44% of the isolates. Overall, 69% of infected patients had MDR organisms with MRSA representing 42% of staphylococcal isolates [22]. Since the beginning of the civil war, the Syrian health system has been declined. Indeed, many Syrian hospitals and medical

Table 1. Infectious diseases outbreaks following the war.

Infectious disease outbreak	War	Natural Disaster	Ref
Acinetobacter baumannii and *Acinetobacter baumannii-calcoaceticus* complex(ABC)	Syria (2014, 2013–2014), Lebanon (2012–2013), Iraq (2009–2016), Military operations in Iraq and Afghanistan (2003–2008, 2013)	China (Earthquakes 2008)	[22,24,25,40,41,53,60,61,62,63,64,65,66,67,68,69,62,70,149,150,151,152,153]
Escherichia coli	Syria (2014), Lebanon (1975–1984, 2013, 2012), Kingdom of Saudi Arabia (1991), Iraq (2009–2016), Military operations in Iraq and Afghanistan (2013), Vietnam (1968, 1969)	China (Earthquakes 2008)	[22,38,40,41,49,53,62,85,86,149,150,151,152,153]
Klebsiella pneumoniae	Lebanon (2012–2013), Iraq (1981–1987, 2009–2016), Military operations in Iraq and Afghanistan (2008), Vietnam (1969)	Pakistan (Floods 2010), Philippines (Typhoons 2013), Indonesia (Tsunamis 2015), East Japan (Tsunamis 2011)	[40,41,52,53,70,85,86,115,123,138,139,140,141,142,143]
Proteus species	Iraq (2009–2016), Vietnam (1969)	Indonesia (Tsunamis 2015)	[53,85,86,138,139]
Tuberculosis (TB) and *Mycobacterium* species	Syria (2014),), Iraq (2014), Afghanistan (2002), India (1998), Korea (1950–1953)	Philippines (Typhoons 2013), East Japan (Earthquakes 2011), China (Earthquakes 2008), Asian tsunami (Tsunamis 2004).	[32,55,56,57,90,83,131,132,133,134,135,136,137,123, 146,147,148,149,150,151,152,153]
Staphylococcus aureus and Methicillin-resistant Staphylococcus aureus (MRSA),	Lebanon (1975–1984), Iraq (2009–2016), Military operations in Iraq and Afghanistan (2010, 2008), Vietnam(1971), Syria (2014, 2013–2014),	China (Earthquakes 2008)	[38,53,69,70,87,22,24,25,149,150,151,152,153]
Clostridium species	Israel (1982), Military operations in Iraq and Afghanistan (2011–2016)	Taiwan (Tsunamis 2012–2013), Asian tsunami i(Tsunamis 2004), China (Earthquakes 2008) Taiwan (Typhoons 2012–2013)	[44,45,77,78,126,127,128,131,132,133,134,135,136,137,149,150,151,152,153,126,127,128]
Bacteroides species	Israel (1977–1991), Military operations in Iraq and Afghanistan (2011–2016)	Indonesia (Tsunamis 2015)	[44,45,77,78,138,139]
Vibrio cholerae	Yemen (2017), Iraq (2015),	Pakistan (Floods 2009–2010), India (Floods 2010–2016), Bangladesh (Floods 2008), India (Typhoons 2009 and 2012), Indonesia (Tsunamis 2015)	[50,54,116,117,118,119,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36, 37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72, 73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,26,92,93,94,95,96,97,98,99,100,101,102,103,104, 105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125, 138,139]
Diarrhea and bacillary dysentery	Kingdom of Saudi Arabia (1978–1982), Korea (1950–1953)	Huai river, China (Floods 2007), Hunan, China (Floods 2016), Pakistan (Floods 2010), Pakistan (Earthquakes 2005)	[47,48,83,109,115,144,145]
Burkholderia pseudomallei	Japan (2005)	Asian tsunami (Tsunamis 2004)	[84,131,132,133,134,135,136,137]
Aeromonas species.	Not detected	Thailand (Tsunamis 2004), Indonesia (Tsunamis 2015).	[129,130,138,139]
Malaria	Not detected	Huai river, China (Floods 2007),	[109]
Leptospirose and melioidosis	Not detected	Philippines (Typhoons 2009), Taiwan (Typhoons 2012–2013), Asian tsunami (Tsunamis 2004)	[121,122,126,127,128,131,132,133,134,135,136,137]

(Continued)

Table 1. (Continued).

Infectious disease outbreak	War	Natural Disaster	Ref
Enterobacter species	Iraq (1981–1987, 2009–2016)	Not detected	[52,53]
Pseudomonas species	Syria (2014), Lebanon (1975–1984, 2013), Israel (1982), Iraq (2009–2016), Military operations in Iraq and Afghanistan (2013, 2008), Vietnam (1969)	Not detected	[22,38,40,44,53,62,70,16,85,86]
Plague, and diphtheria	Vietnam (1962), Tajikistan (1992)	Not detected	[22,24,25,88,89,91]
Brucella melitensis.	Military operations in Iraq and Afghanistan (2011–2016)	Not detected	[77,78]
Rickettsia prowazekii and *Coxiella burnetii*	Military operations in Iraq and Afghanistan (2001–2010)	Not detected	[79,80]
Shigella sonnei	Kingdom of Saudi Arabia (1991)	Not detected	[49]
Bordetella pertussis	Military operations in Iraq and Afghanistan (2006)	Not detected	[80]
Sepsis, intracranial infections, *Alcaligenes*, and *Aerobacter aerogenes*	Lebanon (1991, 1981–1988), Vietnam (1968, 1969)	Not detected	[38,16,85,86]

institutes have been demolished by bombardments and jet strikes, which have resulted in the deaths of many doctors and other medical personnel. Since 2013, the wounded, especially those wooded in combat, have been receiving treatment in Lebanon, Israel, and Turkey.

The Syrian war caused 1300 wounded combatants and civilians to flow to the Israeli borders in search of medical care [23]. Among those patients, the prevalence of MDR isolates ranged from 47% to 66%, the most common being ESBL-producing or carbapenem-resistant Enterobacteriaceae (CRE), MRSA and *Acinetobacter baumannii-calcoaceticus* complex (ABC); two of the CRE isolates produced New Delhi metallo-β-lactamase [24,25]. Another study has been conducted in four hospitals of northern Israel receiving patients displaced from the Syrian territory. During the study period, a total of 595 Syrian patients were admitted to the study hospitals. Thirty patients (6.5%) were found to be carbapenemase-producing Enterobacteriaceae (CPE) carriers. The bla_{NDM} gene was detected in 19 out of the 30 isolates, while the $bla_{\text{OXA-48}}$ gene was detected in 13 [26]. The acquisition of the CPE might have occurred in Syria in the community, during the patients' stay in Syrian healthcare facilities, during the evacuation to Israel, in the Israeli medical facility operational along the border [27], or during the transfer to one of the Israeli civilian hospitals. The presence of new clones in this study from Syrian patients who have been admitted to the Israeli hospitals suggests a common source of acquisition of these clones that precedes the hospitalization in northern Israel [26]. Moreover, in Lebanon, a study reported the emergence of $bla_{\text{NDM-1}}$-producing *A. baumannii*, isolated from Syrian civilians [28]. It has been shown that in wartime, MDR *A. baumannii* infections have already been reported as shown by Scott et al. and Kusradze et al., who reported the presence of this isolated bacterium in wounded American soldiers in Iraq [29,30]. Due to the impossibility to obtain information on the date of injury, conditions of care, or the treatment managed in Syria, they showed that the infection might have been picked up from environmental sources on the battlefield, during the patient's visit to Syrian clinics, or during migration to Lebanon.

In addition to infections caused by the direct effect of war, Syrian refugees have played an important role in the spread of bacteria. By March 2016, the United Nations have reported more than 4.8 million refugees outside Syria. They were mainly divided between Turkey and Lebanon [31,32]. This huge movement of the Syrian refugees has contributed to the increase in the number of tuberculosis (TB) cases in the region and between refugees who usually live in crowded and unhealthy conditions. In Lebanon, according to the World Health Organization (WHO) and the Lebanese Ministry of Public Health, TB declined until 2011, when the refugee influx into the country began [32]. In 2012, there was an increase of 27% in TB cases when compared to 2011. The main factor in the spread of the disease is that there are no official refugee camps in Lebanon, as in Turkey, but rather hundreds of makeshift tents spread throughout the country where refugees live in crowded and difficult hygienic conditions [32]. In a study conducted in Turkey, 10,589 Syrian refugees were screened for TB, and the rate was found to be 18.7/100,000. In 2015, 558 new cases among Syrian refugees were detected and treated [33,34].

2.1.2. Lebanon

Since 1975, Lebanon has been under pressure from wars and military conflicts and the country has perceived several armed battles such as the civil war in Lebanon (1975–1978) or the war with the Israeli army (1982–2006). However, few reports describe the war injuries in Lebanon [35,36,37,38]. During the civil war, a study was conducted, over a 10-year period between 1975 and 1984 at a tertiary hospital, on 1021 Lebanese patients. This study showed that there was an infection rate of 12% with *S. aureus, P. aeruginosa*, and *E. coli* being the most common organisms, respectively [38]. A similar study from a similar center on the outcome of 1500 patients, showed a 2.1% occurrence rate of sepsis as the second most regular reason for death after hemorrhage (3.7%) [38].

Between 1981 and 1988, following missile-induced brain damage, intracranial infections with brain abscesses were reported by Taha et al. in a study conducted for patients treated at the American University of Beirut Medical Center [38]. Lately, the 2006 war with Israel, resulted in the release of more than four million sub-munitions over Lebanese soil, including one million unexploded duds [39]. Fares et al. conducted a study on 350 injured casualties in 2013 and showed an overall infection rate of 19.4% with bacterial infections accounting for 86.8%. *P. aeruginosa* was the most common isolate described (30.5%), followed by *E. coli* [40]. As mentioned above, Lebanese hospitals have been considered as recommended centers for the war wounded in Syria and Iraq. This explains the emergence of $bla_{\text{NDM-1}}$ producing *A. baumannii* [40], *E. coli* and *K. pneumonia* [41] in Lebanon.

2.1.3. Israel

Israel has always been at war with the neighboring Arabic countries. During the Yom Kippur war, the infection rate rose from 4.9% to 58.3%, with *P. aeruginosa* being the most common pathogen [42,43,44], as was the case after the 1982 war in Lebanon [45]. These studies showed a low frequency of clostridial infections, in contrast to the result of the Korean War, due to the primary and sufficient surgical treatment including debridement, and the routine rapid administration of penicillin G to all cases with tissue destruction [44]. In both conflicts, the spread of infection was linked to the penetration of abdominal wounds concerning the colon, the loss of large and delicate tissues, burns representing more than 25% of the body surface, open drains drowned in the first operation, various operations and wounds located under the diaphragm [17,43,44]. Simchen et al [44] prescribed the early administration of clindamycin and gentamicin combination therapy for all abdominal injuries and treatment must be sustained for 48–72 h if colonic contribution appeared at laparotomy. This was valuable because the infections due to penetrating abdominal wounds involving the colon can be qualified to substantial colonic bacterial flora, especially the presence of *Bacteroides* spp. and *Enterobacteriaceae*.

During the Yom Kippur War, the administration of prophylactic antibiotics did not have a significant influence on the prevention of wound infection [17]. Moreover, this practice possibly contributed to the spread of infections due to the increase in the presence of Gram-negative rods [19,46].

2.1.4. Kingdom of Saudi Arabia

The diarrheal disease has been always a serious issue for military forces, especially during combat [47,48]. During operation desert shield, the US troops slept on beds in tents, or in sleeping bags on the sand or over equipment. In addition, sanitation facilities extended from open canals to indoor toilets and sheltered wooden latrines [49]. Under combat conditions, regardless of general efforts to provide a safe source of food and water, in addition to a high level of sanitation, infectious diseases can become a major risk to military forces, particularly when many soldiers are displaced. Between September and December 1990, stool cultures for enteric pathogens were collected from 432 military personnel presenting these following clinical signs: cramps, diarrhea, vomiting, and hematochezia. It has been shown that 49.5% of the troops with gastroenteritis were infected with a bacterial enteric pathogen, *E. coli* and *Shigella sonnei* being the most common bacterial pathogens [49].

2.1.5. Yemen

Yemen, located at the southern tip of the Arabian Peninsula, is a country with a population of about 25 million people, which recently witnessed one of the largest cholera outbreaks. Even before the conflict between the Yemeni regime and Houthi rebels, Yemen was among the poorest country of the Arab world, and considered among the most water-stressed countries in the world, due to droughts and lack of water [50]. In 2014, WHO-UNICEF statistics showed that only 53% of the population uses improved sanitation facilities and only 55% have access to clean drinking water [51]. The situation has obviously worsened since the beginning of the conflict. Millions of people have been evacuated and are now living in precarious situations, in places where shelters are unsanitary and water, sanitation, and food supplies are insufficient. The epidemic that began in October 2016 seemed to peak in December, before beginning to decline in April 2017, with about 25,000 suspected cases [9]. Cholera can be treated simply, but access to basic health care is hampered by war, in addition to the destruction of these centers, which have become more frequent in recent years, particularly in Yemen and Syria [9].

2.2. Wars in Iraq and Afghanistan

In recent years, Iraq and Afghanistan have been afflicted by multiple wars and military conflicts: the Iran-Iraq war, Operation Freedom for Iraq, the war on terrorism in Afghanistan and finally the recent war against the Islamic State of Iraq and Syria (ISIS). These wars have wounded many civilians and military alike, and millions of refugees have moved to areas where hygiene conditions are poor.

2.2.1. Iraq

During the Iran-Iraq war, the main weapon used was a missile. Contamination, metal fragments and the presence of retained bone are the main factors responsible for the growth of microorganisms, making the treatment of missile injuries a major challenge [52].

Between February 1981 and August 1987, 379 patients with missile head injuries and dural penetration were transferred to Nemazee Hospital in Shiraz for initial debriefing and closure. Infections happened in 18 patients, 16 of them had meningitis, where *K. pneumoniae* and *Enterobacter* species represented the most common isolated pathogen. The study revealed that the chance of contagion was augmented 20 times in patients with cerebrospinal liquid fistulas [52].

Orthopedic damage, related to the war, is frequently complicated by contamination of the environment, management delays, and putting patients at high risk for long-standing infectious problems. Between October 2016 and June 2009, a retrospective analysis was conducted on Iraqi patients suspected of having long-term war-related osteomyelitis and admitted to the Médecins sans frontières reconstructive surgery project in Amman. 107 patients have osteomyelitis with Gram-negative organisms representing 63% of isolates. The most frequently isolated bacteria were *E. coli* (20%), *P. aeruginosa* (18%), *K. pneumonia* (12%), *Proteus* spp (9%), *Enterobacter* spp (9%) and *A. baumannii* (4%). In addition, *S. aureus* was the most widely isolated bacteria and represented 21% of all isolates. This study showed the nosocomial infection in Iraqi health facilities [53].

In September 2015, Iraq encountered, in the Euphrates valley of the country, an outbreak of cholera. As indicated by WHO, approximately 2800 cases of *Vibrio cholera* were described in the state that was controlled by the ISIS. These two major problems, in addition to the complications related to the displacement and conflict, made the outbreak a severe problem [54]. According to WHO, in 2012, Iraq ranked 44th out of 212 countries and territories in terms of the estimated number of tuberculosis cases. It is deliberated among the nine countries having 'high tuberculosis burden' in the World Health Organization Eastern Mediterranean Regional Office (WHO-EMRO) Region, leading to 3% of the total cases of tuberculosis that were reported worldwide. The last protracted war, in particular, the one against ISIS, resulted in a decrease in the infrastructure and human capital capacity of the National Tuberculosis Control Programme (NTP) to provide active diagnosis, treatment, and prevention measures in the best-known country. In addition, this war has caused huge human displacements, which, under difficult hygienic conditions, has led to a high prevalence of tuberculosis [55].

2.2.2. Afghanistan

The war of more than two decades has had dramatic effects on Afghanistan. Due to tuberculosis, morbidity, mortality, and disability are of concern [56]. A study conducted in Afghanistan in 2002, showed that the frequency of active cases of TB is 278 per 100,000, and the mortality accounts for 15,000 cases per year [57]. Furthermore, the increase in the number of cases of TB among prisoners of war is an additional feature of war. This situation worsened during the war due to the disruption of tuberculosis control activities. Moreover, the absence of treatment facilities and overcrowded refugee camps have increased the risk of additional transmission [57]. After the attacks of 11 September 2001, hundreds of thousands of Afghans rushed to the border with Pakistan, many of whom were infected with tuberculosis, and lived in catastrophic circumstances that led to an increased incidence of tuberculosis [58].

2.2.3. Military operations in Iraq and Afghanistan

Over 46 000 US military personnel and 2000 British troops have been injured since the beginning of military operations in Afghanistan in 2001 and Iraq in 2003 [13]. Following the early emergency treatment in the combat field, around 30% of conflict-related trauma wounded have required aeromedical evacuation to military medical services in their host country for additional care. In Afghanistan and Iraq, the withdrawal route from the fields of operations is difficult, representing a continuum of medical care of wounded soldiers that work over several thousands of miles through a diversity of treatment facilities in diverse countries over adjustable durations. After an injury, American casualties are evacuated from the battlefield within 1 to 3 days, then transported by an average of four facilities, for example remaining in Germany for a short period of time, before reaching their final medical treatment facility in the United States within 6 to 8 days of their injury [59]. Therefore, the prospective for nosocomial colonization and infection of combat-injured personal with MDR organisms during the challenging procedure of treatment of wounded persons and evacuation is essential.

In 2004, an obvious proliferation in infections with *A. baumannii*, mainly with MDR organisms, was first described between the US military wounded injured in Iraq and Afghanistan. The wounded soldiers were first treated in the medical services on the ground before being transferred to Germany and the United States. In these services, between January 2002 and August 2004, 102 bloodstream infections of *A. baumannii* were identified, 83% of which occurred in injured victims in Iraq and Afghanistan, and the most common isolates showed a high level of resistance to a large group of antimicrobial agents [60]. Since initial reports, MDR *Acinetobacter* was considered a leading cause of osteomyelitis, respiratory infections, and deep-wound infections, and can lead to bacteremia in trauma-related combat-wounded person in Iraq and Afghanistan [61].

In 2013, a retrospective study, performed on 211 trauma casualties who were evacuated from Iraq to the US Navy hospital ship (USNS) comfort, revealed that there was a total of 56 infections. 84% of cases were due to wound infections, and 38% to bloodstream infections. The most common organisms found were *Acinetobacter* species (36%) followed by *P. aeruginosa* and *E. coli* (14% each) [62]. Another 7-year retrospective study evaluating changes in the prevalence of segregated MDR agencies from abroad combat local civilian and military casualties and casualties in an American military therapeutic center showed not only an increase in the occurrence of MDR *A. baumannii* from 4% to 55% mainly recovered from the airways but also that most of these isolates come from deployed wounded (52%) compared to neighborhood patients (20%) [63]. A study conducted in 2011, intended to molecularly study the imipenem-resistant *A. baumannii* isolated from the US service members who were injured in Iraq and Afghanistan from 2003 to 2008. 298 *A. baumannii* isolates were collected of which 46 were recognized to be resistant to imipenem. The strains isolated from different overseas and local military treatment services, exhibited, by PFGE, a 90% genetic similarity. These results provide a possible cross-transmission of bacteria during the environmental contamination of treatment facilities [64]. Another study confirmed these findings and reported a significant increase in the frequency of MDR *Acinetobacter* complex infections among military casualties evacuated from Iraq and Afghanistan, resulting in osteomyelitis, extreme soft tissue contamination of deep wounds and burn infection [65]. Furthermore, other studies on osteomyelitis and deep-wound contagions in military patients with conflict-related orthopedic injuries have established the high prevalence of Gram-negative organisms, particularly *Acinetobacter* spp., in polymicrobial infections and that at the same time primary infections are more frequently related to these organisms [66]. It has been demonstrated that, in Iraq and Afghanistan, the major mechanism of injury sustained through operations comprises burn in 5-10% of combat-injured person [67,68]. A recent study, evaluating burn infections between deployed and non-deployed civilian patients who received treatment in a US military facility, revealed the prominence of *A. baumannii* as the most common organism among military burn victims who were injured during actions in Iraq and Afghanistan (58%), unlike *S. aureus* in non-combat patients (46%) [69]. From January 2003 to May 2006, a surveying cohort study was achieved to evaluate bacteremia in the burn-patient population in the US Army Institute of Surgical Research burn center. 1,258 patients who were hospitalized became bacteremic during their admission to the burn center. Of these, 92 had bacteremia with the highest four types of pathogens in this burn center, such as *K. pneumonia, A. calcoaceticus-baumannii* complex, *P. aeruginosa* and *Staphylococcus aureus* [70].

In response to the perceived proliferation of infections among American military victims, several studies have been conducted to determine the source of infections. Numerous possible sources of infection have been measured and examined, including the contamination of environments such as soil, with the introduction of the infection at the period of traumatic injury, pre-injury skin colonization, the transmission of nosocomial disease and gaining of infection after injury in healthcare facilities. It has been shown that prior to deployment to Iraq or Afghanistan, about 17% of a population of 102 healthy American soldiers on active duty, had *Acinetobacter* complex that colonized their skin [71]. Furthermore, these strains were not related to strains isolated from injured soldiers admitted to military medical facilities, neither genotypically by ribotyping nor phenotypically by antimicrobial susceptibility testing. In addition, due to the presence of *A. baumannii* species everywhere in nature, environmental contamination may be a source of infection at the time of injury. These assumptions are established before species differentiation within the genus and are probably inappropriate. In their study, Scott et al. [30] included environmental soil sampling and sampling from organized healthcare services. Results reported that out of 49 soil samples collected from inside and around seven field hospitals in Iraq and Kuwait (18 collected during environmental sampling and 31 archived soil samples), *A. baumanii-A. calcoaceticus* (ABC) complex was found in 1 sample only. The remaining 36 isolates were gotten from samples of the playing field hospital environment. Studies have never been able to identify a natural habitat for these living organisms outside medical services and have only rarely been isolated from water and soil samples, probably reflecting the hospital environment, rather than the natural environment as intrinsic habitat. Other studies showed that non-US patients, who have encountered broadened hospital admissions and have regularly moved among the US and Iraqi hospitals, may have served not exclusively to introduce *A. baumannii* and gram-negative bacilli into military treatment facilities, but also a reservoir for nosocomial transmission of infection [72–75].

Far from the common gram-negative bacilli and *A. baumannii*, data from the recent wars in Iraq and Afghanistan associated with war injuries and mandatory anaerobes are limited. It has been assumed that the anaerobes complicating war wounds came from the environment, mainly the soil [76]. A study by White et al. [77], demonstrated that of a total of 4180 US combat casualties therapeutically dislodged for treatment in Germany during the investigation, 59 had developed obligate anaerobes on culture, where *Bacteroides* spp. was the most prevalent organism, in contrast to the previous results, that showed that species *Clostridium* species were the main obligate anaerobes amongst war trauma (WWI to the Korean War).

In addition, many studies have described uncommon bacterial infections that were isolated during the wars in Iraq and Afghanistan. A study conducted in 2011, reported the infection due to the presence of *Brucella melitensis* following military duty in Iraq [78]. Infections associated with the ingestion of high-risk foods or travel to endemic areas are less prevalent in the United States but are more frequent in the Middle East. The case involved a 23-year-old patient who was sent back to the United States after his second deployment to Iraq, where he participated in combat and patrol operations.

On the other hand, it has been shown that rickettsial and rickettsial-like diseases have played a significant role in military activities through history [79]. These diseases, which can be spread internationally and cause a large number of diseases and deaths, can contain the selective agents *Coxiella burnetii* and *Rickettsia prowazekii*, which are the main cause of typhus and Q fever outbreaks respectively. In 2011, in the province of Bamiyan in Afghanistan, the outbreak of brucellosis and Q fever among indigenous people, the significant existence of rickettsiae from the spotted fever group (SFGR) and the presence of vectors carrying SFGR, highlight the essential risk of contracting rickettsia disease in Afghanistan. A recent study performed among the US marines who had been deployed in Afghanistan from 2001–2010, revealed the presence of seroconversions for *Coxiella* and Rickettsial pathogens. It also revealed that the frequency of *C. burnetii* was 3.4% and that of SFGR seroconversions was 0.5% [80]. This study emphasized the risk of contracting Q fever and the urgent need to diagnose Q fever in military actions in Central Asia.

Troop disease, such as acute respiratory disease (ARD) poses a severe public health problem to an organized army. In November 2006, an important proliferation of ARD was perceived in soldiers of different nationalities, with an increase of 10-fold through the French troops at week 51 in Kabul, Afghanistan. This epidemic, mainly due to pertussis, highlights the importance of non-traumatic diseases in wartime, when the circumstances of the military field improve exposure to endemic diseases and their incidence [80].

2.3. Wars in East Asia

Few studies have described bacterial infection during wars in the eastern zone of the continent. During the Korean War, which ran from 25 June 1950, to 27 July 1953, prisoners of war (PgOW) fighting for the socialist side of North Korea and the People's Republic of China were imprisoned in camps administered by the United Nations. The camps have been built on Geoje-do (Geoje island), Jeju-do, and various continental areas of the southern part of the Korean peninsula under the American cape, and the largest camp was established in Geoje-do. Several studies have revealed the reasons for the deaths of prisoners of war during the Korean War [81,82]. A most recent investigation has reported that the most widely recognized reason leading to the death of POW's was infectious diseases, where tuberculosis and dysentery/diarrhea were considered the most well-known or driving reasons for death, trailed by tetanus [83]. The study reported that the death of prisoners by infection disease was principally due to two reasons. First, the Korean population experienced weakness during the war, with low immunity and low resistance to pathogens due to an inadequate diet. Second, the idea of sanitation in Korean society was new and poor [83]. In addition, the large population of prisoners of war camps could allow the rapid spread of infectious diseases, aggravate sanitation problems in the camps and lead to a decrease in individual sanitation. Another investigation conducted in Japan described cutaneous melioidosis in a man who was taken as a prisoner of war by the Japanese during World War II [84]. The infection caused by the presence of Gram-negative bacillus *Burkholderia pseudomallei*, is endemic to Southeast Asia and Northern Australia. The human infection develops by contact with water contaminated by percutaneous inoculation, which clarifies the contamination in this inmate who presented himself with a non-healing ulcer on his right hand.

2.4. Wars in central & South-East Asia

Vietnam has been considered a war-torn country for a long time, with masses in constant motion and countless refugee camps. Several studies have reported bacterial infections during the Vietnam War. A survey of the Vietnam War revealed the presence of 112 initial wound cultures, 2 of which were recognized as *Alcaligenes* (possible *Acinetobacter* species). The other gram-negative pathogens recognized included *Aerobacter aerogenes* and *Pseudomonas* species. However, no *Acinetobacter* species or Mimeae-Herellea-Bacterium-*Alcaligenes* group were portrayed [16]. In Japan, an analysis of 1531 initial wound cultures was carried out by wounded American soldiers in Vietnam in 1967 and 1968 and revealed that the most widely recognized Gram-negative bacteria were *P. aeruginosa, Proteus species, E. coli, Aerobacter aerogenes* and *Klebsiella pneumonia* [85]. Throughout the orthopedic war wounds assessed at Brooke General Hospital (Brooke Army Medical Center) during the Vietnam conflict, 100 tissue samples showed that the most common Gram-negative bacteria were: *P. aeruginosa, Klebsiella-Enterobacter* group, *Proteus species*, and *E. coli* [86]. Unlike other wars, *A. baumannii* did not play a role in the Vietnam conflict.

Moreover, bacteriological studies were performed on 45 craniocerebral missile wounds that were incurred in Vietnam within 2 to 4 hours of incidence. All rockets had entered the brain. Cultures that were aerobically and anaerobically were taken from the skin wound, brain, and driven bone fragments. Forty-four of the skin wounds were infected mostly with staphylococcus. Only five brain wounds presented bacterial infection following 2 to 4 hours after hurting, showing that various missile tracks inside the brain are sterile at first. Of the patients who required rapid debridement, 45% had infected bones inside the brain; about 75% of all dragged bone fragments could be disinfected. This study reported that subsequent bacterial attack of the cerebral parenchyma from infected bone or skin wound can occur and may lead to the development of a cerebral infection as the time interval between injury and complete neurosurgical debridement with dural and skin closure increases [87]. Vietnam was considered one of the endemic regions of the world for the plague, and since 1962, the number of cases described has gradually increased, particularly during the Vietnam War. Those conditions in Vietnam have been considered favorable for the spread of the disease: the harmed of villages and towns by military activity gave adequate breeding places for rats, and unmoved trash offered a nourishment supply near individuals [88]. Overcrowding, for example, refugees and people who have been made homeless have made the situation worse. In January and February 1966, 44 occasions of plague with 36 passing happened in Hoa Do in Vietnam [89]. This was the prime incidence of plague to be investigated in the city.

As mentioned earlier in this review, TB is an undeniably imperative driving component of morbidity and mortality among refugees and displaced people. Between June and December 1998, 178 people were infected with tuberculosis during the civil conflict in the Churachandpur region of India [90]. However, tuberculosis treatment and control were possible in this region, unlike civil conflict, and WHO's treatment objectives were achievable. The factors that were related to the success of the program were the strong support of the local community, the choice of the outreach specialists from each social group to allow admission to all areas and patients, the use of specifically observed treatment three times each week rather than day by day in light of a legitimate concern for expanded security and the reduction of distances traveled by outreach workers and patients.

Wracked by civil war, Tajikistan has rehearsed the most elevated revealed rates of diphtheria observed in the epidemic that cleared across the Newly Independent States (NIS) of the former Soviet Union. The factors that worsened this situation during the 1992 civil war are the increase in the number of people who have not been vaccinated, the failure of disease surveillance and social insurance administration, the civil war, the proliferation of the movement, the lack of qualified medical personnel and the lack of resources, products and services [91]. The distribution of bacterial infections in countries affected by wars is shown in (Figure 2).

3. Prevention of bacterial infections during wars

The prevention of bacterial contamination by wars depends on the prevention of these infections among wounded citizens, refugees, and soldiers. Refugees or displaced people are the common thread of public health and play a significant role in the spread of bacterial infections. At present, there is no agreement on screening and infection control measures for refugees. Upon admission of refugees, guidelines for screening have been discharged in Germany and Israel, while there was no particular guideline regarding pediatric refugees. However, numerous reports demonstrate that the displacement of refugees and migrants harboring the MDR pathogens can constitute a risk factor to introduce the MDR pathogen into non-endemic or low-endemic host nations, thus representing a serious public health problem [26,92]. Routine carriage tests should be carried out on the date of admission to a refugee and migrant health care facility for MDR pathogens, including adolescents and children, and contact-protected hospitalization should be recognized until screening results are available, in order to prevent cross-infections of MDR in the medical setting [10].

In addition to the screening of MDR pathogens, scan for TB was also necessary. A sufficient organization of TB care services across borders can prompt expanded quality of care and thus a break in the transmission. Recently, the WHO Regional Office for Europe and the TB Advocacy ad-hoc Working Group of the European Respiratory Society have proactively propelled a new office of the TB Consilium (a free Internet-based platform) in order to allow a better cross-border TB control through refugees and migrants [93]. Besides, admission to persistent healthcare services is of extraordinary significance for the prevention and control of TB among refugees and should be part of a general way to deal with their healthcare needs [94]. Although the screening of pathogenic bacteria and MDR organisms among refugees is a priority to avoid bacterial dissemination, good hygiene, sanitation and access to clean water in refugees' shelters represent a major key in preventing the dissemination of bacterial infections. Infection prevention among the war-wounded includes not only good hygiene, sanitation and the use of clean water but also several steps from evacuation to post-operative wound care must be carried out (Figure 1).

3.1. Evacuation time and nosocomial transmission

During the evacuation of the harmed soldiers back to their homes in their countries, evacuation time was the most important factor of nosocomial transmission. A study conducted by Kaspar *et al.* showed that a relationship between war wounds, the evacuation chain and the transmission of nosocomial pathogens do exist [59]. The nosocomial transmission of organisms acquired from the hospital remains a vital risk to all patients. Healthcare-associated infections can be related to transmission by different patients, to therapeutic specialists or to the physical condition itself. In the midst of the Iraqi conflict, prisoners and ordinary citizens in the neighborhood represented up to 50% of patients in organized field hospitals [95]. In any case, when union troops can stay in deployed hospitals for a few hours before cleaning, the time spent by indigenous troops, civilians and prisoners can be much longer. Inadequate medical infrastructure and the lack of treatment may require these people to stay for a long period of time. These circumstances represent an 'open reservoir of pathogenic bacteria' as described by Miles *et al.* [96]. These surveys assumed that nosocomial infectious diseases increased throughout the healing time. These investigations presumed that the nosocomial infectious disease increase, as the clearing time last. Therefore, infection

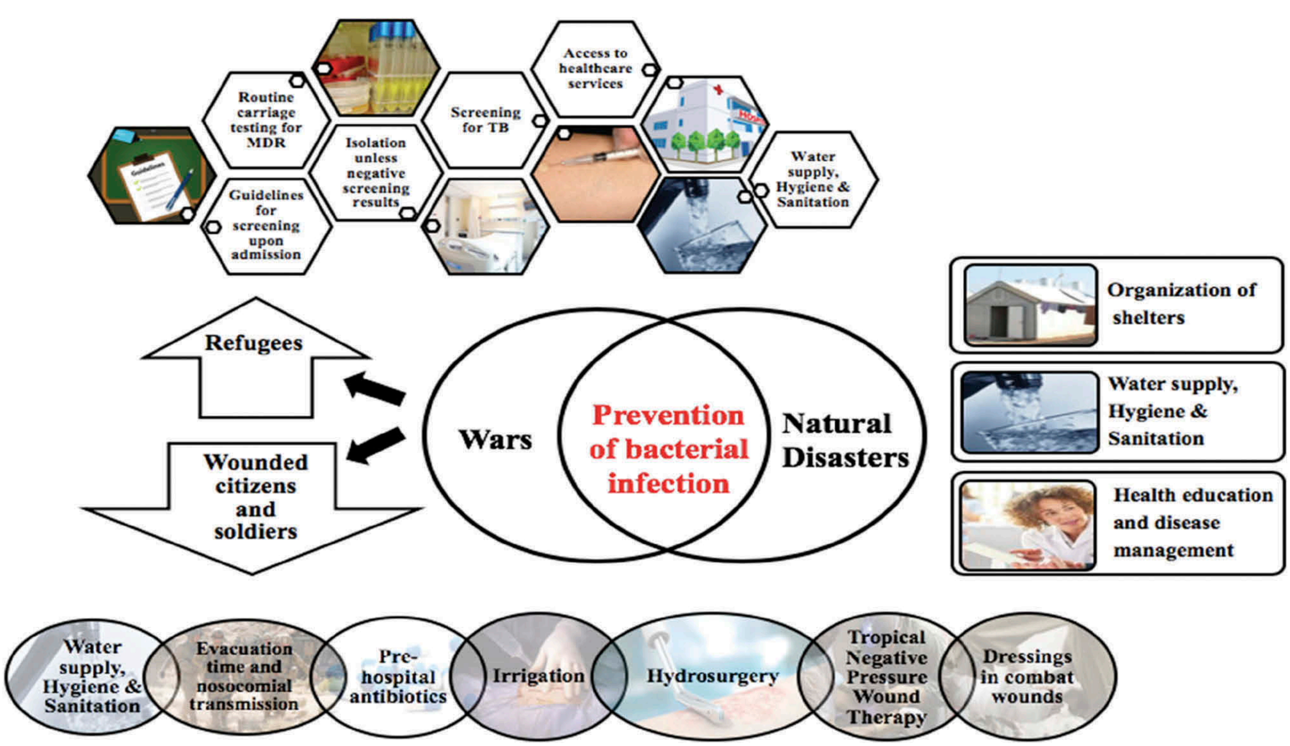

Figure 1. Prevention of bacterial infections during wars and following natural disasters.

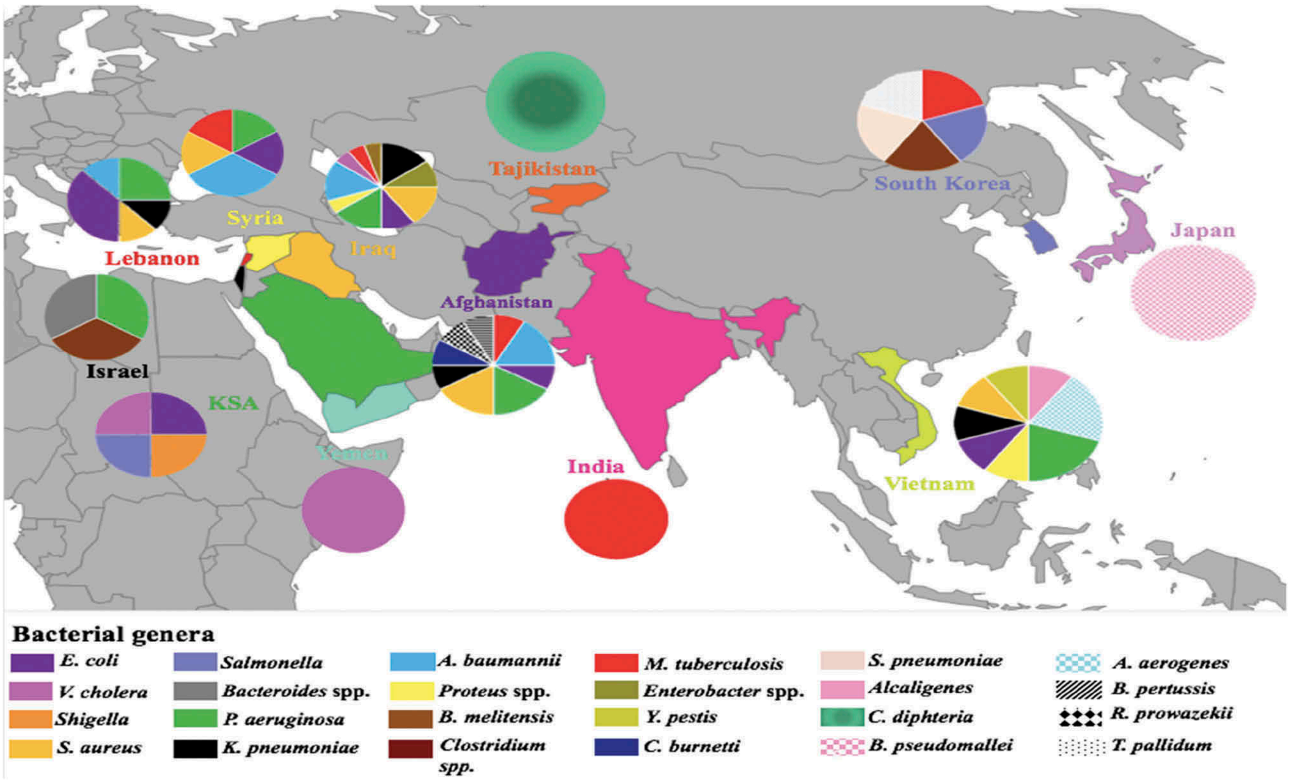

Figure 2. Distribution of bacterial infections in countries affected by wars.

prevention and control within the medical chain is currently recognized as a high need in medical facilities, which includes:

- Up to dated structure and development of healthcare facilities
- Appropriate infrastructure
- High level of surveillance of the infections and 'alarm' organisms
- High level of education
- Trained people to control infection, both as a major aspect of the organized hospital strength and 'reach-back' capacity to home nation-state subject matter experts (SMEs) [20].

3.2. *Pre-hospital antibiotics*

The detail behind the administration of prehospital antimicrobial agents to the military is based on inadequate animal studies [97] and on timeframes suggested in an investigation of just 49 cases [98]. More strong animal models ought to be set up to analyze the adequacy of antimicrobial agents and their conveyance frameworks. These models need to cover all kinds of wounds and all the different types of bacteria related to the infection of the wound. Until then, standard practice with thin spectrum agents only for delayed migration remains the most appropriate practice.

3.3. *Irrigation as a complement to debridement*

Animal studies have shown that wound irrigation can reduce postoperative infection and resulting contamination, compared to wounds that have been done in a comparable manner and for which no irrigation is done have demonstrated that irrigation of wound can decrease postoperative infection and resulting contamination when compared to those wounds that were made comparable in which no irrigation is done [99]. For more than 30 years, the delivery of irrigation water by high-pressure methods has been the subject of discussion. The use of pulsatile lavage (PL) for irrigating wounds that were contaminated has been uncovered after beginning preclinical work [100]. Several studies showed that PL was an efficient and well-organized technique of irrigation to eliminate bacteria than the technique of conventional irrigation [101]. Svoboda *et al.* [102] used PL to compare the use of water against normal saline. However, they were able to demonstrate that there was no distinction in bacterial counts between the two groups. Another study looked at both the delivery mechanism of low versus high-pressure irrigation and the use of various solutions [103]. This study shows that none of the solutions tested is better than sodium chloride and that the best choice for wound irrigation was to use a low-pressure device using a saline solution. A study conducted by Owens & Wenke [104], showed that prior irrigation will probably have more effect. It seems plausible, based on the reviews conducted to date, that wound irrigation may have an impact on reducing wound infection rates.

3.4. *Hydrosurgery as a complement to debridement*

Hydrosurgery might be the new expansion to the armamentarium of the military doctor. It depends on the use of high-pressure irrigation in a blend with conventional sharp debridement in a solitary hand device and has a vital role in battle wounds particularly for rehash debridement at reconstructive surgery. In addition, this strategy has shown a decrease in initial bacterial counts, as well as a decrease in overall operating time and costs, which probably makes it invalid in advanced surgical care, at least currently.

3.5. Post-operative wound care and infection: tropical negative pressure wound therapy (TNPWT)

TNPWT exposes the wound bed to an environment of negative pressure and by twisting the wound edge, a signaling cascade is known that ultimately leads to the formation of granulation tissue and wound healing [105]. It has been demonstrated that TNPWT can decrease the time from injury to decisive wound coverage, which may indirectly influence the wound contamination rates [106]. In an animal model, Lalliss et *al*. [107] showed a decrease in the number of bacteria in TNPWT compared to a standard dressing in a contaminated open fracture model. Additionally, Waterman *et al*. [108] examined the execution of various TNPWT systems in an infected wound of animal model and found no important variance in the decrease of the bacterial count among various fragments of equipment. They presumed that it was the technique rather than the specific equipment that was important.

3.6. Post-operative wound care and infection: use of dressings in combat wounds

Military soldiers providing remote surgical care cannot benefit from the TNPWT technology that is suitable for conventional hospitals. Enhancing wound care is guaranteed by starting dressings that are applied to the wound. However, there is no evidence as to the best dressing to use for the preliminary care of the infected military wound, despite the fact that the examination is currently in progress [20].

4. Bacterial infections after natural disasters

Natural disasters are considered a major global problem and represent a high risk to humans as they lead to increased morbidity and mortality. The alterations in climates, such as global temperature alteration, have been proposed as the fundamental causes for the expanded severity of these disasters [5]. Natural disasters pose a public health problem because they cause the emergence of infectious diseases such as cholera, bacillary dysentery, melioidosis, leptospirosis, typhoid fever, and malaria. These disasters could be partitioned on water-related catastrophe such as floods, tsunamis, typhoons (hurricanes and cyclones) and non-water related disasters such as the volcanoes and earthquakes.

The exposure to environmental water increases the risk of skin infection; even in recreational marine or freshwater environments with no known source of infection because of residential sewage. During water-related disasters and due to contact with waste and sharp objects lying invisible in unclear waters, and by adhering to trees or climbing structures in attempts at self-rescue, wounds can occur and infections may consequently develop [4]. Moreover, even in the absence of wastewater contamination of water, infections can occur in saltwater due to the presence of *Vibrio vulnificus* and atypical mycobacteria or in fresh water due to the presence of *Aeromonas hydrophila, Burkholderia pseudomallei* (melioidosis) and *Leptospira interrogans* [4]. Furthermore, disasters that were related to water might also cause the interruption of the purification of water and the systems of sewage disposal, a burst of underground pipelines and storage tanks and flooding of poisonous waste. This can prompt expanded presentation to contaminated waste, food and more pathogens, which can lead to gastrointestinal disease [109]. On the other hand, numerous diseases can also occur in non-water related disasters, such as earthquakes and volcanoes. These diseases include cholera, TB and other respiratory diseases. A major leading cause for the outbreaks of such disease might be due to the movement of large numbers of people from their homes into overcrowded shelters where provisions may be restricted [5]. Moreover, the availability of medical services after such natural disasters may also pose a major problem [110]. The infectious diseases outbreaks that occur after a natural disaster are summarized in Table 1.

4.1. Floods

One of the most common and severe forms of natural disasters is a flood, which represents up to one-half of all-natural disasters on the planet [111,112]. The intensity and frequency of flooding are expected to increase due to sea-level rise and more frequent and extraordinary precipitation [113]. China is considered one of the most flood-prone countries in the world. There are many factors that promote a high risk of exposure to floods, such as the large population, complex topography, climate conditions and sudden urbanization [109]. During the flood that occurred in Huai river in 2007, the most generally announced diseases were malaria, diarrhea, and bacillary dysentery, with an incidence rate of respectively 17.867/100,000, 8.113/100,000 and 3.474/100,000 [109]. A quantitative study of the burden of bacillary dysentery related to flooding in Hunan, China, showed that these floods were responsible for the increased risk of cases contaminated by bacillary dysentery (Odds ratios (OR) which were used to quantify the risk of the floods on the disease is equal to 3.270, in Jishou; and OR = 2.212, in Huaihua) [114].

In addition, between July and August 2010, Pakistan skilled severe flooding that affected about18 million persons. A surveillance study was conducted for outbreak detection and response. The main diseases identified were acute watery diarrhea, bloody diarrhea, and intense respiratory infection. This observation contributed to the quick disclosure of cholera, bacillary dysentery and intense pneumonia [115]. Almost every 12 months, many parts of Assam, India, observe flooding during the monsoon season, which is the rainy season. This flooding resulted in the receipt of a lot of additional water in the glacier-fed Himalayan river system (Brahmaputra). Regularly the following flood, the country was affected by the challenge of diarrheal diseases, with the most common cholera. In a study conducted on distinct sites from the states demonstrated that there was an increase from 40% before monsoon to 86% during monsoon for the sites who were

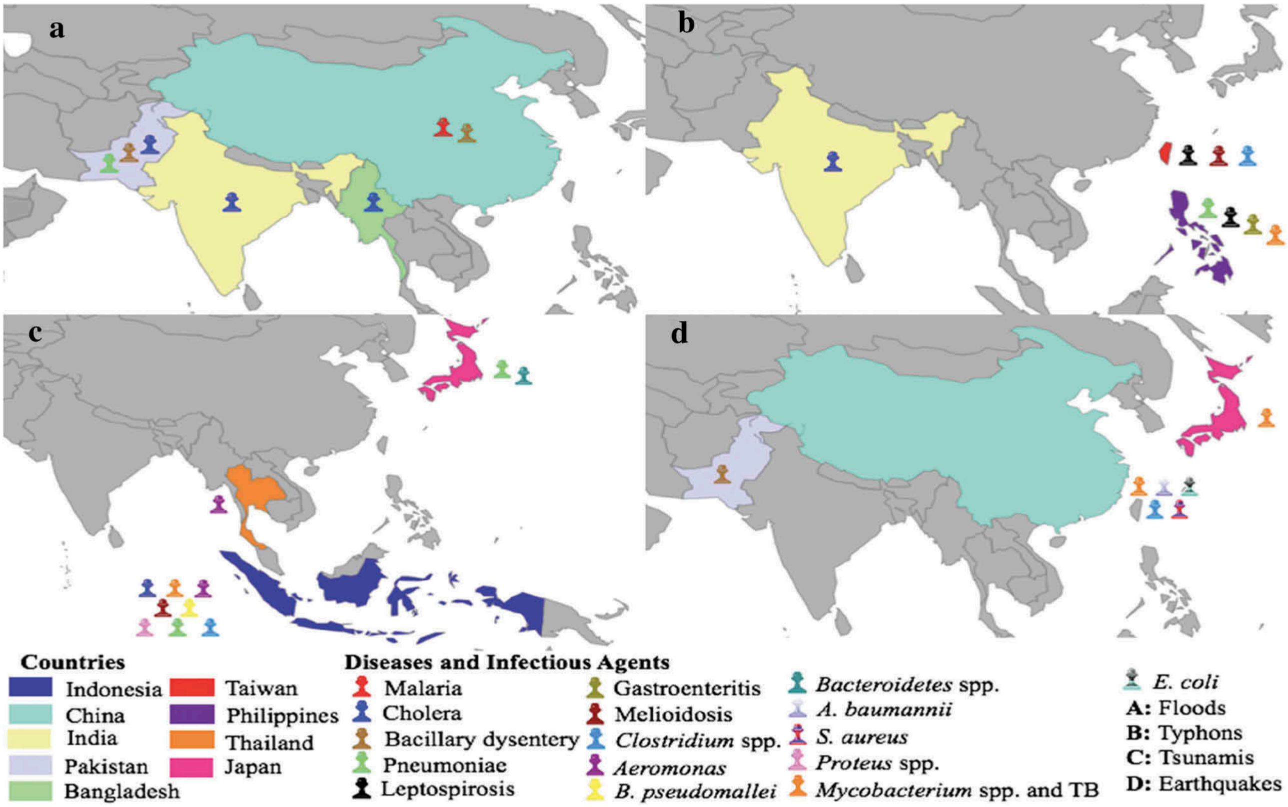

Figure 3. Distribution of bacterial infections in countries affected by natural disasters.

found to be positive for the presence of *V. cholerae* [116]. Numerous different studies described the outbreaks of cholera after a natural disaster, especially after floods in India [117,118] and in South East Asia, in Bangladesh for instance [119]. The distribution of bacterial infections in countries affected by floods is shown in (Figure 3(a)).

4.2. Typhoons (hurricanes and cyclones)

Depending on the geographic location, typhoons can be hurricanes or cyclones. It is a storm system characterized by the speed of winds that range from 119 km/h to over 252 km/h on the scale of Saffir-Simpson. Between 1980 and 2009, typhoons caused around 412,644 deaths and 290,654 injuries and affected 466 million people [120]. The effect of typhoons is going beyond direct deaths and injuries. The spread of bacterial infections and the harm of public health infrastructures, cause long-term health outcomes on the population.

In Asia, the Philippines is well recognized to be a very susceptible disaster-prone country. In September 2009, a typhoon triggered severe flooding in Metro Manila. After that typhoon, an epidemic of leptospirosis took place; where 471 patients have been hospitalized and 51 patients died [121]. In November 2013, a heavy storm produced by Super Typhoon Haiyan (Yolanda) overcomes the whole coastal areas of Tacloban and Palo in Leyte, Philippines. Two months after this heavy storm, a study was conducted on soil samples along with these coastal areas. They found that 22 out of 23 samples contain Leptospires. When they mixed those strains with soil, they found that those isolates were able to survive in seawater for 4 days. These results demonstrate the possibility of leptospires to live in soil and to survive after the storm surge. These results can serve as a warning: in a disaster where saltwater covers the land, a leptospirosis outbreak could occur in the region affected by such a disaster [122]. After the same typhoon, a retrospective study was carried out between October and February 2013, on patients admitted to Ormoc District Hospital (ODH) in Leyte, Philippines. It has been noticed that prior to the typhoon, the major medical causes of admission to the hospital for adults and children were gastroenteritis and pneumonia. Later, there was an important increase in their incidence. The contaminated water from the municipal water system caused an epidemic of gastroenteritis. In addition, an increase in the number of cases of tuberculosis patients has been reported due to treatment interruption and lack of access to health facilities [123].

In 2009, the coastal islands of the Sunderbans, the biggest delta islands in the world, which is located in the southern part of West Bengal, eastern India was hit by the main cyclone named Aila at a speed of 120–140 km per hour. The disturbance of the water distribution system and the inadequate hygiene situation that followed this cyclone was responsible for the cholera outbreak [118,124,125]. Also in 2012, the area of Pondicherry, Southern India, was affected by the severe cyclonic storm and it was the reason for the additional cholera outbreak. In addition, another study found that the ingestion of contaminated water by drainage after the cyclone was the main cause of the cholera outbreak [6]. In 2009, the moderate-strength Typhoon Morakot, with an extreme cumulative rainfall amount up to 3,059.5 mm, damaged Taiwan and lead to the dissemination of leptospirosis and melioidosis cases [126,127]. Furthermore, after the severe floods caused by the typhoon Morakot, the presence of *Clostridium tetanus* and *Clostridium chauvoei* in Pingtung country increased meaningfully from 13.73 and 7.84% to 53.85 and 50.00%, respectively. These results were obtained from an analysis performed in Taiwan on soil samples collected from different regions that are most frequently spoiled by the typhoon. This study also revealed that there are changes in the environmental distribution of *Clostridium spp*. after a water-related disaster and showed that screening for soil-bound zoonotic pathogens is a prospective strategy that can help control the spread of these diseases [128]. The dissemination of bacterial infections in countries affected by typhoons is shown in (Figure 3(b)).

4.3. Tsunamis

Tsunamis are considered the nightmare of all coastal lands. The most frequent countries affected by tsunamis in the world are East (Japan) and South-East (Indonesia, Thailand) Asian countries. Ordinary bacterial pathogens, such as pyogenic *Staphylococcus* and *Streptococcus*, are the major cause leading to skin infections following tsunamis and flooding and ought to be treated with suitable antibiotics. On the other hand, another less frequent bacterial infection related to marine (e. g. *Vibrio vulnificus*) or aquatic (e. g. *Aeromonas hydrophila*) habitats may occur, much of which is naturally present in the soil, vegetation and waters of some geographical areas. Though, tsunamis lead to an expansion in the exposure to these pathogens, leading to an increase in infection rates [4]. In December 2004, the west coast of Thailand was submerged by a tsunami that left 8457 people injured and 5395 dead. Following this disaster, a great number of infections due to the presence of *Aeromonas* were reported. 777 patients have been moved from southern Thailand to four Bangkok hospitals. Among them, 515 (66.3%) had Skin and Soft Tissue Infections (SSTIs) and the most common isolated organism was *Aeromonas*, which accounts for 145 (22.6%) of 641 bacterial isolates [129]. Additionally, the Bangkok Hospital in Phuket, Thailand, stated that about 25% of the isolates from hundreds of patients with extended water exposure contained *Aeromonas* [130].

All over the world, atypical mycobacteria are non-tuberculous, slightly acid-resistant bacilli that could be abundant in soil and water in many environmental media. They are the primary cause of infections in healthy individuals, mainly when traumatic wounds are exposed to water that is contaminated; in addition, they are more virulent in patients who were immunocompromised. Following the Asian tsunami in 2004, many reports of patients diagnosed with these atypical mycobacterial infections have been published [131,132]. In one study that described 15 tsunami survivors who suffered from traumatic injuries and consequently developed late-onset SSTIs, mycobacterial isolates comprised seven cases of *M. abscessus*, six cases of *M. fortuitum* and one case each of *M. peregrinum* and *M. mageritense* [132].

In Southeast Asia and coastal areas of Australia's Northern Territory, the major cause of the disease was mainly due to the presence of *Burkholderia pseudomallei* that infects humans and animals. This disease is developed after direct exposure to polluted soil or water and has an increased prevalence all through rainy or monsoon seasons, tsunamis and floods. Furthermore, after the 2004 Asian tsunami, there are many reported cases of severe post-immersion, aspiration pneumonic melioidosis [133,134], and *B. pseudomallei* cutaneous wound infections [135,136,137]. In addition, the same tsunami influenced different neighboring countries, such as Sri Lanka, India, and Indonesia, which represent the huge loss portion. A study was performed in Indonesia to determine the impact of this tsunami on health [138]. It has been shown that in the first month following the tsunami, up to ninety-six cases of tetanus had been depicted in Aceh with a plague crest between January 8 and 17 of the year 2015. This was due to the low inclusion rates of vaccination of tetanus in Aceh that represented a main post-tsunami risk of the disease. Moreover, in a clinic of the Indonesian army, wound infections represented 16.9% of all patients diagnosed. In addition, the WHO reported that through the first five months that followed the tsunami, 37,492 cases of acute respiratory infections have been described [138].

19 months following the tsunami in Banda Aceh, another study examined the presence of pathogens in natural aquatic habitats in the affected area. At the same time, interviews were performed with tsunami survivors to decide the leading factors that facilitated wound infections following the tsunami. Out of the 49 water samples examined, *Aeromonas* sp., *Vibrio* sp., *Klebsiella* sp., and *Proteus* sp. have been removed from 24, 16, 15, and six samples, respectively [139]. This confirms the results of previous studies that have shown that bacteria in natural aquatic environments are a vital source of infection.

An earthquake happened off the coast of eastern Japan on 11 March 2011, which has been named the Great East Japan Earthquake that caused an enormous tsunami that leads to 20,000 deaths and left 23 million tons of debris. Sludge transported by the tsunami may contain pathogens with the ability to hurt workers. In 2011, a study was carried out in Japan to detect bacteria introduced into the sludge in order to determine the fundamental safety measures for personnel handling the sludge [140]. The study revealed the presence of 51–61 genera in sludge samples and 14 and 17 genera in water samples that were collected from the areas affected by the tsunami. The major genera that were collected in sludge samples, belonged to *Proteobacteria* than to *Bacteroidetes*, and the main genera collected from water samples belonged to *Bacteroidetes* than to *Proteobacteria*. They concluded that sludge brought by the tsunami contained a few pathogens; in this way, frequent hand washing is prescribed for workers who have direct contact with the sludge to reduce the risk of infection. Within 3 weeks of the same tsunami, there was an increase in the number of pneumonia patients and deaths who were admitted to the local hospitals. A multicenter survey was carried out in three hospitals of the Kesennuma City (population 74 000), northern Miyagi Prefecture [141]. 550 cases of pneumonia hospitalizations were identified, with 225 cases occurred throughout the post-disaster period. Due to the suction of seawater, a clear increase in the prevalence of pneumonia was detected in the 3 months following the disaster [141]. Other studies have also reported a similar kind of infection during this tsunami [142,143]. Figure 3(c) shows the spread of bacterial infections in countries affected by tsunamis.

4.4. Earthquakes

After floods, the second most reported natural disaster and the first of the geophysical disasters are the earthquake disasters. They are particularly described in regions with excessive seismic activity such as America (central and south) and Asia (southeast and central Asia). The earthquake disasters lead to substantial dislodgment of the population into spontaneous and stuffed shelters, with inadequate access to food and safe water, thus leading to outbreaks of infectious diseases. Additionally, the earthquakes cause the destruction of water/sanitation structures and the degradation of sanitary conditions leading to disease outbreaks [3]. Among victims, the contamination of feces and of water during transportation and storage is one of the leading causes of the epidemics of diarrheal diseases. In addition, sharing water containers and cooking pots, scarcity of soap and contaminated food can be additionally related to the outbreaks of the diseases. In Pakistan after the earthquake that occurred in 2015, there was an increase of 42% in diarrheal infections that had been reported in an unplanned and poorly equipped refugee camp [144]. This was due to poor hygiene, swarming, the absence of potable water and lack of sanitation. Following the same earthquake, another study showed that wound infection was the most widely recognized complication in the earthquake patients because of the infection of wounds by debris caused by the earthquake [145].

In a post-conflict situation, TB is considered the most important treat in refugee settings. Factors that increase the disease problem include the displacement of the population, poor access to healthcare facilities and disruption of on-going treatment or control programs. After the Earthquake of Great East Japan that occurred in 2011, several studies have reported the increasing frequency of TB [146–148], which was due to different factors, such as the overcrowded shelters, poor hygiene, and sanitation. Moreover, in 2008, the increasing rates of TB were described in China after the earthquake that hits Wenchuan [149]. Several other reports have described wound infections among patients who were still alive after that earthquake [150–152]. The most common isolated bacteria were *A. baumannii, E. coli* and *S. aureus*. During the Wenchuan earthquake, most patients have been covered under ruins with soil, stone or block. Following the rainstorm and high temperatures, the circumstances turned out to be far worse and most of the wounds reported were severely contaminated. On the other hand, the cases of patients affected with gas gangrene caused by earthquakes were rarely described, and no hospitals described the admission of patients suspected of having gangrene gas in the time following the earthquake. In the victims of the Wenchuan earthquake, a study was conducted to examine the clinical characteristics, appropriate treatment and successful control of the nosocomial cross-infection of gas gangrene [153]. The results showed that there were 67 suspected cases of gas gangrene, including 5 positive cases for the presence of *Clostridium perfringens*, due to the following factors such as serious and long-term injuries (which promote infection) and decreased hygiene in medical centers. The distribution of bacterial infections in countries affected by earthquakes is shown in (Figure 3(d)).

5. Prevention of bacterial infection after a natural disaster

Numerous studies have described the direct effect of natural disasters on public health, leading to an increase in mortality and morbidity rates. The outbreaks of diseases and bacterial infections are considered a major problem in disaster settings. The results of devastating disasters such as the Great Eastern Japan Earthquake and tsunami (2011) and Hurricane Katrina in the USA (2005) have shown that even the best-developed countries are vulnerable to natural disasters. Risk evaluation is fundamental in post-disaster circumstances and an urgent strategy needs to be implemented to prevent the dissemination of bacterial infections. Prevention of bacterial infections after natural disasters is shown in (Figure 1)

5.1. Organization of shelters

Shelters have to be structured according to the standard international guidelines [154]. This consists of giving 3.5 m2 of shelter space per individual, constructing one toilet for every 20 persons and putting the lavatories at 30 m far from shelters and 100 m far from water supplies [155]. This good organization of shelters enables to prevent water-borne and air-borne diseases.

5.2. Water supply, hygiene, and sanitation

The proper supplies of water per individual (minimum approved standard of 20 l for each individual every day) for drinking, showering, washing and excreta disposal, as well as control of solid wastes, are necessary for inhibiting the outbreaks of diarrheal diseases and vector-borne diseases. Moreover, suitable and appropriate cooking pots and water containers must be provided. People need to know that food must be thoroughly cooked and that water storage containers must be well covered. It is essential to give adequate amounts of soap to each individual with a minimum of 250 g per person per month and to teach the community the importance of personal hygiene and the conditions under which handwashing is necessary [156]. Chlorine remains the standard disinfectant and the most inexpensive one for drinking water, especially in places where no alternative supply of safe water can be found [157].

5.3. Health education and disease management

Due to the presence of an adequate level of sanitation, medical materials must be provided and training of healthcare personnel on suitable case management needs to be performed. Health workers and volunteers should inform people of the threat of ongoing epidemics and should also be advised on defensive measures to be taken. In addition, every country must have an emergency plan to be followed specifically in developing countries in which outbreaks may go without being seen due to the absence of simple medical facilities. However, these countries are still living in conditions of insecurity that make it impossible to understand the emergency plan.

6. Antibiotic prophylaxis

The conflicts of war continue to happen with breaks of human rights, and the destruction of infrastructure continue to occur due to the interests of the state. In parallel, natural disasters are in continuous rise because of forces out of our control and have a significant human impact. Beyond damaging and destroying physical infrastructure, wars and natural disasters can lead to injuries, homelessness, displacement and most importantly to bacterial infections. There are no national guidelines or international practices of protocols for the use of antibiotics to prevent bacterial infections resulting from wars and natural disasters. However, several studies have described the use of several classes of antibiotics to prevent these infections. For example, injuries resulting from war could constitute an easy medium for bacterial infection. Thus, after wound excision, broad-spectrum antibiotics should be given, and tetanus prophylaxis measures should be adopted [158]. In addition during World War II (WWII), sulfonamides and penicillin were administrated to wounded soldiers to prevent the development of bacterial infections. In Britain during the Spanish civil war, they used the sulfonamides in military campaigns in war wounds and burns. However, penicillin was reintroduced because of the emergence of sulfonamide resistance bacteria [159]. Nowadays, there are two broad measures to cope with carbapenem-resistant bacteria (CRE): defensive and offensive. During the war and natural disasters, if there is colonization with CRE, the dissemination must be blocked using a defensive strict infection control such as early detection, active surveillance, contact precaution, cleaning environment and antimicrobial stewardship etc. However, if CRE infection occurs, an offensive measure must be taken such as the use of polymyxin E (colistin), tigecycline, and fosfomycin, and/or a combination of these antimicrobials [160]. On the other hand, water prone natural disaster is considered the main risk factors for leptospirosis and many outbreaks have been described following severe weather events. Prevention of this infection is done using oral doxycycline [161]. Although chemoprophylaxis may afford some defense in decreasing the number of cases of patients affected with leptospirosis after a high-risk exposure, the real benefit may be determined by different factors such as timing and coverage of prophylaxis [161].

7. Conclusion

Over the past 50 years, wars and natural disasters have become a serious public health problem. The outbreaks of bacterial infections and infectious diseases that result from these two phenomena constitute a main worldwide challenge. This review described bacterial infections and outbreaks occurring during wars and after natural disasters in Asia and the Middle East. Furthermore, it focused on the prevention and control measures that must be taken to inhibit the dissemination of bacterial infections during and after these two phenomena. It has been revealed that, through wars, bacterial infections are not confined to military persons but rather to refugees who represent the most important source for this dissemination. In addition to wars, natural disasters will keep on being a warning to our global community. They occur constantly on a global scale, causing the displacement of people and the aggravation of the factors that promote the spread of bacterial infections. Therefore, the major challenge now is to prevent the transmission of bacterial infections during wars and following natural disasters. During wars, the prevention of bacterial infections depends on the prevention of these infections among refugees (screening for a specific pathogen, an organization of shelters, adequate water supply …), and in wounded citizens and soldiers as well (quick evacuation, wound care, prevent nosocomial transmission ….). With regard to natural disasters, the rapid implementation of prevention and control measures should be a necessity in communities displaced by disasters. Management conventions ought to be executed according to the national guidelines.

8. Expert opinion

Wars and naturals disasters will always be a major challenge to public health. Over the next few years, it is expected that the government and states will implement new approaches to fight infection resulting from these two phenomena. We believe that is necessary to set up quality training for health professionals and threatened the supervision of infection in human. Control measures must be taken by the countries receiving refugees such as the screening of specific pathogens upon the admission of these refugees and good organization of shelters according to the standard international guidelines. Moreover, war-prone countries must prevent the displacement of wounded people increasing the healthcare services to inhibit the spread of bacterial pathogens but also the nosocomial infections.

Dissemination of bacterial infections was and will always be a major worldwide problem. Wars and natural disasters have worsened this situation. Historically, the Asian continent is well known as one of the major continents in which natural disasters occur especially earthquakes and tsunamis. In addition, the Middle East region and Afghanistan are considered as the worldwide war regions. This review provides an overview of bacterial infections resulting from these two phenomena in Asia and the Middle East. Countries of this region of the world are afflicted with repeated arm conflicts affecting both civilians and soldiers. In addition, countries of East Asia are considered as the most natural disasters prone countries in the world. The coevolution of Human beings with the microorganisms that infect them often develops faster than does the understanding of the resulting infectious diseases, mainly during wars and natural disasters. Historically, during wars, diseases, such as plague, typhoid, cholera, smallpox, have been responsible for enormous deaths. Bacterial infections have been shown to spread during wars in either refugees or soldiers. In military settings, infections are linked to wounded soldiers through environmental contaminations or during their transit from one setting to another. However, refugees can spread the dissemination of these infections while leaving in inadequate and crowded shelters suffering from poor hygiene conditions.

In the recent decade, the incidence of natural disasters has developed resulting in bacterial infections affecting and killing millions of people. The important leading factors for this rapid dissemination are the displacement of large people into shelters with unsuitable conditions, the availability, and accessibility of medical services and the contamination of food and water.

Prevention of infectious diseases is essential during conflicts and wars and after natural disasters. Surveillance programs are necessary to evaluate the ongoing risk of infectious disease during the displacement of refugees and military persons. For example, it is necessary to implement surveillance programs in order to avoid the spread of MDR bacteria, implement infection control measures in healthcare settings, control antibiotic resistance dissemination and promote research on antibacterial resistance prevention and surveillance. In addition, it is very important to organize adequate shelters for refugees of wars and natural disasters to prevent the rapid spread of bacterial infections. Enhancing the wound care of civilians and military soldiers, in addition to the limitation of displacement of these wounded people between healthcare services and evacuation back to their native country before treatment, are essential to prevent the dissemination of infections and nosocomial transmissions.

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Declaration of interest

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