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Geospatial Analysis of Water-associated Infectious Diseases: Case of Myanmar

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Slobodan Tofiloski

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CENTRAL EUROPEAN UNIVERSITY

ABSTRACT OF THESIS

Submitted by:

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For the degree of Master of Science and entitled: **Geospatial analysis of water-associated infectious diseases: Case of Myanmar**

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Water can serve as a medium for pathogenic organisms, posing substantial health treats to humans through the variety of pathways. Water-associated infectious diseases are a major cause of morbidity and mortality in Myanmar. The recent environmental and social changes in Myanmar have significant influence over water-associated infectious diseases and it is expected for that trend to continue in future. Alterations in climate factors, human migration caused by several ongoing armed conflicts, low levels of sanitation, difficult access to clean drinking water, increased agricultural practices and industrialization; all of them can change the patterns of distribution, emergence, and re-emergence of the water-associated infectious diseases in Myanmar. This research utilizes the social and environmental determinants mentioned above and water-associated prevalence data in conjunction with a GIS analysis method, to present the distribution and risk of the water-associated diseases in Myanmar and their relation with diverse factors. The results show that Yangon has the highest number of waterborne diseases outbreaks and second highest number of water-related diseases outbreaks. Results also show that there is specific interconnected influence of different factors, with some of them dominating in certain states or regions.

KEYWORDS: GIS analysis, Myanmar, water, water-associated diseases, social and environmental factors.

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List of Abbreviations

CDC- Centers for Disease Control;

GIS-Geographic Information System;

GWR- Geospatial Weighted Regressions;

JE-Japanese encephalitis;

IDP-Internally Displaced Persons;

OECD-Organization for Economic Co-operation and Development;

STD-Standard Deviation;

UNHCR-United Nations High Commissioner for Refugees

UNICEF- United Nations Children's Fund

WB- Waterborne;

WR- Water-related

1. Introduction

1.1. Background of the problem

Water is very important condition for life. It has the critical aggregation of physical, chemical and biological properties essential for developing and maintaining of the life processes in the living organisms including humans.

Having these properties, water represents an ideal vessel for many microorganisms, a large share of them parasitic by nature. These parasitic microorganisms find an almost ideal host in humans causing what is called pathogenic processes or better known as diseases, which sometimes result with a death of the host. In some cases, a human individual can be the final host in the life cycle of parasitic microorganism, with potential to infect other humans with the pathogen and spread the disease further, or remain the last infected person. The proliferation of the parasitic pathogenic microorganisms developing in the water can be done in two ways: directly from contact with the contaminated water or via so called “vectors” which can be different animal organisms (insects, fish, birds, mammals) which can deliver the pathogen to the humans through different kinds of contact with them.

The concept of “water-associated diseases” was firstly introduced by el Gaddal (1985), but was further clarified and systematized by Yang et al. (2012) in five groups of diseases: water-borne, water-based, water-related, water-washed and water-dispersed.

Today, our civilization has developed different means of dealing with these water-associated pathogens, in form of improved water hygiene, sanitation, powerful medicaments (mostly in form of antibiotics), different control measures like changing the human or vectors environment and quarantine and isolation measures. Still, there are some factors involved which we as humans cannot control quite well. These unknowns result with outbursts of emergence or re-emergence of different water-associated infectious diseases. The connection between environmental and social factors and vector population dynamics is crucial to determine parasite proliferation, activity and risk of outbreaks.

This problem is especially present in the developing countries with limited access or management of their own resources. Myanmar is one of these countries. As a country which came out of 60 years of military dictatorship, internal armed conflicts and isolation, and country which belongs to the tropical and subtropical region, it is somehow predestined to suffer from epidemiological outbreaks of different infectious diseases, including water-associated.

According to a Myanmar Red Cross report summarized by Eleven Myanmar (2017), 77% of the diseases in Myanmar are waterborne. The water-associated diseases registered on the territory of Myanmar are: malaria, dengue, cholera, acute diarrhea, schistosomiasis, plague, leptospirosis, Japanese encephalitis, Chikungunya, hepatitis A and typhoid fever (CDC, 2016; CIA, 2018).

GIS is a powerful tool that can be used in health and epidemiological studies. By integration of both geospatial data and processes, GIS can explore and explain spatial-temporal phenomena (Brown et al., 2005). In case of the health and epidemiology sciences, GIS can provide assessment on the hazard, exposure and outcome surveillance (Jarup, 2004). The number of health agencies which use GIS within the public sector in the developing countries, is constantly rising (Kurwakumire, 2014). In case of Myanmar, there are still issues with the open data policy (OECD, 2015). Also, Myanmar still has to develop their system of geospatial health and epidemiological data collecting and its geospatial analysis (Ebener et al., 2018).

1.2. Aim and objectives of the thesis

The aim of this study is to research the relation between the major water-associated diseases prevalence in Myanmar and several possibly influencing social (population density, access to safe drinking water and sanitation and armed conflicts), environmental (temperature, humidity, precipitation, humidity, precipitation, elevation and deforestation) and socio-environmental factors (natural disasters). The water-associated diseases have been defined and categorized according to Yang et al. (2012). Following the country health report by CDC (2016) and CIA (2018), only two major groups of water-associated diseases have been identified: waterborne and water-related. Both of them have been included into this study. In order to accomplish this aim, I focus on the following objectives:

- Present the geospatial distribution of the major waterborne and water-related diseases on the territory of Myanmar, by regions, according to the current official administrative division;
- Analyze the general patterns of geospatial correlation between the water-associated diseases prevalence and distribution, and social and environmental factors on the territory of Myanmar;
- Analyze the correlation between the possible environmental and socio-economic factors and diseases prevalence in the most affected regions.

1.3. Thesis outline

The subchapter 2.1 from the Literature review will introduce the relation between water-associated diseases and water. Also, this subchapter will try to assess the question of whether water-associated diseases are part of the history or are still actual contemporary problem. Subchapter 2.2 will give a brief description of the geography, climate and socio-historical status of Myanmar. Subchapter 2.3 will give overview of the major water-associated infectious diseases in Myanmar. It will also cover the diseases epidemiology and the vectors behavior and environment. In the subchapter 2.4 I will discuss how possible social and environmental factors can influence the diseases prevalence. Subchapter 2.5 will cover the current trends in the GIS usage for epidemiological and health studies and will indicate some of the studies of these type in the region of South and South-East Asia.

Chapter 3 describes the methodology of the research in the following subchapters: Data collection and organization, data analysis and creation of the maps. It also indicates the limitation of the research.

Chapter 4 provides the results of the research and discussion about them.

Chapter 5 summarizes the research outcomes, gives conclusion and recommends future possible policy recommendations.

2. Literature review

2.1. Water and water-associated diseases

Water, sanitation and hygiene are necessary for human health and development. Whether it is used for drinking, cleaning, food processing or recreation, safe and reliable water sources are always a priority. Investments in better access to safe water and sanitation empower the poor population in particular, both in rural and urban areas (WHO, 2011). SDG target 6 (UN, 2015), among the other issues related to water, is dedicated to "universal and equitable access to safe and affordable drinking", and "access to adequate and equitable sanitation and hygiene for all and end open defecation".

Understanding the full impact of water in human lives is a matter of many debates (Gleick, 1993; Syme and Williams, 1993; Cotruvo et al., 2004; Strang, 2004; Pahl-Wostl et al., 2007). Beside the commodities that water allows to humanity, negative effects can also be present. The negative effects can be in form of chemical (Warren, 1971; Novotny, 1994) or biological influence (Gleick, 2002). This thesis will emphasize the negative water-related influences, in a form of diseases that can be connected to the water in different ways.

This thesis will use the classification of Yang et al. (2012), who developed the umbrella term "water-associated diseases", which was firstly introduced by el Gaddal (1985). According to the authors, the water-associated diseases can be classified in five groups:

- Waterborne diseases that are caused by enteric pathogens that enter in the human body orally and contaminate the water usually through feces;
- Water-based diseases caused by aquatic worms;
- Water-washed diseases as a result of a poor hygiene;
- Water-related diseases caused by insect vectors for different kinds of pathogens (virus, bacteria, protozoa), which spend part of their reproduction circle in a water environment;
- Water-dispersed diseases caused by parasites (mostly viruses), which dwell in fresh water and infect humans by respiratory way.

Some researchers also include schistosomiasis as a waterborne disease because the Schistosoma worm pathogen originates from the eggs found in the feces, the contaminated water is the main vessel of the pathogen and it enters the body orally, or in some cases dermally (Hunter, 1997; Beck et al., 2000; Nithiuthai et al., 2004; Spear et al, 2006).

2.1.1. Water-associated diseases: question of history or visible presence?

Through the history there were dozens of devastating plague outbreaks that decimated the human population. In the ancient times many diseases were known by the umbrella term "plague" (Watts, 2003). People in those times didn't make any distinction.

But what they noticed is that some of these diseases had been coupled with several different factors. Ancient people acknowledged that there is a certain connection between the "plagues" and the water cycles (McNeill, 1998; Koenig et al., 2012). Following a heavy rain or major flooding there was an outbreak emerging. The same thing applied to the water scarcity and droughts. Wars were also a major factor contributing to the spreading of different diseases (Cartwright and Biddiss, 1972; Hays, 2005). The most populated ancient cities were most of the times centers of epidemics (Watts, 1999; Porter, 2005).

Ultimately, some of the oldest civilizations, like Egypt and Mesopotamia, acknowledged that access to clean water, water sanitation and hygiene, can contribute to decrease of the "plagues" so they started building latrines and sewage and wastewater systems (Watts, 1999; Watts, 2003; Lofrano and Brown, 2010). They were followed up by the Romans who built the aqueducts (Hodge, 2002). This innovation saved millions of lives through the history and in some sense could be considered as one of the civilization establishment cornerstones.

Today, the health status of one fifth of humanity is on the same level as the one of our predecessors (Watts, 2003). The so called "developing countries" in Africa, South and South-East Asia and South, Central America and the Caribbean, still have troubles with the implementation of the water quality and sanitation standards (WHO, 2000; Montgomery and Elimelech, 2007; WHO, 2011; WHO, 2013; WHO[1], 2018).

Some authors proclaimed that with the increasing of the standard of living, education and health status, soon we can expect eradication of the water-associated diseases (Fenwick, 2006). After the initial eradication, suppression or control, there is an evident re-emergence of some of them (Hunter, 2003; Zell, 2004; Harrus and Baneth, 2005).

Even the developed countries today are not entirely immune to the the water-associated diseases. The recent outbreaks in USA (MacKenzie et al, 1994), Canada (Schuster et al., 2005), Australia (McMichael et al., 2007) and Great Britain (Smith et al., 2006), reassure us that the water-associated diseases are far from the brink of eradication.

The ancient, water-associated infectious diseases are one of the leading causes of death in the world (WHO[1], 2002; WHO[1], 2010; WHO, 2013). This situation implies that the access to clean drinking water, hygiene and sanitation, are still very important (Watts, 2003).

There is significant body of researches that proposed by the evolutionary scientists that water-associated diseases are also subject of constant evolution (Ashbolt, 2004; Morens et al., 2004). This is changing the way that water-associated infectious diseases threaten humankind and the innovations and strategies that will protect us (Morse, 2001).

2.2. Myanmar geographical and socio-economic background

2.2.1. Geography and climate

Republic of the Union of Myanmar (formerly known as Burma) is South-East Asian country. Myanmar neighbors China to its north and northeast, India and Bangladesh on the west and on the east its neighbors are Thailand and Laos. Myanmar covers 676,578 km^2, with total perimeter of 5,876 km, from which 1,930 km are uninterrupted coastline along the Bay of Bengal and the Andaman Sea, on the south side (Fig. 1). According to the Worldmeters (2018), the latest estimation of the population in Myanmar is 52.89 million people which consists the density of 81 people per km^2. Myanmar's GDP for 2016 was 67.43 billion USD (CIA, 2018). The capital of Myanmar, beginning from 2006 is Naypyidaw, taking the role from the largest and most populated city and former capital of Yangon (Rangoon) (CIA, 2018). The country is officially administratively divided in 7 states, 7 regions, and 1 union territory (Fig. 1):

- States: Kachin, Kayah, Kayin, Chin, Mon, Rakhine, Shan;
- Regions: Yangon, Sagaing, Tanitharyi, Bago, Magway, Mandalay, Irrawaddy.

Figure 1: ADMINISTRATIVE DIVISIONS AND TOPOGRAPHY OF MYANMAR

Source: Wikimedia Commons (2013)

Biggest part of the Myanmar's territory lies between the Tropic of Cancer and the Equator, putting the country in the Asian monsoon region. During the monsoon season, the coastal regions in the south and south-east of Myanmar receive over 5,000 mm of rain per year (D'Arrigo and Ummenhofer, 2015). According to the authors, the highest annual rainfall is in the Irrawaddy delta region, with over 2,500 mm, while the Dry Zone in central Myanmar receives the lowest rainfall with less than 1,000 mm per year. The lowest average temperature of 21 °C is in the

Northern mountainous regions of Myanmar, while the highest average temperature of 32 °C is registered in the coastal and delta regions (Htway and Matsumoto, 2011).

The geographical landscape of Myanmar can be grouped in five physiographic regions: the northern mountains, the western ranges, the eastern plateau, the central basin and lowlands, and the coastal plains (Terra, 1944).

According to the Köppen climate classification (1884), five major climate zones exist in Myanmar: Subtropical oceanic highland, Temperate oceanic, Humid subtropical, Monsoon and Tropical savannah (Peel et al., 2007) (Fig. 2).

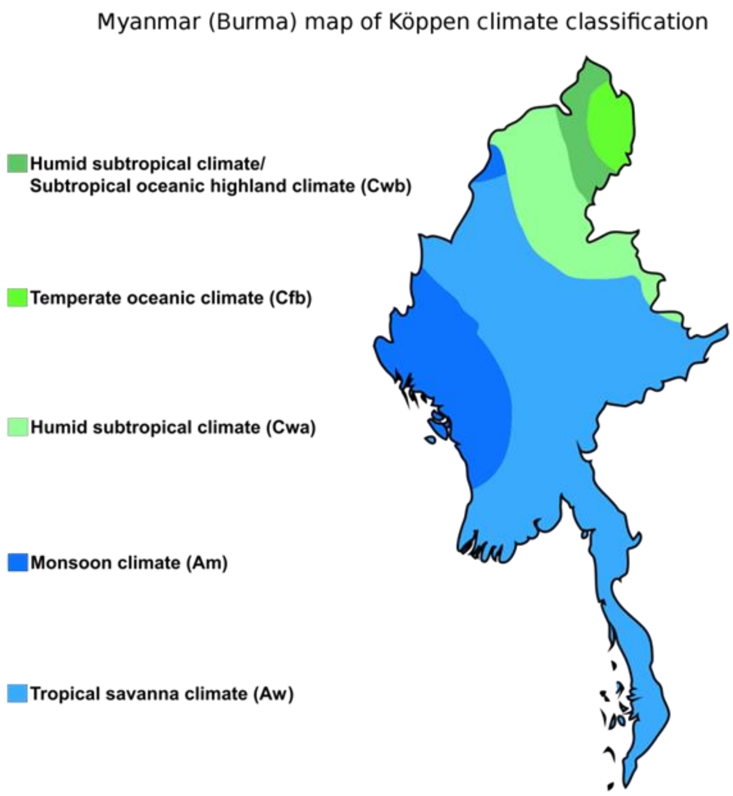

Figure 2: MYANMAR MAP OF KÖPPEN CLIMATE CLASSIFICATION

Source: Wikimedia Commons (2016)

Different climate variations can be present in the highlands of Myanmar according to the elevation. The subtropical temperate climate dominates at around 2,500 m; temperate climate stretches at 3,000 m; the alpine zone dominates the altitude of 3,500 m and above with cold, harsh, tundra and Arctic like climate (Peel et al., 2007). These conditions can often produce bad weather, sometimes joined by heavy snowfalls, especially in the North (Htway and Matsumoto, 2011).

From the other side, the tropical monsoon in the lowlands below 2,000 m very often produces cloudy, rainy, hot and humid summers in the period from June to September, and less cloudy, with scarce rainfall, mild temperatures and lower humidity during the winter, during the period from December to April (Htway and Matsumoto, 2011).

2.2.2. Socio-historical status

Myanmar is a former colony of the British Empire that gained independence in 1948. The state has been established as a democratically organized union of states formed by different ethnic and religious groups. This form of state organization was not in accordance with the ideas about unitary and centralized government that the Burma military had (Silverstein, 1977; Fink, 2001). As a result of this situation, according to the authors, a series of frictions emerged in the Myanmar's (in that period named Burma) political arena, which lead to a coup d'état in 1962. After that, for most of its history until now, Myanmar remained under military dictatorship. The military coup initiated a series of armed conflicts between several different ethnic groups and the military government, fought on a several fronts (Fink, 2001). Most of these armed conflicts are still active.

The winner of the first democratic general elections in Myanmar after the military coup, held in 1990, was the National League for Democracy, which won with huge majority. Military did not recognized the outcome of the elections and organized another coup d'état with which regained the control over the state again (Fink, 2001). Author notices that the harsh dictatorship, never-ending internal armed conflicts, inadequate social and health policies, lack of economic development and the international isolation, led to very poor management of the country's human and natural resources. This downward spiral culminated with the cyclone Nargis in 2007, when all of the inconsistencies of the military rule were exposed by this devastating disaster (Seekins, 2009; Cheesman et al., 2010; Bünte, 2014). The high impact of the disaster, the numerous victims and damages made and the chaotic, disorganized reaction of the military, led to huge distortion of the image that military had as a high organize all ruling body and was maybe the beginning of the end of the military government (Cheesman et al., 2010; Bünte, 2014).

In 2011 military officially stepped down from the country's governance after the 2010 general election which was won by civilian party. However, Myanmar military still remains an influential force in the country politics (Bünte, 2014).

2.3. Major water-associated diseases present in Myanmar

According to the CIA (2018), the major water-associated diseases in Myanmar are: diarrhea, hepatitis A, typhoid fever, malaria, dengue, Japanese encephalitis and leptospirosis. During our research of the existing researches and reports on outbreaks of water-associated diseases in Myanmar, in the period 1991-2018, we have also registered cholera, dysentery, schistosomiasis, giardiasis and chikungunya (Appendix 1). Major outbreaks of leptospirosis have not been registered.

2.3.1. Waterborne diseases

The major waterborne diseases which had outbreaks in Myanmar in the period of 1991-2018 are: acute diarrhea, cholera, dysentery, typhoid fever, giardiasis, schistosomiasis and hepatitis A.

2.3.1.1. Acute diarrhea

Acute diarrhea can be caused by multiple pathogens. The main pathogens that can cause waterborne induced acute diarrhea could be viruses (viral gastroenteritis), rotavirus in children and norovirus in adults. It also can be caused by bacteria, mostly Escherichia coli, or in some cases Shigella, Campylobacter bacterium or Clostridium difficile. Protozoan infections are also possible, mostly Entamoeba histolytica. It is caused by contaminated water used for drinking, cooking or cleaning.

Low level sanitation or open defecation can be major contributors to the disease spreading (WHO, 2000). Water can get contaminated with human or animal feces from community sewage, septic tanks or latrines. Diarrhea can be contracted by personal contact as a result of poor personal hygiene or indirectly spread from the water and contaminated food (WHO, 2000). Floods are also major concern because they can spread the animal or human feces into the drinking water sources (Ahern et al., 2005; Schwartz et al., 2006).

The average timespan of the acute diarrhea is 2 weeks. If it lasts between 2 and 4 weeks it is termed persistent diarrhea (Keating, 2005). Diarrhea that lasts more than four weeks is termed chronic diarrhea (Keating, 2005).

Diarrhea pathogens cause a gastrointestinal infection with more frequent than normal loose or liquid stools. Acute diarrhea can be watery, or in more severe blood form. Both forms can be life threatening due to fluid loss, especially in children under the age of five (Samani et al, 1988), in malnourished people (Schaible and Stefan, 2007; Katona and Katona-Apte, 2008) or people with reduced immunity (Manatsathit et al., 1996).

Acute diarrhea is leading cause of mortality in children bellow five year in the developing world (Ochoa and Surawicz, 2002). According to the authors, it causes 4% of all deaths or round 2.2 million people globally each year and 5% of health loss to disability.

There can be a possible connection between diarrhea and some water-related diseases, like malaria (Caulfield et al. 2004). According to the authors, undernutrition caused by constant loss of fluids could initiate certain forms of anemia that could make the affected person mores susceptible to malaria infection.

According to the WHO (2013), 8.5% and 7.7% of all deaths in the countries of Southeast Asia and Africa are caused by different form of diarrhea.

2.3.1.2. Cholera

Cholera is caused by the Vibrio cholerae bacteria. Mainly it is spread through water drinking or food that came into contact with contaminated water (WHO[1], 2018). Symptoms can range from none, to mild, to severe. Cholera is causing severe, sometimes life threatening, mostly watery form of diarrhea. Vomiting is also possible. The diarrhea and vomiting can cause severe dehydration and electrolyte imbalance. Ingestion of oral rehydration salts (ORS) is the main way for reducing of the dehydration and electrolyte imbalance caused by the cholera (WHO[1], 2018). Similar to acute diarrhea, cholera is spread mostly by contaminated water by human or animal feces or food which was contaminated with the water. Cholera impacts only humans (WHO[1], 2018).

According to Cann et al. (2013), V. cholerae pathogen accelerates its growth at higher temperature, which can lead to increased prevalence of cholera cases in the countries of tropical and sub-tropical belt, due to the climate change induced higher temperatures, precipitation and flooding. According to the last world cholera report by WHO (2017), Myanmar is in the group of countries that had between 10 and 99 cholera cases (Fig. 3).

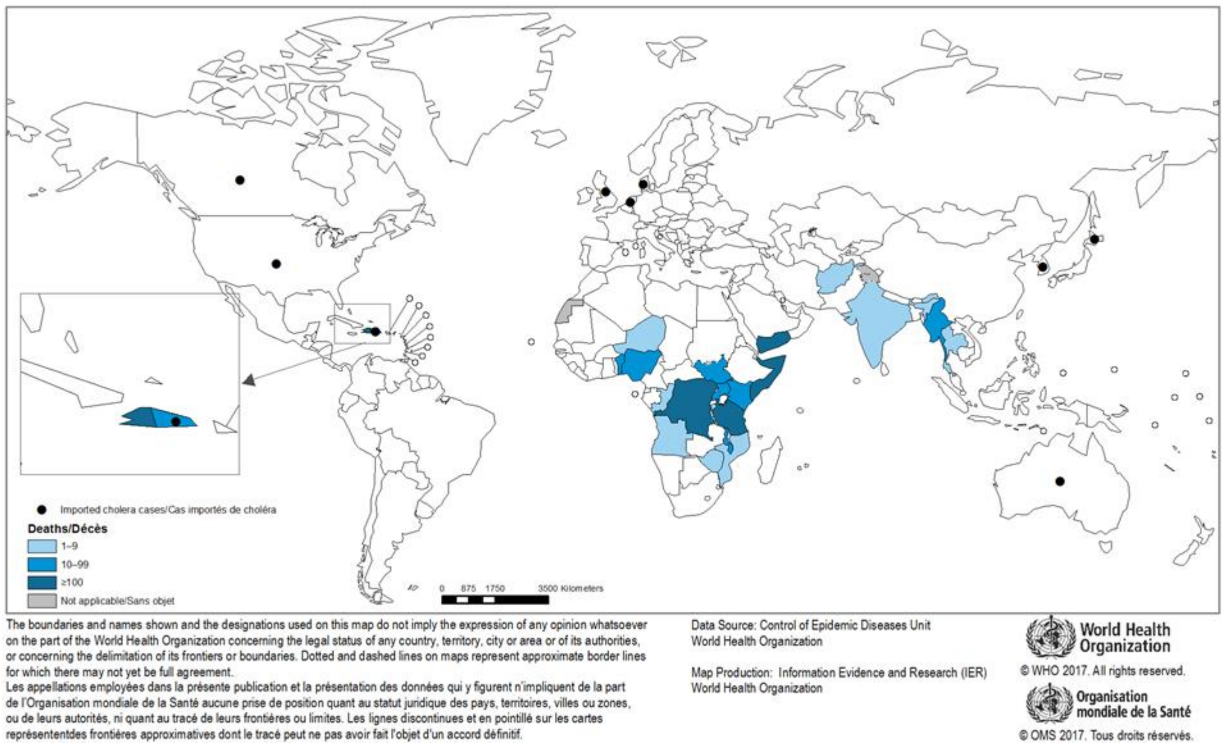

Figure 3: COUNTRIES REPORTING CHOLERA DEATHS AND IMPORTED CASED IN 2016

Source: WHO (2017)

2.3.1.3. Dysentery

Main cause of dysentery is infection of the intestinal tract with the Shigella bacterium or Entamoeba histolyca protozoa. The symptoms can be: intense abdominal pain, fever and fatigue. Dysentery causes severe, sometimes life threatening forms of bloody diarrhea. This can lead to intensive loss of bodily fluids and hemorrhage. Vomiting is also common.

Poor hygiene and contaminated water with feces are the main source of infection (Sazawal et al., 1996). Dysentery is more common in the tropical and sub-tropical regions (Gu et al., 2012).

2.3.1.4. Typhoid fever

Typhoid fever, or typhoid, is an enteric infection caused by bacteria Salmonella typhi. Symptoms vary from mild to severe. The most common symptoms are: abdominal pain, sustained fever in range of 39 °C to 40 °C and headache. Unlike the above mentioned waterborne diseases, usually it is not followed by intensive diarrhea or vomiting (Hornick et al., 1970).

Like the other waterborne diseases, it is caused by poor hygiene, contaminated drinking water or food contaminated with infected human feces (Crump et al., 2004).

2.3.1.5. Giardiasis

Protozoan Giardia lamblia is the parasite that causes Giardiasis infection. Giardiasis is typical intestinal infection limited in the duodenum. The symptoms can be: fatigue, vomiting, bloody diarrhea, weight loss, headaches or abdominal pain.

Giardia lamblia proliferates through contaminated drinking water or food, with feces from animal or human origin. There can also be transmission between two humans, as a result of poor hygiene or it can be contracted from animals (Cráun, 1990).

2.3.1.6. Schistosomiasis

Not alike the other above mentioned waterborne diseases, Schistosomiasis is caused by a multicellular organism, in the form of parasitic flat worm called Schistosoma. Symptoms may vary from bloody diarrhea and urine to mild or intensive abdominal pain. The especially vicious burden of this waterborne disease is the physical and mental impairment that the parasite can cause to small children (WHO[2], 2002).

Like any other waterborne parasite, Schistosoma proliferates through drinking or any other contact with contaminated fresh water. Schistosomiasis is listed among neglected tropical diseases (WHO[2], 2002).

2.3.1.7. Hepatitis A

Hepatitis A is an acute infection of the liver. The causing pathogen is Hepatitis A virus, a type of RNA virus. Hepatitis A causes icterus, diarrhea, vomiting, fever and abdominal pain. Unlike the other, more serious types of hepatitis, hepatitis A rarely induces acute liver failure. Still, it is a wicked disease that sometimes can be present in humans without any symptoms, but with active infective potential (Franco et al., 2012). Also, in some cases, there can be recurrence of the disease after some time (Bell et al., 1998).

Hepatitis A is a waterborne disease with standard way of transmission through contaminated drinking water or food with infected feces (Gerba et al., 1985; WHO[2], 2010).

2.3.1.8. Situation in Myanmar

Rakhine State is the region of Myanmar with the highest risk for waterborne diseases (Motlagh, 2014; Pink, 2016; Mahmood et al., 2017; Ahmed et al., 2018). Constant unrests (Albert, 2017), the impending humanitarian catastrophe (Motlagh, 2014; Ahmed et al., 2018) and the high vulnerability to cyclones and floods (Ahmed et al., 2018), puts this region on the highest priority map for the international UN and other humanitarian organizations (UNHCR, 2018). According to the UNHCR (2018), the lack of transport, health and education infrastructure and the continuous disinterest from the Myanmar government makes the situation even more difficult. Numerous townships are isolated and difficult to be reached from the relief teams. Even if international relief teams succeed in reaching there, they still do not have enough data and precise maps to prioritize the highest priority settlements (UNHCR, 2018). There are many internally displaced persons and Rakhine refugees in Bangladesh (Parnini et al., 2013). Amongst them, there are many children which are the first victims of the waterborne diseases (Motlagh, 2014).

The personal hygiene in the humanitarian camps is on a low level (Ahmed et al., 2018). Access to safe drinking water is also problems (Pink, 2016). UN agencies are constantly trying to provide shallow tube-wells, water purification products, improved sanitary toilets and washing areas (UNICEF, 2012), but the progress is very slow.

2.3.2. Water-associated diseases

2.3.2.1. Malaria

General information

Malaria is a serious, infective, and in some cases deadly disease caused by a protozoan parasite Plasmodium that infects a certain type of mosquito which feeds with human blood. Four different species of Plasmodium can cause malaria in humans: P. falciparum, P. malariae, P. ovale and P. vivax.

Symptoms of malaria infection are different. In most of the cases they are absent or very minor, some of them can lead to severe disease and in more extreme cases malaria can result even in death (WHO[1], 2015). Typical symptoms for malaria are: high fever, shaking chills, and flu-like illness. Nowadays, malaria can be cured in most of the cases, but only if it is diagnosed on time and treated according to the established medical procedures (WHO[1], 2015). Different levels of seriousness of the malaria require different treatment. Also, the causal parasite and the geographical area where the malaria has been contracted are important factors during the medical treatment (Wernsdorfer, 1994; Cooke and Hill, 2001).

Malaria vectors, transmission and vector behavior and environment

The main vector for malaria Plasmodium parasite is the female Anopheles mosquito, which bites mainly between dusk and dawn. The parasite does not affect the mosquito in some visible way. There is no known information of human–mosquito–human transmission of malaria.

Some of the Anopheles species are main cause for the global spreading of several dangerous diseases like malaria, filariasis and some viruses. From 460 known Anopheles species, approximately 100 are transmitters of human or animal diseases (Afrane et al., 2012). In order for successful transmission of the Plasmodium parasite, female anopheles should survive long enough after getting infected from already infected human (CDC[1], 2015). After the bite, Plasmodium needs 7-30 days to finish the development (CDC[1], 2018). In some rare situations people can get infected with malaria from other people, from mother to child, transfusion, transplantation or shared needles (CDC[2], 2015).

According to CDC[2] (2018), the Plasmodium species infecting humans are the following:

- P. falciparum (tropical and subtropical areas, especially in Africa). P. falciparum can cause severe malaria.

- P. vivax, (dominant in Asia and Latin America, present in parts of Africa). P. vivax is the most prevalent human malaria parasite (result of the population density in Asia). This type has dormant stages that can activate several months or years after the bite. P. vivax has higher tolerance to lower temperature than the other Plasmodium parasite species.

- P. ovale (dominant in W. Africa and W. Pacific islands). It has similar dormant stages like P. vivax.

- P. malariae (worldwide). Has a three-day cycle. Other species have two-day cycle.

- P. knowlesi (Southeast Asia). It is a natural pathogen of the macaque monkeys. Has a 24-hour replication cycle.

Anti-malaria measures

Malaria is regularly occurring disease in the countries of the tropical and subtropical strip. Taking this into account, the mechanism for alarming of a possible malaria epidemics and the adequate signal are established on different ground. According to WHO[1] (2012), confirmation malaria cases twice the average number registered in the previous 3 weeks can trigger the alert threshold.

There are few preventive anti-malaria measures that could be more or less effective in different circumstances. They can be grouped in two related groups: chemoprophylaxis and personal protection against mosquito biting (ECDC, 2018). Chemoprophylaxis is the use of drug for disease prevention (McBride, 2010). The personal protection against biting comprises of mosquito bed-nets usage, with emphasis on the insecticide-impregnated beds;   clothes with long sleeves, and treatment of the unprotected skin with insect repellent (ECDC, 2018). Insecticide-impregnated bed-nets can be most efficient way of preventing the disease, because most of the bitings occur during the night (Tun-Lin et al., 1995).

The other type of prevention measures includes the vector control (WHO, 2006). According to WHO (2006), these actions deal with the decrease of the space and time dimension of the potential contact between mosquitoes and humans, the destruction of larvae and adult populations with the use of chemicals or manipulation with natural mosquito larvae predators, and elimination of mosquitoes by indoor residual spraying.

There are several anti-malarial drugs for treatment of post-bite symptoms: Quinine, Chloroquine, Amodiaquine, Pyrimethamine, Proguanil, Mefloquine, Primaquine, Artemisinin and Doxycycline. Artemisinin is the drug which is recommended by WHO[2] (2018) for the treatment of uncomplicated malaria caused by P. falciparum. According to the WHO[2] (2018), Artemisin has an essential share in the recent notable success of the global malaria control. However, some Plasmodium pathogens are resistant to drugs (Baird, 2005). Today, a number of vaccines for malaria are in different development stages, but they are not fully available yet (Matuschewski and Mueller, 2007).

Malaria in Myanmar

Myanmar has the highest reported incidence of malaria in Southeast Asia, with the second place in the list of countries with the most malaria deaths in the region (Ghinai et al., 2017). Indeed, there is a certain progress in the malaria eradication, according to the country's annual reports, but that dynamics of the process is slow and there is need for additional efforts (WHO, 2016). According to WHO (2016), in the period from 2000 to 2008, there was a rice in the number of malaria cases from 120 029 (2000) to 447 073 (2008). But the number of deaths related to malaria in the same period has decreased from 2752 in 2000, to 972 in 2009, which indicates possible improvement in the medical treatment of malaria cases. In 2009 there is a decrease in the number of confirmed malaria cases with 414 008 cases (WHO, 2016).

From 2009 until 2014 there has been a major dropping in the number of reported malaria cases by 81%, with a 93.5 % decline in the number of deaths caused by malaria and 87.2 % decline in the number of hospitalizations (Mu et al., 2016). According to the researchers, this change could be attributed to some of the joint malaria control measures by the central government and international organizations. These measures included training and placement of healthcare workers around the country, coverage with insecticide-treated bed nets in over 60 % of the high risk areas and increase in the access to artemesinin-based therapy. Beside these measures, according to the authors, there are some other factors that might have been influencing this decline, like: more investments in the health sector, population dynamics and deforestation.

The factors influencing malaria distribution in Myanmar could be of different nature. Some authors are stressing the role of the forests as a major environmental driver behind the disease distribution (Guerra et al, 2006; Parker et al., 2015). Other authors are adding the role of the unregulated internal and inter-border migration (Carrara et al., 2013; WHO[2], 2015).

According to CDC[4] (2018), most of the cases of malaria in Myanmar occur on an altitude bellow 1000m. The risk for disease contraction is moderate (CDC[4], 2018). The most dominant Plasmodium species are P. falciparum, which was cause of around 60% of the identified cases of malaria and P. vivax, with around 30%. Other Plasmodium species that are present in Myanmar are P. malariae, P. ovale, and P. knowlesi. Local endemic Plasmodium species are resistant on chloroquine and mefloquine (CDC[4], 2018), but there are also numerous registered cases of artemisin resistance by P. falciparum, which make the situation more alarming (Carrara et al., 2013; Ashley et al., 2014). Additionally, there are cases of false malaria medicine in Myanmar (Morris, 2006; Dondorp et al., 2004; Newton et al., 2003).

Despite the huge interest of the World Health Organization to eradicate malaria in Southeast Asia, there is still a lack of epidemiological data for the situation on the field in Myanmar. The situation is especially complicated in the areas of inter-ethnic clashes and in the border (Stover et al., 2007). According to the authors, these are the regions which do not receive enough social and health support by the central government and are usually almost unreachable by the international organizations. Most of the people in these areas are displaced and vulnerable to many diseases, especially malaria.

Myanmar state government plans to eradicate malaria until 2030 (Department of Public Health, 2015).

2.3.2.2. Dengue

General information

Dengue is mosquito vector-borne, water- associated tropical disease. It is caused by the dengue virus. Dengue is constantly expanding over the past centuries (Brady et al., 2014). It is mainly present in the tropical and subtropical areas of the world. The main symptoms for the disease can be fever with high temperature, nausea and vomiting, headache and characteristic muscle and joint pains. In some cases, dengue can upgrade to its deadlier form, the dengue hemorrhagic fever (DHF), which causes massive hemorrhage from the most of the internal and external organs.

Dengue vectors, transmission and vector behavior and environment

Ae. aegypti

Aedes aegypti or yellow fever mosquitoes are the main vectors of transmission for dengue fever. This insect usually can be found near human settlements. It is present in places with dense human population (Focks et al., 2000; Schmidt et al., 2011), poor sanitation (Carlton et al., 2012; Tapia-Conyer et al., 2012), standing water (Normile, 2013) and haphazard storing of the water (Philbert and Ijumba, 2013). They can also lay their eggs in natural water reservoirs as holes in the soil or trees. The male and female adults feed on nectar. Females need additional amount of proteins for the eggs producing, so they change their feeding behavior and start biting humans.

There are claims that the climate change (Campbell-Lendrum and Reithinger, 2002) and population growth (Hales et al., 2002) are increasing the incidence of dengue outbreaks around the world. Increase of the human population indirectly increases the number of stagnant water reservoirs which are main hotspot for harboring of the Aedes mosquito eggs and completing their development (Normile, 2013).

Aedes life cycle starts when the eggs are laid on the sides of containers with water and they hatch into larvae after exposing to a water environment (rain or flooding). Eggs can survive long periods of droughts. Larvae feed with the microorganisms or the organic matter in the water. That is the reason they prefer laying their eggs into cracked septic tanks. Then, the larva changes into a pupa in about a week and into a mosquito in two days (CDC[3], 2018). A couple of thousands of mosquitoes can hatch from one place. Ae. aegypti life cycle is also perpetuated by humans, because the mosquitos prefer to rest in dark, cool areas, which people provide them with the closets (Dieng et al., 2010) . This is the main reason they are prone to indoors biting.

Ae. aegypti are very adaptive to environmental disturbances. Their adaptation mechanisms can contribute to their resilience by developing an ability to revert to the initial numbers after some shock initiated by natural phenomena or control/elimination measures (Diniz et al, 2017). Mosquito eggs which have been laid down on the inner container walls can survive without water for several months. Ae. aegypti population could recover two weeks later as a result of egg hatching following rainfall or the addition of water to containers harboring eggs (CDC[3], 2018; WHO[3] 2018; Diniz et al, 2017).

Ae. albopictus

It is also called Asian tiger mosquito. Mostly it is a secondary vector for the dengue virus, but in some places can be found like primary (Chan et al., 1971). Ae. albopictus has bigger affiliation for a human blood, but can sometimes also bite other mammals, even birds too (CDC[3], 2018). The mosquitoes of this group bite both indoors and outdoors (Chan et al., 1971), but mostly prefer outdoors (CDC[3], 2018). According to CDC[3] (2018), their natural habitat is tree vegetation, but they can also adapt to the human habitats. Especially they prefer man-made water-filled containers located around the homes (Normile, 2013). Female lays the eggs around five days after her blood meal. Their eggs can hibernate through the winter (Diniz et al, 2017). The main food for the larvae is the mix of protozoans, algae or organic matters which joins around the decomposing litter into the water. The water related phase of the Ae. albopictus mosquito, from eggs to adults, lasts around 9 days. The adult mosquito lives around 3 weeks.

Mosquitoes from this species do not have a big radius of moving, just around 200 m (Paupy et al., 2009). That means that hatching sites could be found near their favorite biting spots, the human settlements. Ae. Albopictus can bite multiple times, mostly during the daytime, early morning or late afternoon (Paupy et al., 2009). The dengue virus is the most viral during the first week of the infection when the virus copies are in high number in the blood of the infected person (Clyde et al., 2006). This period of infection is the most risky for transmission of the virus through the biting of the infected person from the potential vector because it is the period of multiplication for the dengue virus. Transmission of the virus should occur in the max 10 days of the vectors life span (Gubler, 2002).

A. aegypti and A. albopictus can also spread Zika (Wong et al., 2013), chikungunya (Weaver and Lecuit, 2015), yellow fever (Christophers, 1960) and West Nile virus (Baqar et al., 1993). They can also transmit some worm parasites (Hribar and Gerhardt, 1985).

Anti-dengue measures

The air-conditioned housing with mosquito nets is the most secure way for prevention of biting (Morrison et al, 2008). Around the homes, the potential water reservoirs should be cleaned, dried or sealed in case of septic tanks (CDC[3], 2018). According to CDC[3] (2018), in outdoor conditions, wearing protective clothing and using mosquito repellent are the best way of protection.

Dengue situation in Myanmar

The first cases of dengue appeared in Yangon in 1965 (Naing et al., 2002). According to the authors, the first major dengue outbreak in Myanmar was in 1970. In the next years dengue spread to Mandalay, Bago and Mon.

The dengue incidence in Myanmar increased again to 22 398 cases in 2009 (Vineyard, 2016). The incidence decreased in the following years, with another peak in 2013 with 21 255 cases. Next year, the number of dengue cases hit 13 000, from which 0.32% were deadly (Vineyard, 2016). The historical record was in 2015, with 50 000 cases nationwide (Oo et al., 2017). From these, 140 proved fatal. Still, for a deadliest dengue outbreak can be considered that from 1994, when 444 people lost their lives (Naing et al., 2002).

According to the Ministry of Health and Sports of Myanmar, dengue cases have dropped significantly after the last big outbreak in 2015 (Department of Public Health, 2018). Occurrence of the dengue disease is cyclical. Dramatic drop in dengue cases could be consequence of a better management or it could be caused by natural cycles (Department of Public Health, 2016). The spike is during the monsoon season (Vineyard, 2016). Most of the cases occur between June and September (Department of Public Health, 2016; Vineyard, 2016).

Children can be the riskiest population for potential dengue infection (Department of Public Health, 2016).

2.3.2.3. Japanese encephalitis

Japanese encephalitis (JE) is a viral brain infection transmitted through mosquito bites. It is caused by the Japanese encephalitis (JE) virus, which is a flavivirus, closely related to West Nile, Dengue, Zika and. Yellow fever viruses.

Symptoms are usually mild, but in some cases it could develop inflammation of the brain (encephalitis), with headaches, high fever, disorientation, coma, tremors and convulsions. Around

25% of the cases are fatal. There is no known cure for JE. There is just a therapy to support the organism to develop immunity by itself and to prolong the time for immune response.

The virus circulates between the vertebrate pigs and birds, and mosquitoes (Van den Hurk et al., 2009). Humans are not the usual hosts for the virus and they get infected accidentally (Vaughn and Hoke Jr, 1992; Van den Hurk, 2009). The concentration of JE virus in the human victim bloodstream is not enough to pass the infection to the mosquitoes (Vaughn and Hoke Jr, 1992). The virus cannot be spread from person to person (CDC[3], 2018).

The main vectors for the disease are the Culex species mosquitoes, especially Culex tritaeniorhynchus (Van den Hurk et al., 2009). Rural areas and rice fields are the usual dwellings for the mosquitoes (Daniels et al., 2002; Solomon et al., 2003; Van den Hurk et al., 2009). The mosquitoes from Aedes species also have ability to carry and transmit the virus (Rosen et al., 1978).

According to the WHO[3] (2015), there are more than 68 000 registered cases of Japanese encephalitis infections worldwide annually and 75% of them are children under 15. There is a certain cyclical trend of the major JE epidemics on every 2-15 years, especially during the monsoon seasons when there is an increase in the mosquito population, but there is still not enough knowledge on how major water-related natural disaster like floods and tsunamis can affect JE transmission (WHO[3], 2015).

2.3.2.4. Chikungunya

Chikungunya is a water-related disease caused by the chikungunya virus (CHIKV). In most cases the infection is not fatal (Pialoux et al., 2007). The most recognizable symptom of chikungunya is the joint pain, with additional symptoms as: headache, fever, muscle pain, joint swelling, or rash. Symptoms usually begin 3–7 days after being bitten by an infected mosquito and last 5-7 days more (Pialoux et al., 2007). There is not cure for the disease (Majra and Acharya, 2011). The therapy is focused on relief of the symptoms and extending the time for proper immune response of the organism.

The most common vector for the chikungunya virus are the representatives of Aedes mosquito species (Pialoux et al., 2007), Aedes aegypti and Aedes albopictus, the same one which are responsible for spreading of dengue, Japanese encephalitis, zika, yellow fever and other viral diseases. The only way it can be transmitted through human to human contact is from mother to child during the delivery process (Ramful et al., 2007).

Chikungunya has some symptoms which are similar to dengue and zika, which often can contribute to misdiagnosis in areas where they are both present (Pessôa et al., 2016).

2.4. Major factors influencing water-associated diseases

2.4.1. Social factors

Social factors that can influence the prevalence of the water-associated diseases include: population density, population mobility, population distribution, urbanization, poverty, education, access to clean water, sanitation and hygiene, quality of the healthcare, health policy and political situation (Daily and Ehrlich, 1996). Plenty of researches are indicating population density as a possible indicator of other social factors like: mobility, distribution, urbanization and poverty (Cohen et al., 1983; Link and Phelan, 1995; Shah, 1998; Yohe and Tol, 2002; Rygel et al., 2006; Munda, 2006; Birkmann, 2007). The level of open access to clean drinking water and sanitation are very important indicators for the health status in one country (Gleick, 1996; Montgomery and Elimelech, 2007; Viessman et al., 2009; Cosgrove and Rijsberman, 2014). The dynamics of the political situation in Myanmar in the last 40 has been stimulated by few internal armed conflicts fought on different fronts between the government and different ethnically charged paramilitary organizations. Internal armed conflicts create destabilization and havoc. This social chaos can be projected in form of internally displaced persons, severely damaged health facilities, lack of state control over the healthcare sector in the affected areas, lack of medical personnel and lack of sanitation and hygiene. All of these issues caused by the internal armed conflicts tend to have a direct impact over the emergence ore re-emergence of different water-associated diseases.

Taking into account the importance of these three factors, they have been included into the scope of this research.

2.4.1.1. Population density

According to some estimations (Ehrlich and Ehrlich, 1990), the world is going to experience 2 to 4 billion people population increase in the next 30 years, with around two thirds living in the cities (Cohen, 2003). There are indications of links between the population growth and the environmental quality decrease (Cropper and Griffiths, 1994). Population growth increases the pressure on the environment in many different ways. Urbanization, agriculture and industrialization activities are constantly decreasing the buffer zone between the humans and the endemic animal species, making the interaction between them more frequent (Cincotta et al., 2000; Collins et al., 2000; McKinney, 2002). Densely populated urban centers could be the infectious diseases hotspots (Martens and Hall, 2000; Jones et al., 2008).

Human demographics can be deciding factor in the epidemics dynamics (Daily and Ehrlich, 1996; Pimentel et al., 2007). According to Daily and Ehrlich (1996), population growth and density can affect outbreaks by changing the frequency, speed and the severity of infection, the pathogen evolution rate and the coevolution of the human host's immune system. Increase in the human population density contributes to more frequent contacts between humans and pathogens, humans and vectors, and between infected pathogen carrier and non-infected persons. Also, in situation when there are more family members, which is usually related to the places with high population density, there are more individuals with genetically similar immune systems (Daily and Ehrlich, 1996). Pathogens tend to evolve towards overcoming of the particular host immune system, so if there are more people with an inherently similar immune system, the chances are higher for more serious impact of the pathogen.

The increase of the global population, especially in the developing countries of the tropical and subtropical belt, will imminently lead to increase in the land use for purposes of urbanization and agriculture. Newly established farmlands could allow advantageous conditions for the development of the vectors and parasites similar to the ones provided by the swamps or the humid forests (Martens and Hall, 2000; Afrane et al., 2004). The agriculture lands which are positioned near the riversides can provide ideal temperature and humidity conditions for the vectors (Yeryan et al., 2016). Water temperatures in farmland environment can significantly increase (Munga et al., 2006;; Munga et al., 2009; Zhou et al., 2011). Authors noticed that this change is increasing the humidity in the habitats which subsequently shortens the time needed for larval development. Also, higher water temperatures are increasing the fermentation rate of the litter in the water which allows more nutrients for the larva.

Increased population density, in both rural and urban areas, can have synergetic effects with the increasing global temperatures, towards more frequent diseases incidence (Lindgren et al, 2000; Rezza et al., 2007). In some cases where there is a warmer climate during the most of the year, the disease prevalence is higher in the urban areas (Lolekha et al., 2001).

The increase of the air surface temperatures may contribute to a risky human behavior. People living in the villages or the sub-urban settlements may have tendency to sleep outdoors (CDC[1], 2015). Also, they may put down the guard and avoid using bed nets (CDC[1], 2015).

Different potential vector species may differentiate in the ability for parasite transmission. Some can have no capacity for carrying of the parasite; others can have only limited capacity under specific conditions, and the most suitable vector have the physiological capacities that makes them ideal for carrying and transmission of the vectors (CDC[2], 2015).

Vector behavior also plays an important role for the potential of parasite transmission. The females in some species favor to bite humans, which makes them anthropophilic. Others tend to bite more animals (zoophilic) (CDC[2], 2015). The spatial dimension of the biting can also be a matter of difference, as some species favor the indoor blood feeding, while the others attack more outdoors (CDC[2], 2015). Resting patterns are important too. The ones that are biting indoors can endophilic or exophillic. Endophilic are the ones which rest inside the homes where they had meal. Exophillic rest outside. Endophilic can come more frequently in contact with the insecticides. So generally, the human, indoor, exophillic biters would be the most dangerous transmitters of the diseases (CDC[2], 2015).

Immigration can be also huge problem concerning the control and elimination of the water-associated diseases (Yeryan et al., 2016). There is a high risk of spreading of water-associated infectious diseases across the Myanmar borders (Marshall, 2005). The border areas of Myanmar with China, Thailand, India and Bangladesh are mostly deep into the mountain forests and are difficult to control. There are many Myanmarese migrant workers circulating between Myanmar, China and Thailand (Chantavanich et al., 2007). Illegal emigration also makes the eradication programs more difficult to be carried out (Triteeraprapab and Songtrus, 1999; Wiwanitkit, 2002). Internally displaced people are especially vulnerable group for different water-associated diseases (Pink, 2016; Ahmed et al., 2018).

2.4.1.2. Access to safe water and sanitation

Limited access to safe drinking water and poor sanitation are two of the leading causes for development of waterborne diseases outbreaks (Montgomery and Elimelech, 2007; Waldman, 2013). There is a close relation between the two factors. The unsafe drinking water and unhygienic sanitary facilities, if not properly managed in long-term, can initiate slow onset health disaster in one region (Waldman, 2013). Exposed shallow wells, unprotected springs and poorly constructed pit latrines can expose vulnerable human populations to waterborne diseases (Banda et al., 2007; Cumming et al., 2014). Unhygienic traditions, such as using canals and other convenient bodies of water for religious ablutions and bathing, allowed further spread of water-related diseases (Zolnikov, 2013). Low income countries like Myanmar are particularly susceptible to this kind of issues (Sorenson et al., 2011).

Children are especially vulnerable population. Many children in Myanmar, between age 1 and 5, living in a socio-economically vulnerable families, don't have access to the proper drinking water and adequate sanitation facilities (Munsawaengsub, 2011; Canavati, 2011). Diarrhea (Ochoa and Surawicz, 2002) and cholera (Waldman, 2013) are the most prominent waterborne diseases that result from unsafe drinking water and unsanitary conditions. Diarrhea was one of the main causes for putting Myanmar on the third highest place in the childhood mortality numbers in Asia only exceeded by Cambodia and Laos (Hoehn and Hoppenz, 2009). Recently, there are reports for some improvements in the availability of safe water and sanitary conditions in Myanmar (Tin et al., 2010).

Increase of the access to clean drinking water decimates the infant mortality rates (Ogawa, 1997). There is also an interesting notion that the access to clean drinking water decreases the maternal mortality rates, but only to certain level, after which it doesn't have any influence (Ogawa, 1997). According to Ogawa (1997), the more educated women are the more clean water they use, which correlates with the infant mortality rates decreasing.

Access to safe drinking water and sanitation are closely related to other socially influencing factors like armed conflicts and natural disasters. The ongoing armed conflicts in Myanmar increase the risk for emergence and re-emergence of waterborne diseases in the conflict zones (Checchi, 2003), but also in the established refugee camps (Phillips, 2013; White, 2017). Internally and externally displaced persons have difficulties reaching the adequate water quality and sanitation conditions in the rural areas refugee camps (Mahn et al., 2008). The authors state that the refugees are not properly registered and as a consequence of that there is no an equal distribution of the resources according to the real needs. Therefore, Myanmar has to improve the system for collection and compilation of health and epidemiological data concerning the refugees, in order to fill the gaps and to plan better policies (UNFPA, 2010; FAO, 2015).

Major water related natural disasters, like floods and tsunamis, also can trigger disintegration of the water distribution system, water quality and sanitation and hygiene standards (Wisner et al., 2002; Blaikie et al., 2004; Clasen et al., 2006; Du et al., 2010; Myers et al., 2013). This collapse of the system can lead to occurrence of different water-borne diseases (Moszynski, 2005).

2.4.1.3. Armed conflicts

War always causes destruction of the existing infrastructure and post-war calamities. Especially affected can be the availability and safety of the access to clean drinking water which brings intensive dropping in the sanitation and personal hygiene standards. The lack of food, health services and transportation can be also decisive factors during the times of the post-war outbreaks. Humanitarian catastrophes are the impending doom that follows the war. Refugees or the internally displaced persons (IDP'S) are not in position to keep the pre-war quality of life. The situation can be most difficult in some of the parts of the developing countries where the standards of living are low even before the break out of the armed conflicts.

These several deficits can trigger the water-associated outbreaks. Waterborne diseases like diarrhea and cholera are usually the first that follow up after each humanitarian crisis (WHO[1], 2002; WHO[1], 2012). With no safe access to clean water and food, the question of outbreak of these diseases is just a matter of weeks.

Water-associated diseases could be also on the rise during the armed conflicts. Sleeping in the open air and lack of repellents and medicaments are factors which increase the probability for bites by infected vectors (WHO[2], 2012). The unmonitored movement of the IDP's or refugees in the deep forest areas where there is a lack of medical help can be also risk factor for potential outbreaks of malaria, dengue or other water-associated vector borne diseases.

Myanmar currently has around 25 still active paramilitary organizations (July, 2016). According to the author, some of them are heavy armed and are respectful opponent for the Myanmar's army. There is almost 60 years of continuity of the armed conflicts in Myanmar. The level of intensity differentiates between the conflicts. Some of them could be qualified as real frontal wars and some of them are small scale conflicts (July, 2016). But in both cases there is a massive devastation of the infrastructure, intense migration of IDP and refugees in the neighboring countries.

2.4.2. Environmental factors

The geographical range of areas where water-associated diseases are present has been expanding exponentially during the last decades (Parkinson and Butler, 2005; Afrane et al., 2012; Siraj et al., 2014). There are debates about the effects of the climate change on the prevalence and distribution of the water-related vector-borne diseases (Lindblade et al, 2000; Patz et al., 2000; Patz and Olson, 2006; Afrane et al., 2012). Researchers have debated about the existence of these effects, and if they exist, how they affect these types of diseases. They are reporting possible findings that vectors are moving to higher altitudes during the warming period and return back when the temperatures are dropping (Afrane et al., 2012).

The mosquito populations, enhanced by the increasing world temperatures, can possibly distribute malaria, dengue, chikungunya, zika and the other water-related vector-borne diseases to new areas in the densely populated regions of Africa, Asia and both Americas. Both the parasites and the vectors that spread them flourish as temperatures increase (Patz and Olson, 2006).

This diversity in the temperature, humidity and precipitation tolerance among the Anopheles species could contribute to introduction of new species in areas and decreasing of the endemic ones (CDC[2], 2015). This could also modify the dynamics of water-related vector-borne disease transmission (Mordecai, 2013).

However, some of the assumptions behind these projections were criticized. Some researchers have argued that the better-quality of life and improving of the socioeconomic conditions will impose as a buffer zone to the spreading of diseases induced by the climate change effects (Blaikie et al., 2004).

2.4.2.1. Temperature

Global climate change brings extension of the warm season around the world. Temperature increase of 2-3 ^{0}C will increase the risk of malaria by 3- 5%. The reproduction cycle of Aedes mosquitoes at higher temperatures is faster, which implicates that we can expect more frequent bites. Previously unsuitable environments became suitable for mosquito vectors. There are reports all over the world, about both vectors spotted and identified water related diseases cases in high-altitude human settlements (Chen et al., 2006; Afrane et al., 2012).

Mordecai et al. (2013) found that the optimal transmission for malaria is 25 °C. The temperature range for uninterrupted mosquito reproductive cycle, according to Beck-Johnson et al. (2013), is 17-33 ^{0}C. The authors conclude that the optimum would be 20-26 ^{0}C. Diurnal temperatures (DTR) can also be one of the limiting factors for the parasite development. Paaijmans et al. (2010), concluded that DTR fluctuations around 21 ^{0}C could increase the speed of the growth, while fluctuations below this temperature would slow it.

Temperature can influence all of the development stages of the vector (Snow and Gilles, 2002; Russell et al., 1963). Temperatures above the optimal range and abundant rainfall might be limiting factors for the dynamics of the mosquitos' population. Larval growth can be interrupted by low temperatures (CDC[1], 2015). Cohen et al. (2008) agree with that notion, adding that the extreme limits for Plasmodium survival would be 18 ^{0}C (low limit) and 40 ^{0}C (high limit). Other researchers also came to a similar conclusion (Mourya et al. 2004; Fernandez-Becerra, 2009; Mohammed and Chadee, 2011; Couret et al., 2014; Marinho et al., 2016).

The effects of the temperatures can also vary between the Aedes vectors. One study claims that Ae. albopictus can develop broader scope of tolerance than Ae.aegypti (Brady et al., 2014). Chang et al. (2007) indicate that a temperature of 13.8 °C can be critical for the survival of the Ae. aegypti larvae, which reduces the population of adult mosquitos during the East Asian winter monsoons. Marinho et al. (2016) report high adult viability and female fecundity in the temperature range of 16-36 ^{0}C.

These findings correspond to the findings of Costa et al. (2010) and Carrington (2013) that reported decreased adult viability bellow 16 ^{0}C and decrease in the female mosquito's interest for feeding with blood. Similarly dependent patterns exist between E. aegypti population fluctuations, dengue prevalence and the rainfalls (Barrera et al., 2011).

2.4.2.2. Humidity

Humidity has significant influence over the life cycles of the parasitic organisms (Patz et al., 2000; Rose et al., 2000). The viruses are more resistant to changes in humidity than bacteria, protozoa and the parasitic worms (Crabtree et al., 1997). Humidity also has defining impact over the reproduction cycle and development of the vector insects (Smith, 1993; Moyer et al., 2002; Auger et al., 2003; Parkinson and Butler, 2005). The patterns of humidity and precipitation are changing under the pressure of the climate change. Depending of the geographic location, some areas are feeling the extended water season in duration and amount of rain, while the others are experiencing a water scarcity. One of the climate factors related to this issue is extension of the tropical belt by 2.0°–4.8° latitude in the last 40 years (Seidel et al., 2008). This change has not been anticipated previously.

Increased humidity can change the habitat (Suttle et al., 2007). Increased humidity can also increase the rate of reproduction of the vectors (Patz et al., 2000). This will bring increase in the outbreaks of malaria, dengue and the other water-related vector diseases (Patz et al., 2000; Parkinson and Butler, 2005). This environmental change will inevitably lead to some kind of adaptation or extinction.

Ae. albopictus colonies demonstrated a consistent preference for higher humidity, opposite to Ae. aegypti colonies which preferred more dryer climate (Reiskind and Lounibos, 2013). According to Mogi et al. (1988), Ae. aegypti is dominant in urban and indoor spaces during the dry season and Ae. albopictus is dominant in rural and outdoor areas during the monsoon season.

The biological effects of the humidity are often synergistic with the temperature (Fig.4) (Parkinson and Butler, 2005). To any kind of temperature and humidity increase, insects like an ectothermic animals, react with an increase in their own body temperature and the intensity of their metabolism (Allen et al, 2002). There are some claims that as a result of the intensified metabolism, the mosquitoes will start with more frequent feeding with blood (Lyimo and Ferguson, 2009). Still, the stimulating effect of humidity over adult mosquito population significantly decreases at temperature of 22 ^{0}C (Alto and Juliano, 2001).

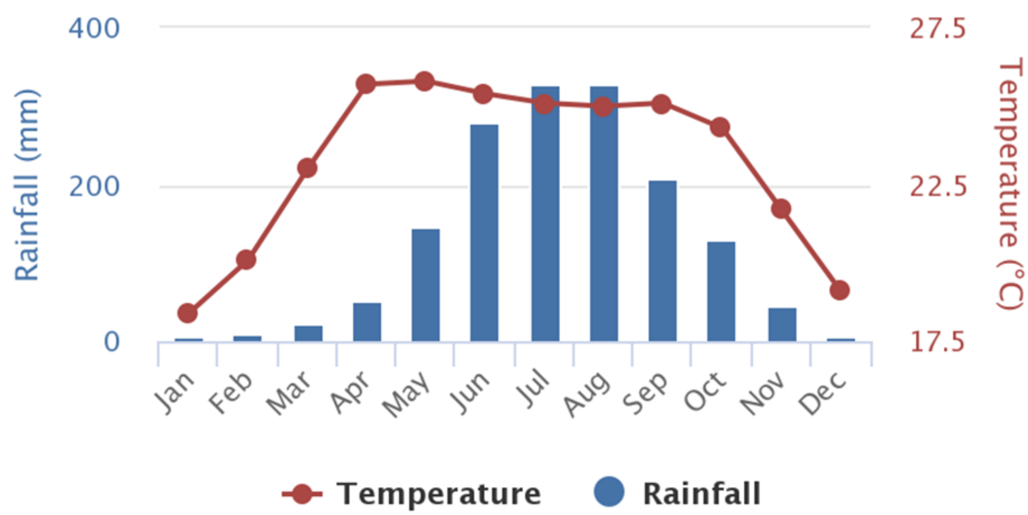

Figure 4: AVERAGE TEMPERATURE AND RAINFALL IN MYANMAR BY MONTHS

Source: The World Bank Group, Climate Change Knowledge Portal (2018)

2.4.2.3. Precipitation

The climate change and the global warming are intensifying the rainfall on the global scale. The hydrological cycle accelerates and intensifies because the higher temperature transforms more liquid water to vapor and then warmer air can hold more vapor and release bigger amount of rain (Fig. 4) (Seinfeld and Pandis, 2012). Rainfall is an important factor for the development of mosquito breeding sites. Rain fills the ground holes, tree holes or the potential artificial man made reservoirs in the urban areas, thus creating potential breeding sites for the mosquitoes (CDC[1], 2015). Rainfall and water runoffs have been associated in waterborne disease outbreaks (Curriero et al., 2001). This is especially the case with the developing countries, but the developed countries are not immune either. Waterborne diseases outbreaks are often heralded by a heavy rainfalls and floods which could contaminate the drinking water in the region (Curriero et al., 2001; Epstein, 2001; Hunter, 2003). If the soil is saturated enough, the diffusion of microbes in the neighboring areas could be increased (Curriero et al., 2001).

2.4.2.4. Elevation

Low altitude areas are usually ideal places for water-related diseases vectors like mosquitoes (Attenborough et al., 1997; CDC[1], 2015). Temperatures in higher elevation areas are lower which prevents the mosquitoes from invading. Some researchers agree that the largest part of the mosquito vector population can be found in the elevation range of 100-2000m (Wolda, 1987; Malakooti et al., 1998; Bishop and Litch, 2000; Mugisha and Arinaitwe, 2003; Azari-Hamidian et al., 2009; Lozano-Fuentes et al., 2012). Areas with elevation close or below the sea level can have complex effects on the mosquito population dynamics. These areas have the proper temperature ranges for larval development and adult mosquito survival. Additionally they are more prone to floods because water from the heavy rains tends to remain there for a longer periods, which means that there will be also a higher humidity. Water and high humidity are essential for vector breeding. However, flashfloods can destroy the mosquito eggs and larvae and decimate their population (Batzer and Wissinger, 1996; Duchet et al., 2017). Rice fields in South-Eastern Asia are typical example for areas that of kind. Most of the year they can be places of high risk for human contact with the mosquitoes which are breeding there (Keiser et al., 2005), but after intensive monsoons and flashfloods, the number of registered cases of malaria and dengue can drop down (Duchet et al., 2017).

Global increases of the temperature can alter the microclimate in the high-altitude areas and make it more suitable for new vector species. Numerous researches are reporting increasing number of registered water-related diseases cases in areas within the elevation range of 2000-2500m (Reiter, 1998; Bishop and Litch, 2000; Hay et al., 2002 Abdur Rab et al., 2003; Mboera et al., 2008). Areas in the range between 2500 and 3000m are susceptible to vectors expansion (Garnham, 1945). Newly established environmental conditions can reproduce the niches of the vector species from lower altitudes. Opposite effect in a form of abandonment of the habitat by the already established endemic vector species, under the pressure of the new conditions, has also been observed (Afrane et al., 2006). According to the authors, cases of malaria have been decreasing in West Africa, in areas bellow 1600m. There are also indications that the spatial distribution of malaria is expanding in the plateaus of Ethiopia and Colombia according to the temperature changes (Siraj et al., 2014). The authors state that the average altitude of registered malaria cases lifted to higher altitudes in warmer years, but in the cooler years it descended back to lower altitudes.

Deforestation is one of the factors that can be interlinked with the change of the microclimate and environment in the high-altitude areas (Lindsay and Martens, 1998; Afrane et al., 2012).

Constantly warmer microclimate in the high-altitude areas can cause dry seasons and droughts which can affect the survival of the forests. This change can initiate forming of new conditions, ideal for introduction of new vectors in the previously impenetrable areas. From the other side it can bring hostile conditions for other types of vector (Afrane et al., 2012). This interaction can be accelerated by the global warming.

1.1.1.1. Deforestation

Deforestation can change the ecosystem and the habitats of many species. The modification of the soil and water structures could lead to changes of the microclimate. Local changes of the temperature and humidity could lead to changes of the behavioral patterns of the animals. Deforestation can accelerate transmission of many diseases (Barrera et al., 2011; Afrane et al., 2012). Water-associated diseases are especially dependent of the process of deforestation. Losing of the tree cover can destroy the vector species natural habitats. From the other side it could initiate increasing of the temperature.

Deforestation can be result of a natural phenomenon or anthropogenic action (Angelsen and Kaimowitz, 1999). Deforestation, as a natural phenomenon, can be caused by different environmental disturbances: forest fires, landslides, storms or droughts. The anthropogenic actions that can cause decreasing of the forest areas are: intentional fires, urbanization, agriculture, mining or dams building. These changes can increase the prevalence of the water-related vector diseases (Afrane et al., 2012).

Cutting of the forest trees for gain of the agricultural land or other kind of land use can increase the surface air temperature and change the relative humidity of the region (Afrane et al., 2012). Agriculture expansion, as one of the forces behind deforestation, can indirectly contribute for water-related vector-borne diseases (Janko et al., 2018). Humidity decreased 22.6% in the populated deforested areas (Afrane et al., 2012).

Deforestation can be decisive factor for malaria spreading, especially the one caused by P. knowlesi which is infecting the macaques (Singh et al., 2004). According to the authors, the natural buffer zone between the humans and the macaques is shrinking, making the incidents of contact between the two species more frequent. There are few cases of deforestation caused by urbanization or dam construction that caused emergence of different vector-borne zoonotic diseases like Ebola in Africa (Alexander, et al., 2015) or SARS in South East Asia (Coker et al., 2011).

Landscape configuration can have a strong influence on mosquito distributions (Patz et al., 2004). Authors claim that these changes have enabled sufficient conditions for introduction of new invading mosquito species and changes in the balance of the vectors population. Indoor average temperature is increased by deforestation between 1.8 and 2.30 C (Afrane et al., 2012). Outdoor temperature in the human settlements near deforested site got 1.4 °C higher than the ones in a forested area (Afrane et al., 2012).

All of these changes in the temperature and precipitation reduced the time limit necessary for the completion of the reproduction phase of the mosquitos for almost 2 days (Li et al., 2014). According to the authors, this reduction in the reproduction phase will accelerated the frequency of feeding with human blood from 5 to 3 days. This change will bring higher possibility for transmission of the vector borne parasites.

This increase in temperature and humidity can also accelerate the Plasmodium reproduction and development between 1 and 2 days (Harvell et al., 2002). The authors further analyze that the time needed for the mosquitoes to become fully infective will become shorter which means that the potential epidemiological imprint of the disease will increase.

In some cases the deforestation had negative effects on the survival of the vector species (Altamiranda-Saavedra et al., 2017). According to the authors, deforestation in Colombia caused decrease of the average indoor humidity, which caused shortening of the lifespan of Anopheles gambiae mosquitoes which have been populating the human dwellings around the area.

Still, the issue of deforestation influence on the water-related diseases is complex. There is need for more researches about breeding sites, temperature of the water as a breeding environment, water pH and types of vegetation (Yasuoka and Levins, 2007). According to the authors, current models cannot predict the total impact of the deforestation on the vectors behavior.

1.1.2. Natural disasters

Natural disasters are result of a complex mixture of environmental and societal risk factors. They have potential to shake seriously the normal functions of society (Penna and Rivers, 2013). Human lives can be equally in danger during and after the natural disasters. Decimated infrastructure, destroyed homes, breakdown of the electricity system, lack of clean water and food, low sanitary conditions, exposure to human or animal carcasses which can contaminate the near environment, lack of medical workers, aid and transportation, are just some of the myriad of outcomes from the natural disasters that could lead to outbreaks of infectious diseases.

Epidemics of water-associated diseases are especially increasing after the natural disasters (Watson et al., 2007). The developing countries are particularly vulnerable to natural disasters because they already have existing problems with the infrastructure and the human resources, which is already a serious vulnerability.

Floods are particularly big risk factor for outbreaks of waterborne diseases. Floods have ability to collect all of the organic waste on their way, fecal matter from sewage canals and carcasses and to carry them to human dwellings, which in situation of lack of medical and sanitation infrastructure and designated responsible persons for managing of this kind of calamities, could be another following catastrophe in the chain (Ahern et al., 2005; Schwartz et al., 2006; Du et al., 2010).

Waterborne diseases like acute diarrhea and cholera are the usual accompanies of the post-disaster period (Schwartz et al., 2006; Waldman et al., 2013; WHO[1], 2018). The contaminated with different parasites water can also proliferate many other diseases like giardiasis, schistosomiasis, hepatitis A, typhoid fever and dysentery (WHO[1], 2002).

Water-related vector borne diseases have somehow more complex relation to the floods and the natural disasters generally. The striking natural disaster can force people to sleep outdoors which means more risk for biting by the infected vectors (WHO, 2006; WHO[1], 2012). The lack of impregnated net, repellents and medicaments can make the situation even more difficult.

The timing of the floods is also especially important. In the countries of tropical and subtropical belt floods usually occur during the monsoon season. The mosquito's eggs usually hatch after the monsoons (CDC[1], 2015; CDC[1], 2018), with swarms of new adult females searching for their blood meal. The heavy monsoon rains and occasional floods can leave many stagnant water places in the natural or urban environments which could serve as breeding sites. But what it is of crucial meaning is the intensity of the floods. In case of flashfloods there is a high probability that the eggs will not survive these calamities (Duchet et al., 2017). Flashfloods could wash away the mosquito's eggs, they will be dispersed with the water and they will not be able to survive. This would mean a decimation of the next generation of mosquito population.

1.2. GIS for health and epidemiological studies

According to Bernardi (2001), GIS technology can explore the condition, location, trends, patterns and modeling of alternative scenarios about certain geospatial phenomenon. Health has a geospatial dimension (Krieger, 2003). As such, it can be subject of geospatial analysis. Almost two centuries ago, John Snow was the first man who understood the potential of mapping for defining of the spatial dynamics of diseases (Snow, 1855). GIS can be useful for different types of epidemiological surveillances on communicable or non-communicable diseases. Different predictive models using GIS and RS have been developed using correlations between disease and environmental variables for different water-associated diseases (Rogers and Randolph, 2003). GIS technology can show the most vulnerable populations and their surrounding environment, which can be helpful in the detection of the possible causes of vulnerability. Mapping of the diseases can explain their overall effect and the possible risk towards vulnerable populations.

GIS can be useful method for health studies, training, design and monitoring of programs for diseases eradication or control (Kandwal et al., 2009). GIS can help forecasting the dynamics of plentiful of threatening diseases and epidemics. Temporal trends are the other important factor for determination of the causes of diseases and prediction of their impact. Some epidemiological studies employ geospatial calculations in correlation with time (Yang et al., 2005; Gething et al., 2007; Gething et al., 2008; Wang et al., 2008) which gives opportunity for better comparison of the trends of interest in the future map iterations (Hay et al., 2009). There are many factors which have complex influences on the emergence or re-emergence of epidemics (Kandwal et al., 2009). GIS can allow clearer picture on the spatial and temporal interconnectivity between the environment, social structures and diseases. Climate change, natural caused or anthropogenic or environmental disturbances, land change, pollution and population, amongst the other factors, can initiate favorable conditions for developing and spreading of water-associated diseases in the places where they were once eradicated or to new areas, never reached before. All of these environmental or socio-economic factors have spatial dimension. These factors can modify the disease patterns in different geographical zones.

According to Brown et al. (2005), proper GIS analysis requires orderly collected geo-referenced epidemiological data. The next step would be GIS data storage and maintenance. Depending on the amount of data collected, data storage and maintenance sometimes can be an issue (Brown et al., 2005). The usual geospatial tools used for health and epidemiological analysis include: spatial overlay and intersection, buffer creation, kernel density, zone statistics, geographically weighted regression, neighborhood analysis, raster calculations and network analysis (Krieger, 2003). These tools can help describe the distribution of disease cases and density of the incidence. Mantel (1967) introduced "disease clustering" as a method that can help identify the diseases hot-spots and clusters. In that way, the source of the disease, human, artificial or environmental, can be indirectly assessed and possibly eliminated.

GIS could be useful tool for the health policy makers (Kurwakumire, 2014). Visual presentation of the facts in most of the cases is the best way of communication. In that sense maps can be a useful way of communicating the risks to the public. National implementation of GIS could intensify the planning and management of the endemic diseases (Bergquist, 2001). Health professionals can track the success of the short or long-term interventions, control or eradication programs.

GIS can blend the medicine, public health, environmental and social sciences in one interdisciplinary knowledge base (Rogers and Randolph, 2003). Environmental and social sciences can offer explanation to many trends in the diseases epidemiology which cannot be assessed by the traditional methodologies used by the medicine or public health. Typical example of interconnection between the environmental information, health and epidemiology data are the so called "risk maps" (Bergquist, 2001). According to the author, the first successful application of epidemiological risk maps was the African Rapid Epidemiological Mapping of Onchocerciasis.

The socio-cultural background of the country is important asset to every GIS health analysis. It can help during the interpretation of the results (Kandwal et al., 2009). Census data can be valuable source of information for GIS health and epidemiological investigations (Bernardi, 2001). Economic data about the country or the smaller administrative region can explain some of the factors for vulnerability of particular populations (Kandwal et al., 2009).

Another geospatial technology, Remote Sensing, allows the health scientists and epidemiologists use of near real time images, or at least, time scale images of the area of interest, for analyses of different environmental factors which can influence the geospatial prevalence and the infection rate (Beck et al, 2000). According to Beck et al. (2000), these factors can be: temperature, humidity, precipitation, elevation and vegetation. Beside the terrain surface, seas and oceans can be also monitored. Today's RS technology allows even monitoring on some forms of water pollution. The same technology can be applied in following of some man-made changes:

a) Landscape changes: agriculture, deforestation, urbanization;

b) Energy usage: sources of heating and heating intensity;

c) Pollution: landfills, air pollution, radiation sources;

d) Transport.

There are some suggestions for broader inclusion of these two technologies in the development and monitoring of the indicators for Sustainable Development Goals (Anderson et al., 2017). But in order for this to be achieved, there is an imminent need for global coverage of data ranging from parasitic identification to reports of outbreaks, clusters of emerging or re-emerging diseases or even single cases. This level of organization can be achieved only by constant recommendations, education and trainings about the advantages of GIS in health policies, channeled from the UN agencies to its final users, the national health agencies (Anderson et al., 2017). Data availability should be also open and emphasis should be put on the data sharing (Bergquist, 2001).

GPS is the third geospatial technology that can be effectively used in health sciences (Chaix et al., 2013). This particular tool empowers the researchers and health workers with accurate, pinpoint precise data and fast-track map building.

Plentiful researches have tried to combine malaria surveys with GIS and RS in order to produce maps (Kleinschmidt et al., 2000; Kleinschmidt et al., 2001; Rogers et al., 2002; Omumbo et al., 2005; Rogers, 2006). These maps require use of model to predict values at locations of the survey data which implies a certain inherent uncertainty in them (Hay et al., 2009). Consequently, according to Hay et al. (2009), quantifying the values would be a primary concern in this kind of disease mapping, because with decreasing of the density of and proximity to neighboring data points the ability of the map to predict decreases.

Maps displaying reliable epidemiological data can play an important role in: (a) assessing the magnitude of the problem, (b) defining priority areas for control, (c) monitoring progress and change following control efforts, (d) advocacy, and (e) identifying areas where further data are needed (Rogers and Randolph, 2003).

There have been efforts for global mapping of the malaria P. falciparum geographical transmission limits (Guerra Loaiza, 2007; Guerra, C.A., 2008). According to the authors, nationally reported case incidence reports and alternative medical intelligence were used like a data sources for the researches, and biological rules of transmission exclusion, according to the temperature and aridity limits of survival of the locally dominant Anopheles vectors. The authors of these researches divided the world into three different classes: no risk, changeable risk and constant risk of malaria P. falciparum.

There are several projects for global mapping of some diseases (Doumenge et al., 1987; Hay and Snow, 2006; Brooker et al., 2010; Simarro et al., 2010). In 1999, WHO in collaboration with UNICEF launched the ‘‘HealthMapper’’-a GIS based application for data collection and maps creation. It was built to processes the incoming health data from national agencies, and on basis of that, to analyze, give a feedback, and help the public health decision-makers (WHO, 2004).

The first idea of defining the transmission of water-associated diseases in a numerical way came from Craig et al. (1999). The authors based the model on the possible disturbances created from climate change, taking into account data from epidemiological surveys and historical maps. Snow et al. (1999) expanded their research on a bigger geographical area, whole Africa, taking into account some social indicators, in form of population, mortality, morbidity and disability.

The lack of stable health system in the developing countries can make the GIS health and epidemiological analyses very challenging. Unstable health system means underdeveloped network of hospitals, lack of medical staff or lack of proper training for data collection and maintenance. This issue can bring into question the reliability of the health and epidemiological data. Especially in relation to GIS, lack of geo-referenced data can undermine the whole process of geospatial analysis. Omumbo et al. (1998), tried to resolve this issue by collecting data from existing cross-sectional surveys and geo-reference them. Additionally, the lack of trained health professional that can use GIS tools complicates the issue more. Never less, today there are plenty of GIS software and tutorials which can be used in health and epidemiological analysis and training.

1.2.1. Geospatial epidemiological and health studies in the South-East Asian region

The situation with water-associated diseases monitoring is especially difficult in the deep forests in the South and South-East Asia. In order to tackle this problem some countries in the region have been using GIS and Remote Sensing technologies. India (Srivastava et al., 1999), Bangladesh (Haque et al., 2009), China and Thailand (Indaratna et al. 1998), are the countries in South and South-East Asia that are already implementing GIS technologies and Remote Sensing in their health and epidemiological researches as part of their national health programs.

Researchers in Bangladesh have done geospatial analysis on the malaria prevalence from a micro-geographic perspective (Haque et al., 2009). China had problems controlling the malaria in the southern border regions where plenty of unmonitored population movement exists (Hu et al., 1998). The researchers collected census and health data from the period between 1990 and 1996 and analyzed them in correlation with the environmental factors.

On the other side, in the south, Thailand, Malaysia and Vietnam had mixed success in the use of GIS tools as a part of the malaria elimination program (Kidson and Indaratna, 1998). Malaria was successfully eliminated in the rice fields but the problem remains in the forests occupying the borders. In several Indian villages, asymptomatic malaria pattern was assessed using GIS and satellite maps identifying the soil composition and water quality as main source of disease fluctuations (Srivastava et al., 1999).

Indaratna et al. (1998) have tried a mixed approach, with assessment of the economic indicators and comparing them with the dengue and malaria incidence in Thailand. Authors concluded that socio-economic and epidemics data collection from various sources and different time-scales can complicate the correlation calculations between the factors.

2. Methodology

2.1. Data collection and organization

2.1.1. Water-associated diseases outbreaks database

A custom made database in Excel has been created, where all of the data from the publications and reports of water-associated diseases outbreaks registered on the territory of Myanmar in the period from 1991 to 2018, were imported. The data which were extracted from the sources and included in the later quantitative and geospatial analyses were these: Name of the disease (identification), pathogen that caused it, the place where the outbreak occurred (geographical unit), number of cases, number of deaths (if applicable), affected population age (if applicable).

It is important to be noted that the sources of information in form of publications or reports, were divided in 2 groups. If the number of cases was clearly indicated in the source of information, and there has been provided a strong evidence for the causal pathogen of the indicated outbreak, these data were included in the custom made database, regardless of the form of the research (lab analysis, self-report or clinical diagnosis). But if the number of cases was just estimated, then the information was recorded in a separate field in the custom made Excel database. Most of these sources offered convincing causal connection between the pathogen and the outbreak, but the data extracted from them required careful interpretation. The other sources that did not provide a well-defined, causal pathogen-outbreak link have not been used as data source and only provided additional background information about the situation in that period. Also, where it was applicable, the number of deaths resulted from the disease outbreak was included. The type of study, citation information and the direct source link were also included in the database. If there were some specific circumstances or environmental or socio-economic conditions noted in the source of information, concerning the disease outbreak, they were registered in the separate column in the custom made Excel database. In situations where two or more publications or reports referred to the same study or to the same time period or portion of it, they were additionally filtered in order not to be doubled. In situation when during the search, other source of information with the relevant data about some outbreak was identified, the data was updated.

Literature was obtained using different combinations of keywords to search through the relevant online databases. Medline and PubMed were searched for peer-reviewed scientific literature. A list of water-associated pathogens identified on the territory of Myanmar was compiled. This list was used to generate search keywords for the search filtration of water-associated infectious diseases epidemiological studies or outbreaks reports in Myanmar. The search procedure included the titles of the publications or reports, key words or abstracts of articles present in the online databases. In cases when the full texts were not available, the data was extracted from the abstracts. The publications which were not available online in electronic form, like a full text or abstract, or did not match the designated search keywords, may have not been taken into account. Because of the language barrier, only English language studies and reports were included. Each relevant reference from the reviewed literature was also analyzed like a possible source of information. All forms of epidemiological studies were included. The emphasis has been put on the primary sources of information like scientific medical studies or national and regional epidemiological surveys, but general reviews and texts (ProMed reports or news) were also consulted. Taking into consideration that not all health data are available in the formally published studies (McAuley et al., 2000; Hopewell et al., 2007), we have also included the "grey" literature (Alberani et al., 1990; Auger, 1994; Conn et al., 2003; Benzies et al., 2006; Rothstein and Hopewell, 2009; Cann et al., 2013) about water-associated diseases outbreaks in Myanmar. We have searched the ProMed mail reports (Cann et al., 2013), as a part of the Program for Monitoring Emerging Diseases. We have also searched the online engine for this kind of information. Some major journals about water-associated diseases epidemiology, health and tropical diseases were additionally searched for fact checking. In summary, 129 water-associated disease outbreaks on the territory of Myanmar were identified and included.

2.1.2. Social and environmental GIS data

The basic map dataset of the administrative borders of Myanmar was downloaded from the Myanmar Information Management Unit (MIMU, 2014).

2.1.2.1. Natural disasters database

The data about the natural disasters happened in Myanmar from 1991 till 2018 was obtained from the EM-DAT, International disaster database (Guha-Sapir et al., 2015). Key terms used for identification of natural disaster events were identified from the EM-DAT International Disaster Database and included: riverine flood, flashflood, landslide, extreme storm, cyclone, earthquake, tsunami and forest fire. Additional geo-referencing of the disasters location has been done with Google Earth Pro, because most of the locations were not geo-referenced.

2.1.2.2. Armed conflicts database

The data about the armed conflicts in Myanmar, happened in the period of 1991-2018, was obtained from the Armed Conflict Location & Event Data Project (Raleigh et al., 2010). All of the locations of the conflicts were geo-referenced. Additional filtering of the data was needed, because the data included some low level armed conflicts and riots and unrests in urban areas, which could not have big impact on the overall infrastructure in the areas.

2.1.2.3. Access to improved water sources and sanitation data

The geospatial data for the population living in households using an improved water source and the population living in households using no toilet facility (practicing open defecation) in Myanmar, has been downloaded from the USAID Demographic and Health Survey (DHS, 2015) database. The data has been handled according to the guidebook by Burgert−Brucker et al. (2016).

2.1.2.4. Population density data

The population density geospatial data of Myanmar was obtained from the Center for International Earth Science Information Network (CIESIN, 2013).

2.1.2.5. Elevation data

The elevation geospatial data of Myanmar was obtained from CGIAR-CSI SRTM 90m database (Jarvis et al, 2008).

2.1.2.6. Deforestation data

The geospatial data about the forest cover change in Myanmar was downloaded from the University of Maryland, Global Forest Change Program (Hansen et al., 2013).

2.1.2.7. Precipitation data

Precipitation data for Myanmar was downloaded from Precipitation-CHIRPS dataset (Funk et al., 2014).

2.1.2.8. Average temperature and humidity data

The geospatial data for the average temperature and humidity in Myanmar was downloaded from MERRAclim, a high-resolution global dataset of remotely sensed bioclimatic variables for ecological modelling (Vega et al., 2017)

2.2. ArcGIS mapping and geospatial data analysis

The Excel table of the water-related outbreaks and cases was joined to the table of the basic map shape file within the Myanmar subnational administrative borders, by the name of the regions. The geo-referenced data for the natural disaster and armed conflicts happened on the territory of Myanmar were put into X, Y system, converted to point shape file and then overlaid to the maps with the distribution of water-associated diseases outbreaks.

Distribution shape file maps of waterborne and water-related diseases outbreaks were cross-analyzed with the raster files for population density, access to improved water sources and limited access to toilet facilities, average temperature, humidity and precipitation using the ”Zonal Statistics as a table” tool. With this tool we obtained the geospatial statistics of these three environmental factors for each of the regions.

The tables with the zonal statistics were then joined with the tables of the basic administrative borders shape file together with the previously joined distribution of the water-associated diseases. “Geographically Weighted Regression” tool was used in order to test the geospatial correlation.

The original forest covers data had categories for the deforestation happened each year in the period of 2000-2017. In order to convert the data to more suitable format, it was reclassified from 17 to only 2 classes: areas with forest cover and deforested areas. Then this reclassified raster file was cross-analyzed with the distribution of the water-associated diseases using “Zonal Statistics as Table”. The tables from the zonal statistics were then joined to the tables from the basic shape file containing the data about the distribution of diseases. Both layers were then tested for geospatial correlation using the GWR tool.

The elevation data raster was reclassified into 5 different classes, each showing the areas availability to the mosquito vectors.

2.3. Research limitations

The limitations of the research are the following:

- **Lack of official health data from the Ministry of health.** The Ministry of Health didn't respond to our query for the data about the cases and outbreaks of water-related diseases in Myanmar. The availability of these data on the township level of incidence would provide us more accurate analysis. In that way, this study was limited by the lack of official reliable epidemiological data, particularly the lack of data confirming where water-related diseases are absent or where prevalence is low.

- **The reports have their own limitations.** Most of the reports do not mention the exact number of cases. Also, the details in most of the reports are very obscure. Finding the reports which could pass the filter for the research, can be a very time consuming work, having in mind the limited time conditions.

- **Missing some papers.** There is always a possibility some of the papers to not be included in the research, just because they didn't have the correct keyword in their title or abstract, or haven't been included in the database.

- **Cases not reported.** The rural areas of Myanmar, which do not have expanded network of hospitals and health professionals, could miss the registration of infected cases. This can especially be a case of tropical neglected diseases.

- **Time scale.** The lack of time referenced data doesn't give us the full picture of the development of the diseases. Without the time dimension, spatial dimension has just a limited research value.

- **Borderline outbreaks.** Few cases of outbreaks were excluded from the mapping because they were registered on the Myanmar's borders with the neighboring countries.

- **English language barrier.** There can be always some papers or reports written on Burmese for internal use.

- **Data variations.** Although we have tried to organize the sampling method in in some standardized way, still there is a variation between the sample sizes and dates of reports which can influence the possible correlations between the factors.

- **Chronological limitation.** This research was based on data for water-related epidemiological cases collected in the period between 1991 and 2018. There is a possibility that in some of the cases there were additional control activities in the designated areas after the epidemiological data were collected. Taking into account this possibility, the data shown here may not necessarily be an accurate reflection of the present situation with the water-associated diseases epidemiology in Myanmar. Nevertheless, GIS gives us an option to update the maps with newly available data.

- **Geospatial limitation.** Each of the above mention limitations brings to this final limitation. The administrative level of the data was adjusted to regions with the purpose of simplification of the data handling. But, the water-associated diseases are focal diseases which means that they appear on very small administrative levels. Extrapolation of the data to region level prevalence could lead to over or underestimation of the problem.

3. Results and discussion

In interest to the results and discussion part, for an easier approach to the names and locations of the Myanmar regions which are part of this research, there is an available map (Fig. 5).

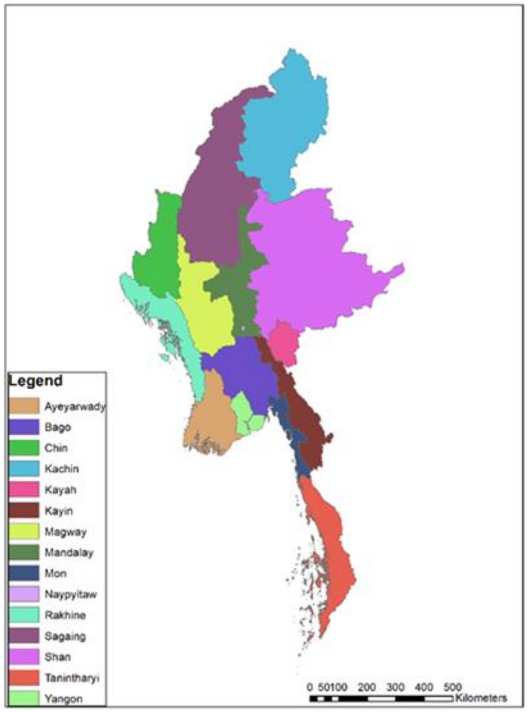

Figure 5: MYANMAR ADMINISTRATIVE REGIONS

3.1. Number of water-associated outbreaks and cases by regions

Number of waterborne outbreaks

During the research we have collected 129 researches and reports which mentioned different keywords related to the waterborne and water related diseases (see Appendix). The total number of registered waterborne outbreaks in Myanmar during the period of 1991-2018 has been 29 (Table 1). Most of them, 10 or 34.8 % were concentrated in the area of Yangon (Fig. 6). Second on the list is Kayin region with 5 outbreaks 17.24% of the cases. On the third place is Shan region with 3 outbreaks or 10.34 percent of the waterborne outbreaks. The other Myanmar regions are below the threshold of 10%, with most of them having 1 or 2 registered outbreaks in the same period (Table 1).

Diseases Regions	Acute diarhea	Cholera	Dysentery	Giraldiasis	Hepatitis A	Schistosomiasis	Typhoid fever	Waterborne outbreaks	Percantage of total waterborne outbreaks %
Mon		1						1	3.45
Ayeyarwady		1						1	3.45
Bago		2						2	6.90
Chin								0	0.00
Kachin		2						2	6.90
Kayah								0	0.00
Kayin		3			1		1	5	17.24
Magway								0	0.00
Mandalay			1				1	2	6.90
Naypyitaw								0	0.00
Rakhine		1				1		2	6.90
Sagaing	1							1	3.45
Shan		2				1		3	10.34
Tanintharyi								0	0.00
Yangon	5	3		1			1	10	34.48
Total	6	15	1	1	1	2	3	29	100.00

Table 1: NUMBER OF WATERBORNE DISEASES OUTBREAKS IN MYANMAR DURING THE PERIOD OF 1991-2018, BY REGION

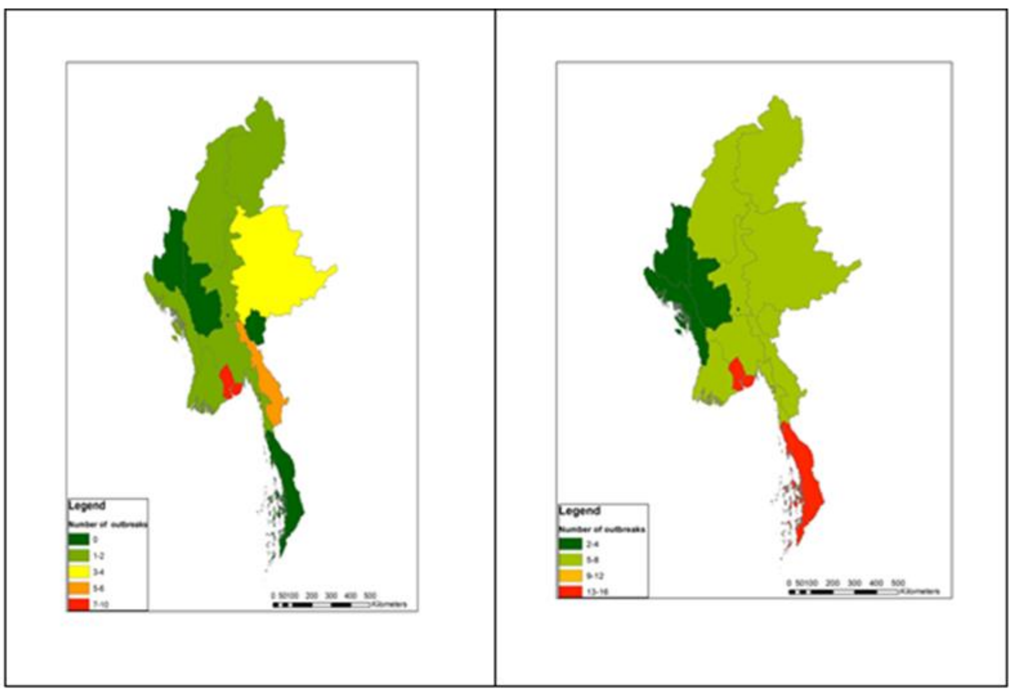

Figure 6: GEOSPATIAL DISTRIBUTION OF WATERBORNE (left) AND WATER-RELATED (right) DISEASES OUTBREAKS IN MYANMAR DURING THE PERIOD OF 1991-2018

Diseases Regions	Acute diarhea	Cholera	Dysentery	Giraldiasis	Hepatitis A	Schistosomiasis	Typhoid fever	Total number of waterborne diseases cases
Mon		61						61
Ayeyawady		90						90
Bago		96						96
Chin								0
Kachin		80						80
Kayah								0
Kayin		407			219		15	641
Magway								0
Mandalay			60				33	93
Naypyitaw								0
Rakhine		45				59		45
Sagaing	40							40
Shan		400				75		475
Tanintharyi								0
Yangon	4176	351		29			64	4620
Grand Total	4216	1395	60	29	219	75	112	6106

Table 2: NUMBER OF WATERBORNE DISEASES CASES IN MYANMAR DURING THE PERIOD OF 1991-2018, BY REGION

Number of water-related outbreaks

The total number of water-related diseases outbreaks during the period of 1991-2018 is 100 (Table 3). This means that according to the researchers and reports available, the water-related diseases are more prominent of the territory of Myanmar in comparison to waterborne diseases. The other possible explanation is that some multiple cases of waterborne diseases may not been entirely registered as an outbreaks in the hospitals.

Diseases Regions	Chikungunya	Dengue	Japanese encephalitis	Malaria	Water related outbreaks	Percantage of total waterborne outbreaks %
Mon		4		2	6	6
Ayeyarwady		4	1	1	6	6
Bago		3		5	8	8
Chin		1		1	2	2
Kachin		3		4	7	7
Kayah		4		2	6	6
Kayin		2	2	3	7	7
Magway		2		1	3	3
Mandalay		3		2	5	5
Naypyitaw		3		1	4	4
Rakhine		2		2	4	4
Sagaing		4		2	6	6
Shan	1	3	1	2	7	7
Tanintharyi		13		3	16	16
Yangon		11	1	1	13	13
Total	1	62	5	32	100	100

Table 3: NUMBER OF WATER-RELATED DISEASES OUTBREAKS IN MYANMAR DURING THE PERIOD OF 1991-2018, BY REGION

By regions, Yangon is second with total of 13 outbreaks (Fig. 6). Tanintharyi has the most outbreaks-16. The most of the other administrative units in Myanmar have between 6 and 8 cases registered (Table 3).

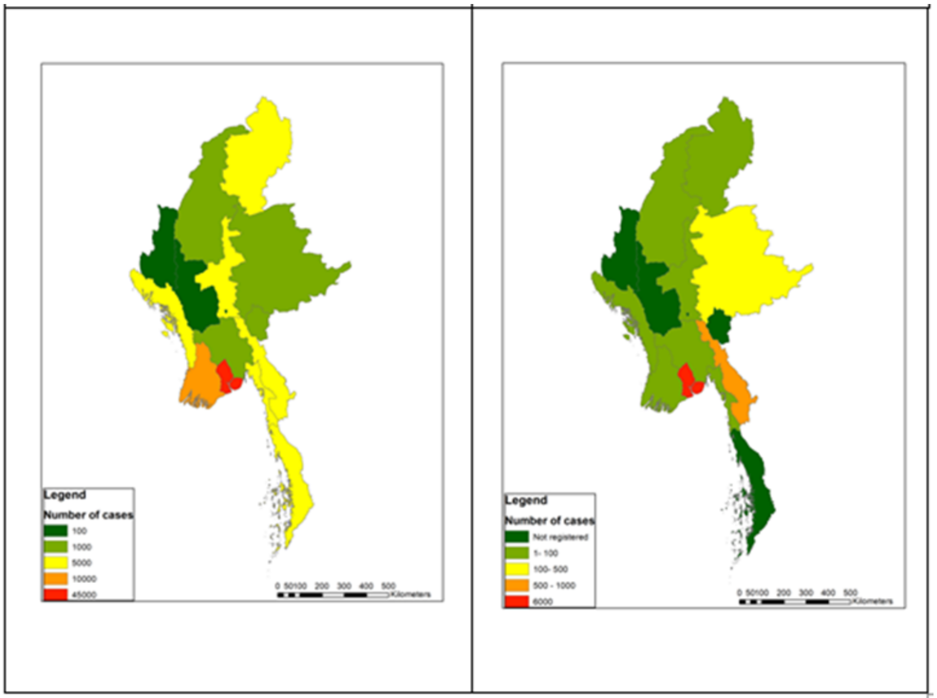

Figure 7: GEOSPATIAL DISTRIBUTION OF WATER-RELATED (left) AND WATERBORNE (right) DISEASES CASES IN MYANMAR DURING THE PERIOD OF 1991-2018

Diseases Regions	Chikungunya	Dengue	Japanese encephalitis	Malaria	Total number of water- related diseases cases
Mon		2948		195	3143
Ayeyawady		5865	69	333	6267
Bago		1920		219	2139
Chin		2		62	64
Kachin		2669		593	3262
Kayah		1663		487	2150
Kayin		2297	52	546	2895
Magway		1068		92	1160
Mandalay		3478		723	4201
Naypyitaw		764		90	854
Rakhine		2891		148	3039
Sagaing		2005		290	2295
Shan	100	2164	13	228	2505
Tanintharyi		2358		703	3061
Yangon		39254	319	710	40283
Grand Total	100	71346	453	5419	77318

Table 4: NUMBER OF WATER-RELATED DISEASES CASES IN MYANMAR DURING THE PERIOD OF 1991-2018, BY REGIONS

3.2. Geospatial correlation between the diseases distribution and the possible factors

3.2.1. Social factors

Population density

Population density has certain effect on the prevalence and the distribution of the both waterborne and water-related diseases (Cinkotta et al., 2000; Hales et al., 2002)). It is evident that certain areas has similar GWR coefficient with the population density for both waterborne and water-related outbreaks (Fig. 8). Sagaiang, Mandalay, Rakhine and Ayeyrawady have the highest degree of geospatial correlation between both of the water-associated diseases and the population density. Kachin and Chin state also have the highest degree of correlation between the waterborne diseases prevalence and population density and Kayah and Kayin have the highest geospatial correlation between the water-related diseases prevalence and population density. Magway, Kayah and Tanintharyi have slightly lower geospatial correlation for the waterborne diseases where STD is in the range -0.5 to -1.5 which means that population density in these regions is marginally higher than the expectation for higher prevalence for waterborne diseases. The similar is the situation between the water-related diseases and population density in Chin, Magway and Mon. Shan and Kayin, from the other side, have slightly higher STD range of 0.5-1.5 and 1.5-2.5 respectively, for the geospatial correlation between WB and PD. That can indicate certain geospatial correlation between them both, with emphasis of the fact that the PD maybe is not the only influencing factor. In case of the water-associated diseases, Bago, Shan and Kachin are in the similar case. The biggest GWR STD range >2.5 in the geospatial correlation between waterborne diseases and population density has the region of Yangon. In the geospatial correlation between water-related diseases outbreaks and PD the biggest GWR STD range has the region of Yangon and Tanintharyi.

Overall, there is a significant indication for some influence of the population density as a social factor on the water-associated diseases prevalence outbreak.

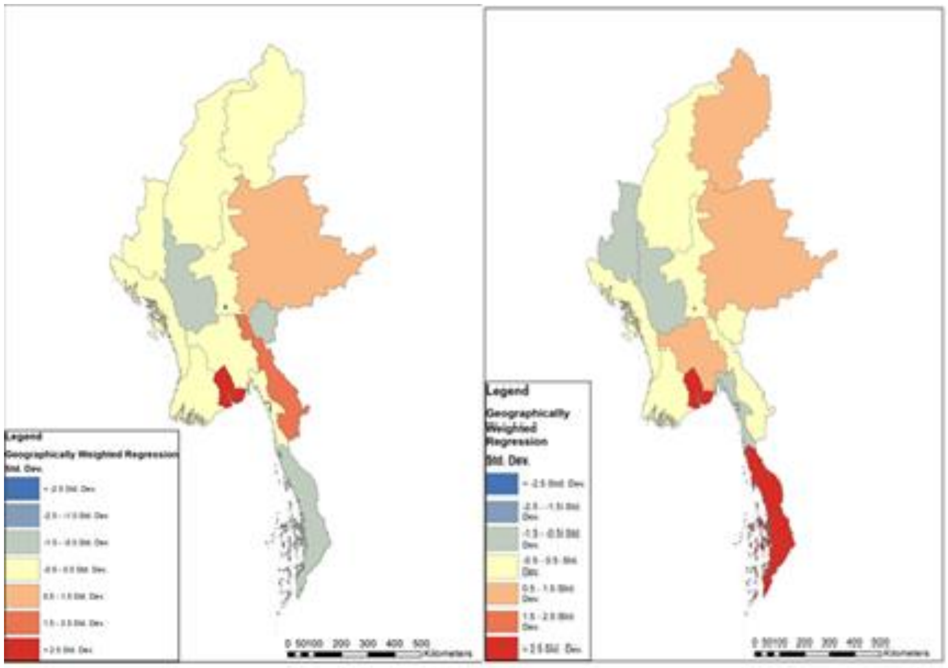

Figure 8: (left map) GEOSPATIAL CORRELATION BETWEEN WATERBORNE DISEASES OUTBREAKES AND POPULATION DENSITY; (right map) GEOSPATIAL CORRELATION BETWEEN WATER-RELATED DISEASES AND POPULATION DENSITY, BY REGIONS

Access to safe water and sanitation

Regions of Kachin, Sagaing, Mandalay, Shan, Bago, Ayeyarwady and Mon have the highest geospatial correlation between the distribution and prevalence of the waterborne diseases outbreaks, population using improved water sources and population not using toilet facilities (Fig. 9). The range of GWR STD for these regions is from 0.5 to -0.5. Chin, Magway, Kayah, Tanintharyi have slightly variance in the GWR STD range from -0.5 to -1.5 which implicates that according to the estimated situation with the access to safe drinking water and sanitation in these regions, there should be more cases of waterborne diseases to some extent. Rakhine and Kayin states have GWR STD range of 0.5-1.5 which indicates possible interference with some other factors. Yangon is the only region which shows highest GWR STD, above 2.5, which points out other possible influencing factors.

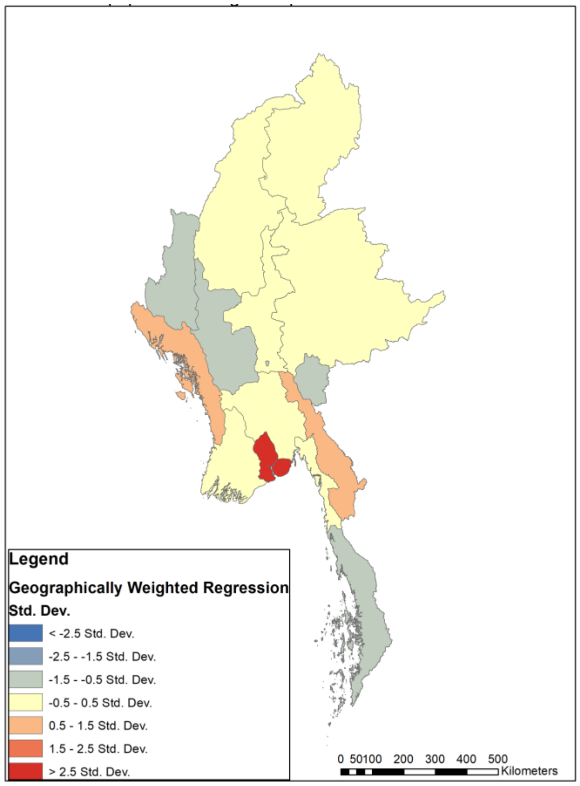

Figure 9: GEOSPATIAL CORRELATION BETWEEN WATERBORNE DISEASES OUTBREAKS, POPULATION USING IMPROVED WATER SOURCES AND POPULATION NOT USING TOILET FACILLITES

Armed conflicts

According to the available data, the eastern near border parts of the country, together with the Rakhine state, has the highest frequency of armed conflicts registered in the period between 1991 and 2018 (Fig. 10). Shan, Kachin and Rakhine are the states with the most armed conflicts. They do not show significantly higher incidence of water-associated diseases. Yangon and Tanintharyi are the regions with the highest incidence of water-associated diseases outbreaks, but have low number of armed conflicts, which indicates that according to the available data, there is not enough proof that armed conflicts in Myanmar influence significantly the occurrence of water-associated diseases outbreaks.

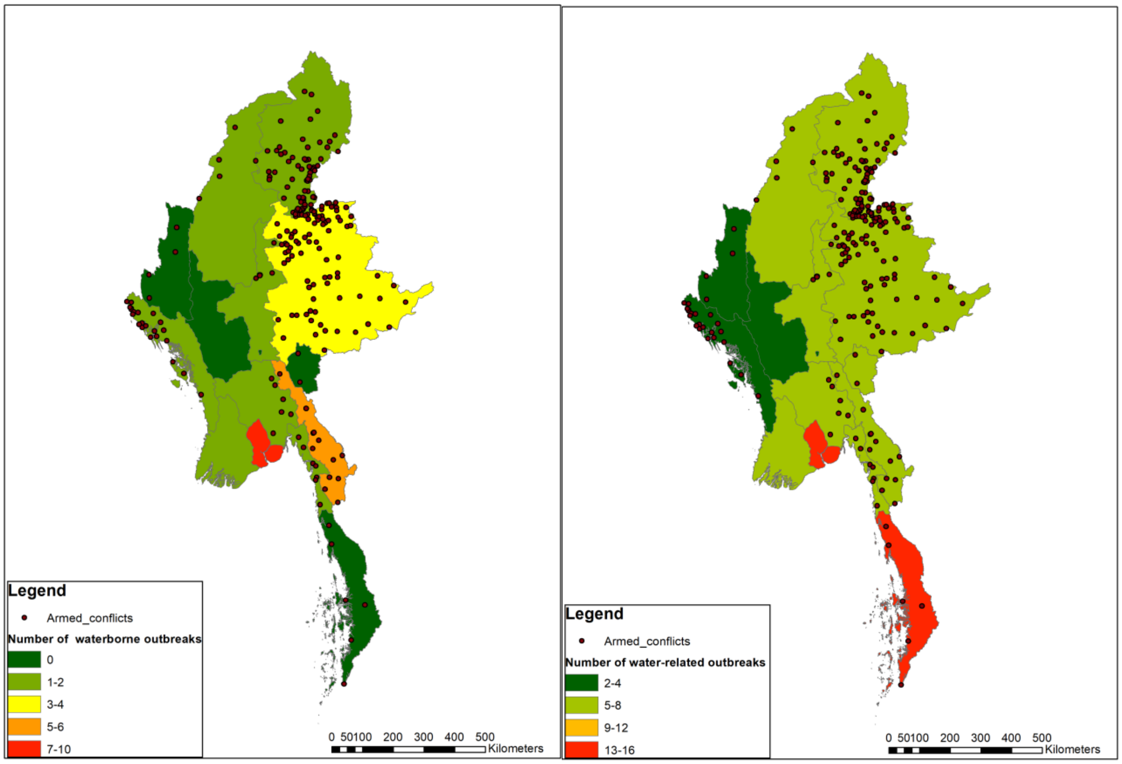

Figure 10: (left map) GEOSPATIAL DISTRIBUTION OF WATERBORNE DISEASES OUTBREAKS AND ARMED CONFLICTS HAPPENED DURING THE PERIOD OF 1991-2018; (right map) GEOSPATIAL DISTRIBUTION OF WATER-RELATED DISEASES OUTBREAKS AND ARMED CONFLICTS HAPPENED DURING THE PERIOD OF 1991-2018, BY REGIONS

3.2.2. Environmental factors

Temperature

Rakhine, Chin, Sagaing, Mandalay and Bago are the states with the highest geospatial correlation between the waterborne diseases prevalence and the average temperature, with GWR STD range from 0.5 to -0.5 (Fig. 11). Magway, Ayeyarwady, Kayah and Tanintharyi have GWR STD range from -0.5 to -1.5, which could indicate that temperature does not significantly affect the prevalence of the waterborne diseases in these regions. From the other side, Kachin, Shan and Kayin have the GWR STD range from 0.5 to 1.5, which can indicate certain possibility for interference with other possible factors. Yangon is the only region with the highest GWR STD higher than 2.5, which can implicate that the temperature is not the crucial factor of influence.

Sagaing, Mandalay, Bago, Kayin and Kayah are the states/regions that have the highest geospatial correlation between the water-related diseases outbreaks and average temperature. Chin, Rakhine, Magway, Ayeyarwaddy and Mon have GWR STD range from -0.5 to -1.5.

Kachin and Shan states have GWR STD range from 0.5 to 1.5. The highest range of GWR STD have Yangon (1.5-2.5) and Tanintharyi (>2.5).

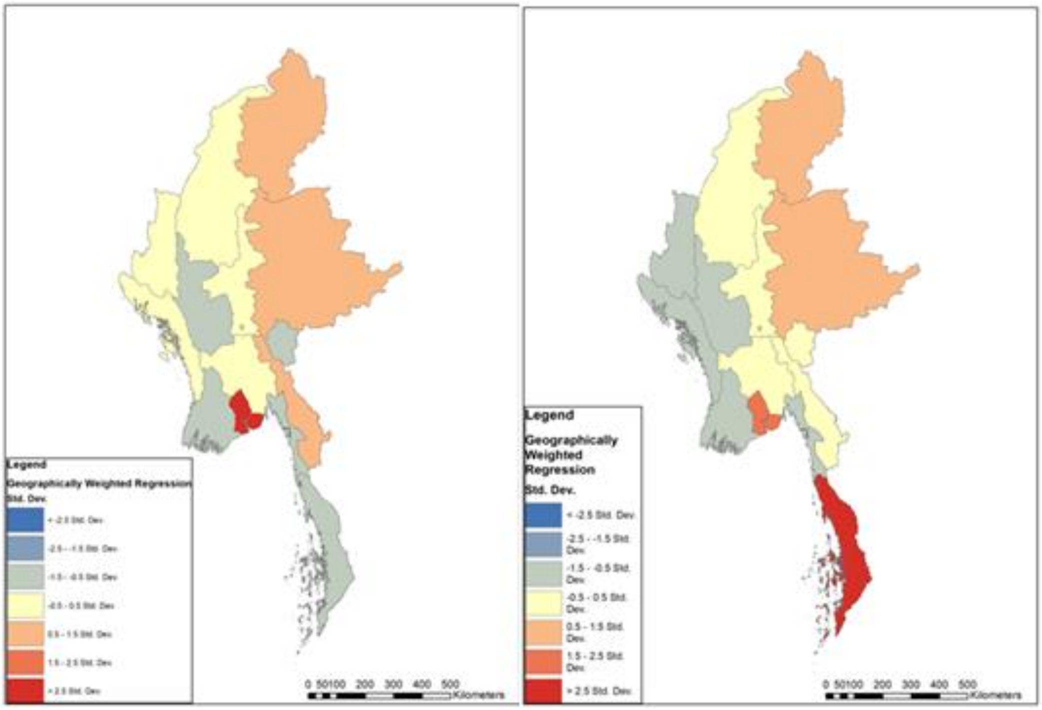

Figure 11: (left map) GEOSPATIAL CORRELATION BETWEEN WATERBORNE DISEASES OUTBREAKS AND AVERAGE TEMPERATURE; (right map) GEOSPATIAL CORRELATION BETWEEN WATER-RELATED DISEASES AND AVERAGE TEMPERATURE, BY REGIONS

Humidity

Kachin, Sagaing, Mandalay, Rakhine, Bago have the highest geospatial correlation between waterborne diseases prevalence and humidity as potential environmental influencing factor (Fig. 12). Chin, Magway, Ayeyarwady, Kayah, Mon, Tanintharyi show GWR STD range varying from -0.5 to -1.5 which implicates lower correlation between these two determinants. Shan and Kayin states have GWR STD from 0.5 to 1.5 which can indicate that humidity may not be the crucial influencing factor on the waterborne diseases prevalence. Yangon has the highest GWR STD, above 2.5, that can point to possibility for other more influencing factors.

Sagaing, Mandalay, Bago, Kayin, Kayah have the highest geospatial correlation between water-related diseases prevalence and humidity. Chin, Magway, Rakhine, Ayeyrwady, Mon states show GWR STD range varying from -0.5 to -1.5 which implicates lower correlation between these two determinants. Kachin and Shan states have GWR STD from 0.5 to 1.5 which can indicate that humidity may not be the crucial influencing factor on the waterborne diseases prevalence. Yangon and Tanintharyi have the highest GWR STD range of 1.5-2.5, indicating humidity as possible minor influencing factor.

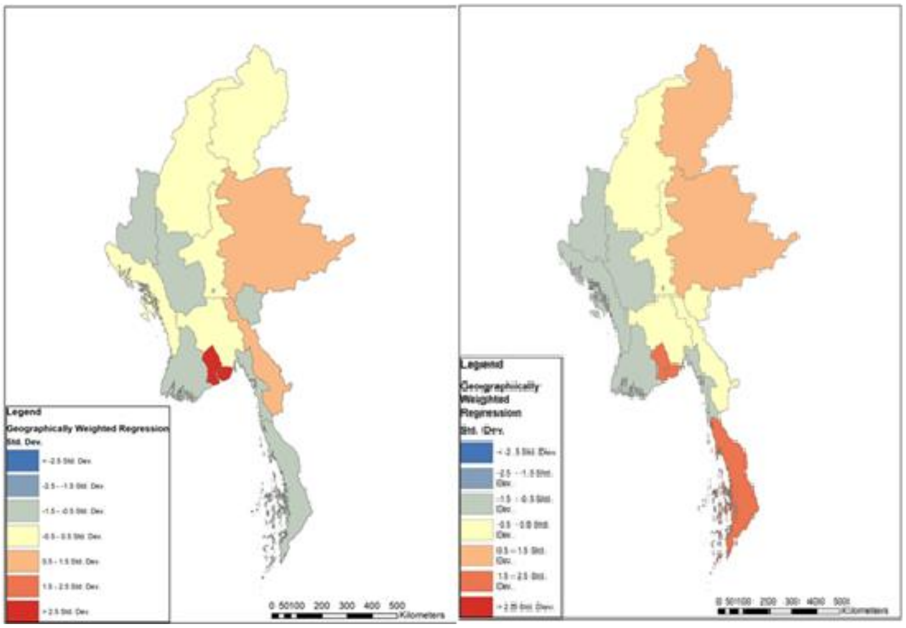

Figure 12: (left map) GEOSPATIAL CORRELATION BETWEEN WATERBORNE DISEASES OUTBREAKS AND HUMIDITY; (right map) GEOSPATIAL CORRELATION BETWEEN WATER-RELATED DISEASES OUTBREAKS AND HUMIDITY, BY REGIONS

Precipitation

Kachin, Sagaing, Mandalay, Rakhine, Bago and Ayeyarwady have the highest geospatial correlation between the prevalence of waterborne diseases outbreaks and the annual precipitation rate (Fig. 13). Chin, Magway, Kayah, Mon and Tanintharyi have GWR STD range from -0.5 to -1.5, which could indicate that precipitation does not significantly affect the prevalence of the waterborne diseases in these regions. Shan and Kayin from the other side, have slightly higher STD range of 0.5-1.5 for the geospatial correlation between waterborne diseases outbreaks and precipitation. That can indicate certain geospatial correlation between them both, with emphasis of the fact that the precipitation maybe is not the only influencing factor. Yangon has the lowest geospatial correlation between the waterborne diseases prevalence and precipitation.

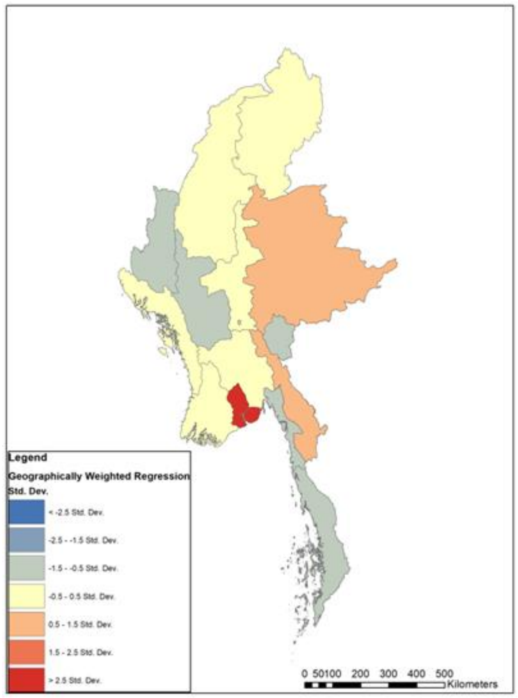

Figure 13: GEOSPATIAL CORRELATION BETWEEN WATERBORNE DISEASES OUTBREAKS AND PRECIPITATION

Elevation

Most of the Myanmar's land falls in the elevation range between 100m and 2000m (Fig. 14), which allows proper temperature and humidity conditions for development of vector larvae, but also for the parasites itself (Wolda, 1987; Attenborough et al., 1997). The coastal states and regions and parts of Myanmar by the Irrawaddy river line and delta Rakhine, Ayeyarwady, Yangon, Bago, Magway, Mandalay, Mon, Kayin and Tanitharyi are highly prone to floods because most of their land is in the range of 35m below, to 100m above the sea level (Terra, 1944). Considering that circumstances, these parts of the country may also be prone to regular devastation of the infrastructure (Seekins, 2009), disruption of the regular access to safe drinking water and sanitation standards, which can cause emergence and reemergence of different waterborne diseases like diarrhea, cholera, schistosomiasis, etc. (Blaikie et al., 2004; Clasen et al., 2006; Du et al., 2010). Flooded lands in these regions also provide ideal conditions for larvae development which can boost the potential vector population for spreading of malaria, dengue, and chikungunya (Wisner, et al., 2002; Watson et al., 2007).

The rest of the territory is in the elevation range from 2000m to the highest peak in Myanmar-5711m. Areas in the range of 2000-2500m, where there are emerging cases of water-related diseases, and areas in the range of 2500-3000m, which according to the previously analyzed literature review (Reiter, 1998; Bishop and Litch, 2000; Abdur Rab et al., 2003) can be suspicious to vector expansion caused by the climate change. These areas are mainly distributed across the mountainous ranges in Kachin (north), Sagaing and Chin states (west), and the Shan plateau (east). The altitudes above 3500m which are non-favorable to the both vectors and parasites (Wolda, 1987) are located in the far north, on the high mountains in Kachin state, where low temperatures are registered most of the year.

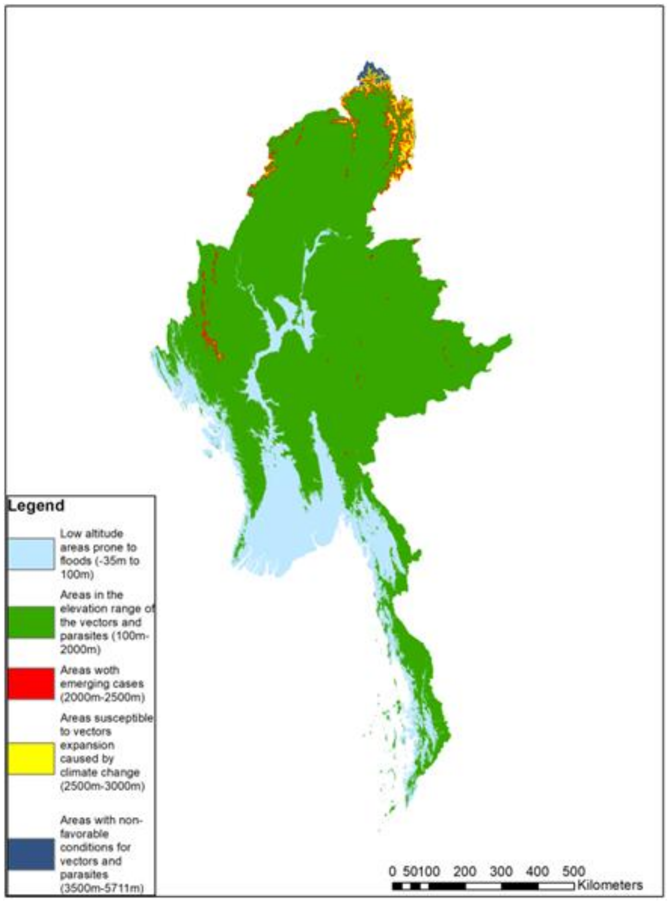

Figure 14: GEOSPATIAL ANALYSIS OF THE RELATION BETWEEEN WATER-RELATED DISEASES RISK AND ELEVATION IN MYANMAR

Deforestation

During the period of 2000-2017, Shan state had the biggest deforested area in Myanmar, between 1000000 and 1600000ha of deforested land (Fig. 15). Kachin, Sagaing, Chin, Kayin and Tanintharyi have between 200000 and 500000ha of deforested areas. Rakhine, Bago and Mon states have deforested lands in the range of 100000-200000ha. The rest of the states and regions (Magway, Mandalay, Kayah, Ayeyarwady and Yangon) have less than 100000ha of deforested area.

All of the states and regions, except Magway, Shan and Yangon, have the highest geospatial correlation between the water-related diseases incidence and deforestation, with the GWR STD range of -0.5 to 0.5. Magway has GWR STD range of (-0.5) - (-1.5). Shan state, owning the biggest deforested areas in Myanmar, has the GWR STD range between 0.5 and 1.5, which can indicate possibility for some other minor factor influencing the water-related diseases outbreaks, and maybe the deforestation itself. Yangon, like a region which has disproportion between the size of the deforested area (<100000ha) and the number of water-related diseases outbreaks, has the biggest GWR STD (>2.5).

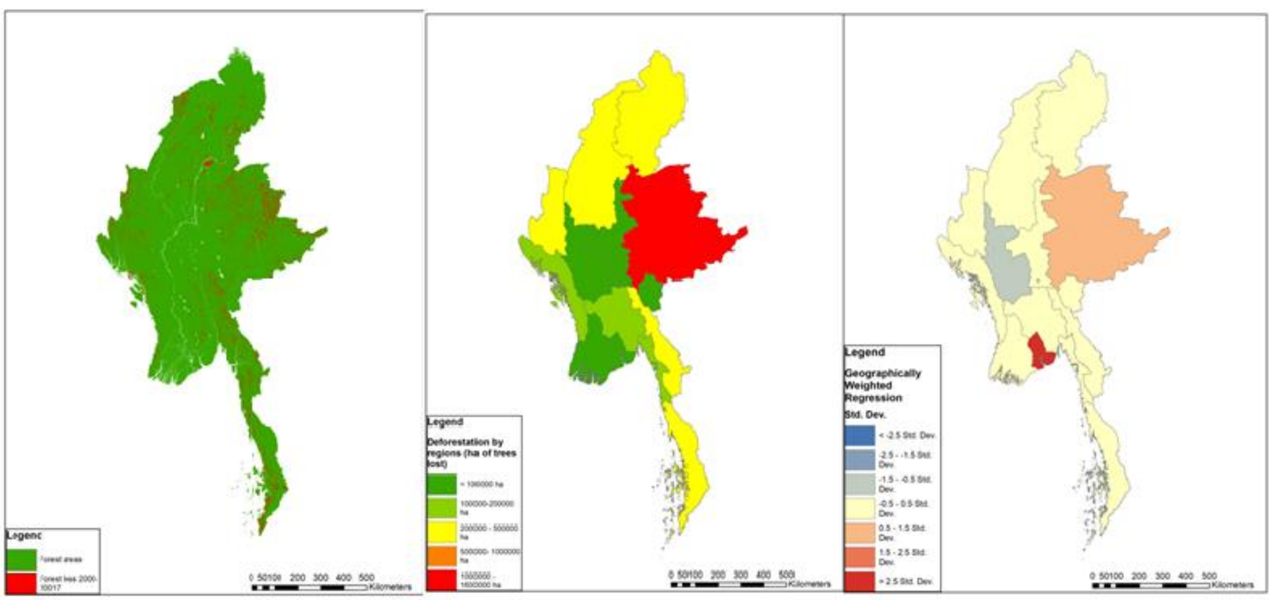

Figure 15: (first map, on the left) FOREST AREAS AND FOREST LOSS IN MYANMAR 2000-2017; (second map, in the middle) DEFORESTED AREAS BY REGIONS; (third map, on the right) GEOSPATIAL CORRELATION BETWEEN WATER-RELATED DISEASES AND DEFORESTED AREAS, BY REGIONS

Natural disaster

According to the EM-DAT, International disaster database (Guha-Sapir et al., 2015), there have been 124 registered natural disasters on the territory of Myanmar. By states and regions, Kachin had 5, Sagaing-10, Chin-4, Magway-8, Mandalay-11, Shan-9, Kayah-2, Rakhine-14, Bago-10, Ayuerawady-15, Yangon-7, Mon-7, Kayin-10 and Tanitharyi-2 (Fig. 16).

From the generated maps there seems that there is not significant correlation between the number of the natural disasters in the each of the regions and the waterborne and water-related diseases prevalence and distribution.

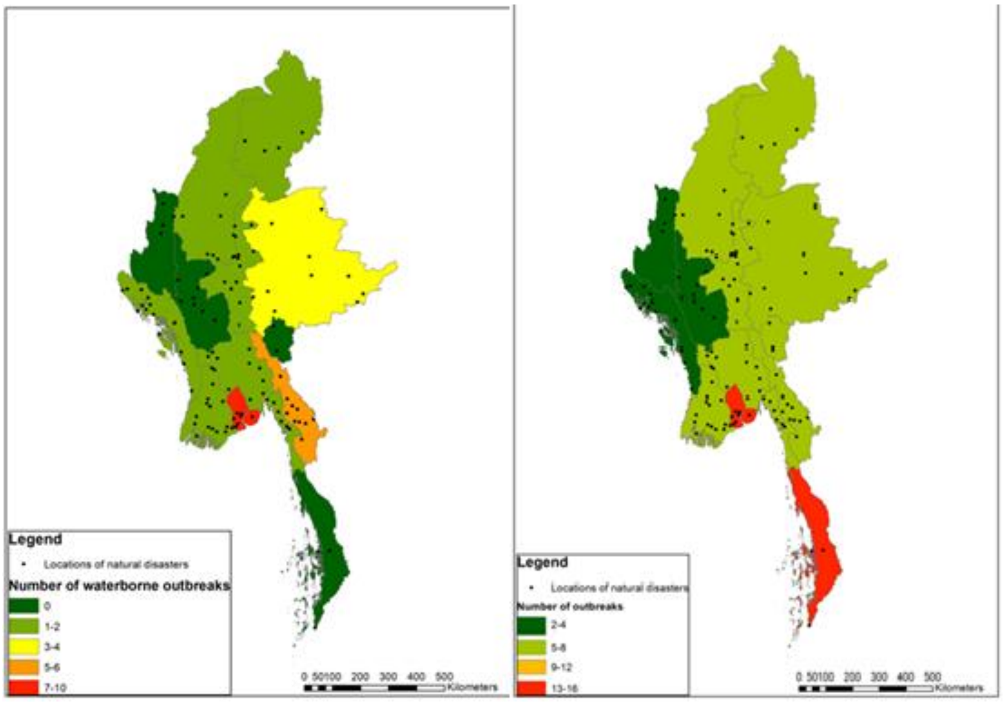

Figure 16: (from left) GEOSPATIAL DISTRIBUTION OF WATERBORNE DISEASES OUTBREAKS AND LOCATIONS OF NATURAL DISASTER EVENTS HAPPENED DURING THE PERIOD OF 1991-2018; (from right) GEOSPATIAL DISTRIBUTION OF WATER-RELATED DISEASES OUTBREAKS AND LOCATIONS OF NATURAL DISASTER EVENTS HAPPENED DURING THE PERIOD OF 1991-2018, BY REGIONS

3.3. Situation in the most affected regions

3.3.1. The curious case of Yangon

According to the aggregated data (Table 1 and Table 3), it is clearly visible that the most populated city and former capital Yangon leads in the number of outbreaks of waterborne and it is second leading region in water-related diseases (Fig. 6). From total of 29 waterborne (Table 1) and 100 water-related outbreaks (Table 3) registered on the territory of Myanmar, according to the data available to our research, 10 (34.48 %) and 13 (13%) respectively, have occurred in the Yangon region.

Also, Yangon has significantly more cases in the both types of water-associated diseases (Table 2 and Table 4). Possible cause of that could be the high number of population in Yangon. According to the last Myanmar census in 2014 (Department of Population, 2015) Yangon has 5.14 million people and population density of 16 000 people/km^2 which makes it the densest populated urban area in Myanmar. More population in limited space can bring higher frequency of contact between an infected person and non-infected ones (Cincotta et al., 2000; Cohen, 2003). Aside from the transmission through the personal contact, Yangon still has wide suburbanized areas where the level of sanitation, access to clean water and personal hygiene is still substandard. In most of the places water is kept in reservoirs which are not secured enough.

But according to the Geographical Weighted Regression (GWR) and the possible geospatial correlation status between the waterborne and water-related outbreaks, by regions (as dependent value), and population density as an independent value, the region of Yangon showed the biggest standard deviation above 2.5 (Fig. 8). The other regions showed standard deviation near zero, which in their case could mean that there is some significant geospatial correlation between the population density, as a factor, and the distribution of water-related diseases.

According to the ArcGIS tool instructions (ESRI, 2012), this kind of specific value could mean that the discrepancy between the values in the Yangon field for the dependent and independent variables is wider than the discrepancies of the same variables in the other fields, in this case regions.

ESRI (2012) recommends two possible explanations for this type of deviation. The first possible explanation could be that there is no large enough sample of values for the dependent variable (the waterborne and water-related outbreaks), which cannot feed the model with data for calculations.

The other possible explanation could be that the range between the highest field value (Yangon) and the rest of the values in the dependent variables is bigger than the range between the highest field value (which would be Yangon again, due to its highest population density) and the rest of the field values of the independent variable. That could mean that population alone would not be significantly influential factor for the distribution of the outbreaks.

In order to test this statement, the GWR correlation test has been done with the other two proposed socio-economic factors: population with access to improved water sources and population not using toilet facilities (Fig. 9). The both of them are closely related to the water usage of the population and could be a direct link between the water, social and health safety (Montgomery and Elimelech, 2007). They can be a good indicator for the influence on the water usage on the development of the water-associated diseases (Carlton et al., 2012; Waldman et al., 2013). The GWR correlation test between the water-associated diseases as a dependent variable and water safety indicators as an independent, showed similar standard deviation above 2.5. The other regions showed significant geospatial correlation between the distribution and prevalence of the water-associated diseases outbreaks and the distribution of population with access to improved water sources and lack of toilet facilities.

Unlike the GWR correlation test with the population density as one independent variable, the GWR test with the two above mentioned water quality, socio-economic factors, is multivariate test, which theoretically would mean that it should be more stable and significant.

The notion that the other regions are showing significant geospatial correlation with all three socio-economic factors, gives certain assurance that the GWR test is credible way for geospatial analysis.

But the possibility of sample limitation for the water-associated diseases outbreaks data cannot still be rejected.

Armed conflicts are not the factor which can influence the higher prevalence of water-associated diseases in Yangon because this area is far away from the military operations of the army and the other militias and paramilitary groups (Fig. 10).

Overall, the socio-economic factors could not be enough to explain the problem of regional distribution of the water-associated diseases. This is a complex issue which involves also the environmental factors.

3.3.1.1. Tanintharyi region

The number of water-related diseases outbreaks-16 in the Tanintharyi region is higher than the capital Yangon. The total number of water-related disease cases is 3061 (Table 3). The GWR's standard deviation for the geospatial correlation between the water-related diseases distribution and the population density in Tanintharyi is above 2.5, which means that the population density, as a factor, is not enough to explain the higher number of outbreaks. The frequencies of natural disaster (Fig. 16) and armed conflict events (Fig. 10), 2 and 5 respectively, are not numerous enough to imply that they might be potential reasons for such a high occurrence of outbreaks in comparison with the other regions.

The level of deforestation in Tanintharyi is less than 100 000 ha of trees lost (Fig. 15). In the recent years after the cease of the military rule, Tanintharyi became one of the fastest developing regions in Myanmar. With few of the biggest seaports in Myanmar, this region exists as a commercial center in the country (CIA, 2018). Also, there are plenty of mines in Tanintharyi. All of this commercial and industrial activity accelerates the level of urbanization and industrialization in this region. This could mean cutting of more trees for building materials and securing of more space for new populated areas, roads and mines. The deforestation near the populated places could become ideal hot-spots for mosquito's reproduction which might intensify the transmission of the malaria, dengue or JE.

From the other side, according to the available online researches and reports, there are not registered waterborne diseases outbreaks in the Tanintharyi region (Table 1 and Appendix). The educational and the health network in Tanintharyi are still underdeveloped (Department of Public Health, 2016). There is a low number of hospitals and medical stuff in the region, aside from the commercial areas, which implies for a high possibility for absence or insufficiency in the record-keeping of the possible outbreaks of waterborne diseases.

3.3.1.2. Ayeyarwady region

Ayeyarwady (Irrawaddy) region is positioned on the south of Myanmar, bordering with Yangon, on the Ayeyarwady (Irrawaddy) river Delta. On the territory of Ayeyarwady, according to the data availible to our research, there has been registered 1 waterborne disease outbreak (cholera) (Table 1) and 6 water-related diseases outbreaks (4 dengue, 1 JE and 1 malaria) (Table 3), with 90 (Table 2) and 6267 cases (Table 4) respectively. It is noticeable that the number of cases of water-related diseases is higher than the number of waterborne cases. According to the EM-DAT, International disaster database (Guha-Sapir et al., 2015), there have been 15 natural disasters in the Ayeyarawady region during the period of 1991-2018 (Fig. 16). Ayeyarawady has been one of the most affected areas during the Nargis and Komen cyclones (Seekins, 2009; Cheesman et al., 2010). It's closeness to the Andaman Sea makes this region ideal ground for cyclones. The complex network of the river delta and the low elevation which in some places can go under the seawater level leaves Ayeyarawady vulnerable to many floods. The floods in this region can last for weeks or even months. This kind of hazard makes the lives of the locals more difficult because many of their activities are tightly connected to the river (Seekins, 2009). Access to clean drinking water, sanitation and the hygiene are the most affected (Banda et al., 2007). Contaminated water and low level of sanitation and hygiene bring forward ideal conditions for incubation and reproduction of many bacteria, protozoa and worm waterborne pathogens, as well as higher frequency of human contact with the contaminated water (Cann et al., 2013). Opposite to the providing of ideal conditions for the waterborne pathogens, flashfloods could destroy the eggs and the adult population of mosquito vectors (Duchet et al., 2017), which might be an explanation for the lower number of case of water-related diseases.

There are not registered armed conflicts on the territory of the Ayeyarwady region. (Fig. 10)

3.3.1.3. Shan

Shan state is the largest of the administrative divisions in Myanmar (Fig. 5). It is mostly rural. According to the available data there have been 3 outbreaks of waterborne (2 cholera and 1 schistosomiasis) and 7 outbreaks of water-related diseases (1 chikungunya, 3 dengue, 1 JE and 2 malaria outbreaks) in the period of 1991-2018 (Table 1 and Table 3). The number of cases has been 475 and 2505 respectively (Table 2 and Table 4).

Population density has shown certain geospatial correlation with both waterborne and water – related groups of diseases (0.5-1.5). The GWR between the distribution of waterborne diseases in the Shan state with the distribution of the population not using toilet facilities and population using improved water sources has shown high geospatial correlation between the two variables (Fig. 8).

With 75 registered armed conflicts, Shan state has been militarily most active territory in Myanmar (Fig. 10). As a result of that, there are many active camps for internally displaced persons on the territory of the both government and rebel controlled territories (July, 2016). The number of refugees crossing the border with Thailand is not precisely known (Parker et al., 2015). The often substandard conditions into the IDP and refugee camps, the unmonitored movement of people inside the territory of Shan state and around the Thai border, and the hilly terrain and deep forest, could help the diseases proliferate (Carrara et al., 2013; Parker et al., 2015; CDC, 2016).

Another possible factor of influence for the prevalence of water-related diseases outbreaks in Shan state could be the high intensity of deforestation. The mountainous and rich with deep forests state, lost between 1000000 and 1600000ha of tree cover, which makes Shan the administrative division with the biggest deforested area in Myanmar (Fig. 15). According to the GWR test, there is a certain geospatial correlation between the two variables (0.5-1.5), but there may be need for another variable to make the model more stable. The GWR test for the average temperature (Fig. 11), humidity (Fig. 12) and precipitation (Fig. 13) gives standard deviation in the range of 0.5-1.5 for each of these independent variables, separately tested for geospatial correlation with the distribution of water-related diseases. This indicates the possibility for application of trivariate correlation analysis for each of the factors together, aimed at bigger certainty of the model.

Most of the Shan territory elevation is in the range of 100m-2000m, which has ideal conditions for development of the vectors and the parasites, with several areas between 2000m and 2500m, where an emerging number of cases can be found (Fig. 14).

3.3.1.4. Rakhine

Rakhine state is the administrative division which could be perceived as the probably most vulnerable region of Myanmar. The vulnerability comes from both of the socio-economic and environmental factors. As can be seen from the elevation map (Fig. 14), most of the territory is low altitude terrain prone to flooding, which in combination with the closeness to the cyclone center in the Andaman Sea creates many floods in the region.

Rakhine state is also known for the series of intensive armed conflicts on its territory in recent years (Fig. 10), joined by many humanitarian catastrophes (UNICEF, 2012; Parnini, 2013; Motlagh, 2014; Ahmed et al., 2018).

But what it is peculiar is that according to the available information, Rakhine state has only 2 registered outbreaks of waterborne diseases (1 of cholera and 1 schistosomiasis outbreak) (Table 1), with total of 104 cases (Table 3) and 4 outbreaks of water-related diseases (2 dengue and 2 malaria outbreaks) (Table 2) with 3039 cases (Table 4). This disparity in the risk status and vulnerability from one side, and the information about the health status is that the most of the health reports that come from Rakhine are not described in numbers and cannot be checked for credibility afterwards (Mahmood et al., 2017). Also, because of the constant breakdown of the infrastructure and system Rakhine it is avoided by the domestic researchers and the foreign researchers cannot get a foothold there (White, 2017), which is understandable from the fact that it is a war zone.

3.3.1.5. Kayin

According to the data available to our research, Kayin state has been affected by 5 outbreaks of waterborne diseases (Table 1), with total of 641 cases (Table 3), and 7 outbreaks of water-related diseases (Table 2), with total of 2895 cases (Table 4). It is on the second place, after Yangon, in the number of waterborne diseases outbreaks (Fig. 7).

According to the GWR test, the SD for geospatial correlation between the number of waterborne diseases outbreaks as a dependent variable and the population density as the independent is between 1.5 and 2.5, which would mean that there is certain correlation between the both variables, but at last one more factor should maybe be taken into consideration (Fig. 8). The same case applies to the geospatial correlation with the distribution of population using no toilet facilities and population using an improved water sources (Fig. 9).

The GWR test for the environment factors average temperature (Fig. 11), humidity (Fig. 12) and precipitation (Fig. 13), showed the same SD range which initiates the possibility that might be useful for the all three factor to be considered into one trivariate analysis.

4. Conclusion

Water-associated diseases are still an ongoing problem in Myanmar. There is a certain determination and plans from the government side to control and eradicate this type of diseases but better health and epidemiological monitoring is needed. In order for the monitoring to be improved, there is a need for implementation of new tools and technologies.

GIS is proper type of technology for health and epidemiological monitoring. It can digest all of the needed information concerning the geospatial distribution and trends of the outbreaks. Additionally, GIS can analyze the correlation between the emerging or re-emerging diseases and potentially influential environmental, social or health factors that can cause or amplify the outbreaks. There are still certain gaps in the availability of health and epidemiological data in Myanmar which can pose as temporary limitation for micro level analysis.

In this study I have tried to research the geospatial relation between the major water-associated diseases prevalence in Myanmar and several possibly influencing social (population density, access to safe drinking water and sanitation and armed conflicts), environmental (temperature, humidity, precipitation, humidity, precipitation, elevation and deforestation) and socio-environmental factors (natural disasters).

In order to achieve that, firstly I have tried to present the geospatial distribution of the major water-associated diseases outbreaks on the territory of Myanmar. According to the available data, there are significantly more water-related than waterborne outbreaks. The highest number of waterborne diseases outbreaks occurred in the Yangon region, while the highest number of water-related diseases occurred in the Tanintharyi region.

After presenting the geospatial distribution of the major water-associated diseases outbreaks on the territory of Myanmar, I have tried to analyze the possible general patterns of geospatial correlation between the diseases prevalence and distribution and the above mentioned social, environmental and socio-environmental factors on the territory of Myanmar. The GWR have indicated that in most of the cases, the potential social and environmental factors that have been part of this research are showing certain geospatial correlation with the analyzed prevalence and distribution of the water-associated diseases. That means that there are indications for some limited influences of these factors over the diseases geospatial distribution. For additional confirmation analysis there is a need for implementation of multivariate models which would include few of the factors together, which in this case was unfeasible because the sample size was not enough to support that kind of model.

In the last step, I have tried to analyze the correlation between the possible environmental and socio-economic factors and diseases prevalence in the most affected regions separately. This analysis has shown that the regional situation is very complex and none of the factors has dominant influence, but all of the factors have interconnected and intermittent influences.

Despite the limitations, these maps provide as accurate as much representation of the current situation with the water-associated diseases epidemiology in Myanmar, according to the available data. These maps, together with the whole research, are the result of an exhaustive attempt to identify all existing water-associated disease epidemiology data available outside of the Ministry of health system.

Future recommendations

Both the positive and negative experiences during this research have some lessons to teach in relation to control strategies and eradication of the water-related diseases. Mapping the existing data on Myanmar's water-associated outbreaks and socio-environmental factors surrounding them, using a GIS, gives us a benefit of pointing these issues in a clear and accessible way. There are some recommendations concerning the future related researches or policies.

More cross border researches. More cross border researches are needed to systematically review epidemiology cases on the Myanmar borders with neighboring countries. Myanmar borders are very porous and including the fact that many of the border areas are in the armed conflict zones, there will be many people crossing the borders in the near future. Most of these crossings are illegal and uncontrolled by the government officials. Many of these migrants or refugees do not have proper protection from water-related vectors or adequate safe water access and sanitation in the neighboring countries camps. This makes them easy target and additional potential vectors for different water-associated diseases. Having in mind the lack of data for this population, they are taken out of the bigger picture of the situation with the water-associated diseases in Myanmar.

Improved data collection and open data access. Improving the system for health and epidemiological data collection will enable more relevant data. For successful monitoring of the disease proliferation, data need to be collected according to some established standards, concerning a uniformity of age and gender group. More efforts should also be focused on people living in remote areas. This data can help building models and maps which will be closer to the real situation. A research concerning water-associated diseases epidemiology needs to be based upon district-level prevalence estimations and that approach requires uninterrupted flow and management of the micro-level data. Also, the Ministry of health will have to acquire more open data access policy towards the researchers interested in this kind of analysis.

Hopefully, this research, together with the published maps will serve as a useful tool in the further development of the Myanmar health policy, helping the decision-makers initiate future actions for control and finally, in some near future, even eradication of the water-associated diseases.

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Appendix

Table 5: DATA SOURCES USED FOR THE RESEARCH

Year	Name of the disease	Name of the infective agent	Place of outbreak	Region	Number of cases	Source
1991	Acute diarhea	Escherichia coli	Yangon	Yangon	100	1
2002	Acute diarhea	Rotavirus	Yangon	Yangon	923	2
2004	Acute diarhea	Rotavirus	Yangon	Yangon	1226	3
2009	Acute diarhea	Rotavirus	Yangon	Yangon	1860	4
2015	Acute diarhea	Entamoeba hystolica	Hlaing Thar Yar	Yangon	67	5
2015	Giraldiasis	Giardia lamblia	South Dagon	Yangon	29	5
2004	Dysentery	Shigella dysenteriae	Mandalay	Mandalay	60	6
2009	Hepatitis A	hepatitis A virus	Myawaddy	Kayin	219	7
2010	Chikungunya	Chikungunya virus	Taunggyui	Shan	100	6
2005	Dengue	Dengue virus	/	Yangon	5621	6
2006	Dengue	Dengue virus	/	Yangon	1531	6
2004	Dengue	Dengue virus	/	Yangon	6000	6
2001	Dengue	Dengue virus	/	Yangon	15695	6
2007	Dengue	Dengue virus	Tamu	Sagaing	91	8
2008	Dengue	Dengue virus	Muse	Shan	49	9
2009	Dengue	Dengue virus	Myitkyina	Kachin	120	6
2008	Dengue	Dengue virus	Yangon	Yangon	3604	6
2009	Dengue	Dengue virus	Yangon	Yangon	49	6
2010	Dengue	Dengue virus	Naypyitaw	Naypyitaw	15	6
2012	Dengue	Dengue virus	Mawlamyine	Mon	500	6
2012	Dengue	Dengue virus	/	Kayah	200	6
2013	Dengue	Dengue virus	/	Mandalay	300	10
2018	Dengue	Dengue virus	/	Tanintharyi	516	6
2018	Dengue	Dengue virus	/	Ayeyawady	373	6
2018	Dengue	Dengue virus	/	Mon	267	6
2018	Dengue	Dengue virus	Myeik	Tanintharyi	142	6

2018	Dengue	Dengue virus	Palaw	Tanintharyi	65	6
2018	Dengue	Dengue virus	Dawei	Tanintharyi	21	6
2018	Dengue	Dengue virus	Launglon	Tanintharyi	25	6
2018	Dengue	Dengue virus	Thayetchaung	Tanintharyi	15	6
2018	Dengue	Dengue virus	Yebyu	Tanintharyi	33	6
2018	Dengue	Dengue virus	Myeik	Tanintharyi	38	6
2018	Dengue	Dengue virus	Tanintharyi	Tanintharyi	17	6
2018	Dengue	Dengue virus	Kawthoung	Tanintharyi	17	6
2018	Dengue	Dengue virus	Bokpyin	Tanintharyi	7	6
2017	Dengue	Dengue virus	Yangon	Yangon	750	6
2018	Dengue	Dengue virus	Bago	Bago	80	6
2018	Dengue	Dengue virus	Kayah	Kayah	370	6
2016	Dengue	Dengue virus	Naypyitaw	Naypyitaw	168	6
2016	Dengue	Dengue virus	Kachin	Kachin	276	6
2016	Dengue	Dengue virus	Kayah	Kayah	57	6
2016	Dengue	Dengue virus	Kayin	Kayin	528	6
2016	Dengue	Dengue virus	Sagaing	Sagaing	782	6
2016	Dengue	Dengue virus	Tanintharyi	Tanintharyi	645	6
2016	Dengue	Dengue virus	Bago	Bago	225	6
2016	Dengue	Dengue virus	Magway	Magway	188	6
2016	Dengue	Dengue virus	Mandalay	Mandalay	1076	6
2016	Dengue	Dengue virus	Mon	Mon	355	6
2016	Dengue	Dengue virus	Rakhine	Rakhine	402	6
2016	Dengue	Dengue virus	Yangon	Yangon	995	6
2016	Dengue	Dengue virus	Shan	Shan	792	6
2016	Dengue	Dengue virus	Ayeyawady	Ayeyawady	829	6
2016	Dengue	Dengue virus	Chin	Chin	2	6
2012	Dengue	Dengue virus	Tamu	Sagaing	30	11
2012	Cholera	Vibrio cholerae	Mrauk-U	Rakhine	45	6
2012	Cholera	Vibrio cholerae	Waimaw	Kachin	30	6
2014	Cholera	Vibrio cholerae	Mansi	Kachin	50	12
2014	Dengue	Dengue virus	Yangon	Yangon	1200	12
2015	Cholera	Vibrio cholerae	Kawkareik	Kayin	57	12
2015	Cholera	Vibrio cholerae	Kyainseikgyi	Kayin	160	12
2015	Cholera	Vibrio cholerae	Kyethi	Shan	230	13
2015	Cholera	Vibrio cholerae	Mong Hsu	Shan	170	13
2015	Cholera	Vibrio cholerae	Kyeinsekgyi	Kayin	190	13
2014	Cholera	Vibrio cholerae	South Okkapa	Yangon	234	6
2008	Cholera	Vibrio cholerae	Ananbon	Mon	61	6
2015	Acute diarhea	Entamoeba hystolica	Kalay	Sagaing	40	13
2016	Malaria	Plasmodium	Naypyitaw	Naypyitaw	90	6

2016	Malaria	Plasmodium	Kachin	Kachin	69	12
2016	Malaria	Plasmodium	Kayin	Kayin	233	12
2016	Malaria	Plasmodium	Mon	Mon	187	12
2016	Malaria	Plasmodium	Rakhine	Rakhine	119	12
2016	Malaria	Plasmodium	Shan	Shan	207	12
2016	Malaria	Plasmodium	Sagaing	Sagaing	244	12
2016	Malaria	Plasmodium	Tanintharyi	Tanintharyi	391	12
2016	Malaria	Plasmodium	Bago	Bago	114	12
2016	Malaria	Plasmodium	Magway	Magway	92	12
2016	Malaria	Plasmodium	Mandalay	Mandalay	542	12
2016	Malaria	Plasmodium	Yangon	Yangon	710	12
2016	Malaria	Plasmodium	Ayeyawady	Ayeyawady	333	12
2008	Cholera	Vibrio cholerae	Bogale	Ayeyawady	90	6
1993	Cholera	Vibrio cholerae	Yangon	Yangon	117	14
2002	Cholera	Vibrio cholerae	Yangon	Yangon	1023	15
2016	Cholera	Vibrio cholerae	Pyay	Bago	63	12
2016	Cholera	Vibrio cholerae	Bago	Bago	33	12
2017	Dengue	Dengue virus	Yangon	Yangon	954	12
2018	Dengue	Dengue virus	Ayeyawady	Ayeyawady	1679	12
2018	Dengue	Dengue virus	Yangon	Yangon	2855	12
2000	Typhoid fever	Salmonella typhi	Madaya	Mandalay	33	16
2006	Typhoid fever	Salmonella typhi	Payathonzu	Kayin	15	17
1998	Typhoid fever	Salmonella typhi	Mingalar Taungnyunt	Yangon	64	12
2018	Schistosomiasis	Schistosoma	Sittwe	Rakhine	59	6
2013	Schistosomiasis	Schistosoma	Shan	Shan	75	18
2017	Dengue	Dengue virus	Ayeyawady	Ayeyawady	2984	12
2017	Dengue	Dengue virus	Rakhine	Rakhine	2489	12
2017	Dengue	Dengue virus	Kachin	Kachin	2273	12
2017	Dengue	Dengue virus	Mandalay	Mandalay	2102	12
2017	Dengue	Dengue virus	Mon	Mon	1826	12
2017	Dengue	Dengue virus	Kayin	Kayin	1769	12
2017	Dengue	Dengue virus	Bago	Bago	1615	12
2017	Dengue	Dengue virus	Shan	Shan	1323	12
2017	Dengue	Dengue virus	Sagaing	Sagaing	1102	12
2017	Dengue	Dengue virus	Kayah	Kayah	1036	12
2017	Dengue	Dengue virus	Magway	Magway	880	12
2017	Dengue	Dengue virus	Tanintharyi	Tanintharyi	817	12
2017	Dengue	Dengue virus	Naypyitaw	Naypyitaw	581	12
2016	Japanese encephalitis	Japanese encephalitis virus	/	Kayin	17	6
2014	Japanese encephalitis	Japanese encephalitis virus	/	Yangon	319	6
2016	Japanese encephalitis	Japanese encephalitis virus	/	Shan	13	6

2016	Japanese encephalitis	Japanese encephalitis virus	/	Ayeyawady	69	6
2017	Japanese encephalitis	Japanese encephalitis virus	/	Kayin	35	6
2002	Malaria	P. vivax	Dawei	Tanintharyi	252	19
2014	Malaria	P. vivax	Muawaddy	Kayin	25	20
2012	Malaria	P. vivax	Kawthoung	Tanintharyi	60	20
2007	Malaria	P. falciparum	Laiza	Kachin	21	21
2013	Malaria	P. falciparum	/	Bago	52	22
2013	Malaria	P. falciparum	/	Chin	62	22
2013	Malaria	P. falciparum	/	Kachin	70	22
2013	Malaria	P. falciparum	/	Kayah	2	22
2013	Malaria	P. falciparum	/	Kayin	288	22
2013	Malaria	P. falciparum	/	Mandalay	181	22
2013	Malaria	P. falciparum	/	Mon	8	22
2013	Malaria	P. falciparum	/	Rakhine	29	22
2013	Malaria	P. falciparum	/	Sagaing	46	22
2013	Malaria	P. falciparum	/	Shan	21	22
2016	Malaria	Plasmodium	/	Kachin	433	23
2013	Malaria	P. knowlesi	Phyu	Bago	16	24
2013	Malaria	P. vivax	Phyu	Bago	7	24
2016	Malaria	Plasmodium	/	Kayah	485	25
2016	Malaria	Plasmodium	Schwegyin	Bago	30	26

Sources: The Author, Various sources, see references.

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