# Epidemiology study of Diarrhoea, Cholera, Typhoid, Hepatitis A and Hepatitis E in Middle East and North Africa Region

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**Abstract.** Middle eastern countries are among one of the highly water stressed region in the world. Which renders it highly susceptible to water borne diseases. Water borne diseases epidemiology in Middle eastern countries were investigated in this research to determine existing health security in Middle eastern countries. Recent conflicts in the region, deteriorating water supply and infrastructure has led to major outbreaks of diarrhoea and cholera in Syria, Iraq, and Yemen. The water borne disease investigated are; diarrhoea, cholera, hepatitis A, hepatitis E and typhoid to present an overall scenario in the region. Despite proper infrastructure and water supply, stability (social, political and economy) of each country is vital to contain and curb water borne diseases and its outbreak in Middle eastern countries. According to the research results, it can be assumed that there is a high need for an elaborate study to come up with a comprehensive plan to mitigate and control water borne diseases in Middle eastern countries in terms of present and future perspective.

**Keywords**: epidemiology, infections, water borne diseases, disease scenario estimates, health security, childhood morbidity, morbidity prediction

## 1. Introduction

Human Health is at risk when water quality or quantity are ever compromised (Mazzoni & Zaccagni, 2018; Dhingra et al., 2022). Vector-borne diseases put 80% of world population under risk (Franklinos et al., 2019). Everyday about 3800 child death is attributed to water related diseases. Pathogens result in water sources owing to non-maintenance of water

facilities, purification process not followed appropriately (Ziarati et al., 2021; Hussain et al., 2022). This presents a great risk to human health leading to fatal illnesses such as typhoid, fever, diarrhoea, cholera, Hepatitis A and Hepatitis E (Mazzoni et al., 2018). Diarrhoea is the most dominant global burden as water infectious diseases (UNESCO, 2016). The regions experiencing water scarcity or water stress are highly susceptible to water borne diseases. Middle Eastern countries are among one of the highly water stressed region in the world (UNESCO, 2016; Mate et al., 2016).

This Study covers; The Gulf states (GCC) Saudi Arabia, Kuwait, Bahrain, Qatar, Oman and United Arab Emirates, and other middle eastern countries are Iraq, Lebanon, Jordan, Syria and Palestine (West Bank and Gaza) Iran, Lebanon and Yemen (Mate et al., 2016; WBG, 2015; Wasimi, 2010; Al-Saidi et al., 2016; Sida, 2017; Sowers et al., 2011). This division is based on similarity shared by majority of people in the region based on religion, culture, history and language (Moustakbal, 2009). The study area is presented in Figure 1.

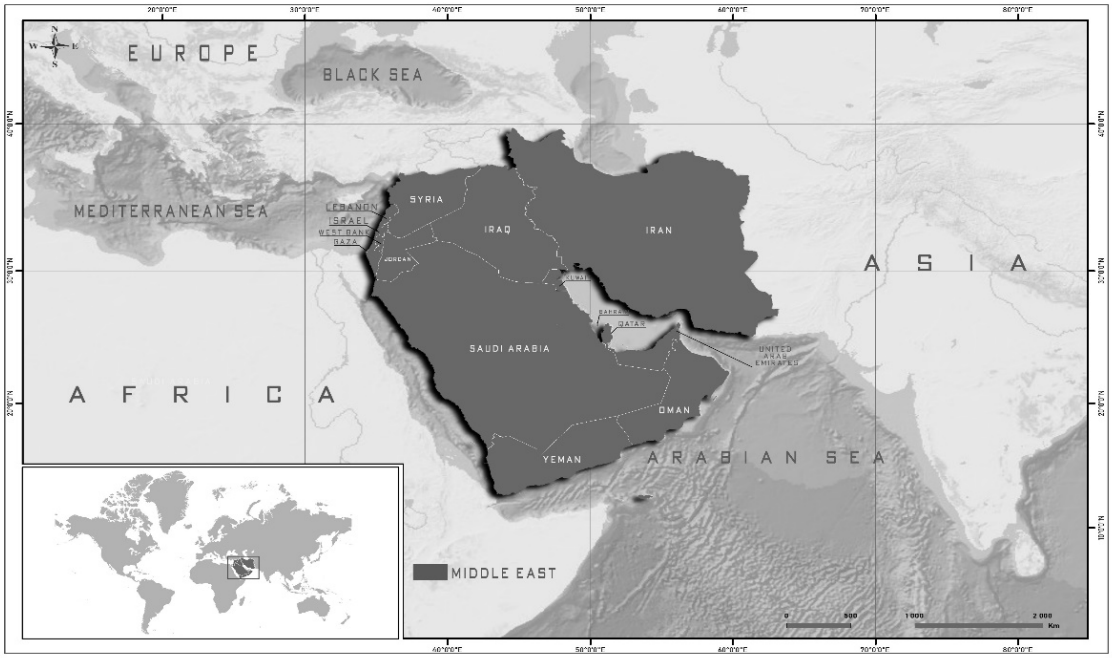


**Figure 1.** Study area Map

About 65% of Middle east population experiences water stress/scarcity as compared to world population of 36% (Al-Rimmawi, 2012). The water scarcity experienced in Middle eastern countries renders it highly susceptible to water borne diseases.

Considering what was said above, this study aims to assess the prevalence of waterborne diseases in the Middle East in order to understand and present an overall scenario in the region to develop the necessary solutions to improve health security

### 1.1. Literature search strategy

In order to assess water borne diseases scenario in middle eastern countries systematic review was carried out based on online articles published from 2006-2019. PubMed, Web of science, Google Scholar, Science Direct, Scopus, World Bank and WHO report and scientific database were explored to retrieve necessary information for assessment. The present review was performed using keywords, Hepatitis A, Hepatitis B, Diarrhoea, Cholera, Typhoid, Cryptosporidiosis and Giardiasis combined or as individual country for Middle eastern countries.

### 1.2. Study framework

The study explored middle eastern countries in terms of water borne diseases in the region. The health security was covered in terms of water borne diseases (cholera, diarrhoea, typhoid, A, hepatitis E). Diarrhoea and cholera are the diseases, which gives instant symptoms upon ingestion of contaminated water and food and are reported for decades in the Middle eastern countries. However, hepatitis A and hepatitis E are relevantly new in Middle eastern countries. Typhoid takes 1-4 weeks of time before any symptoms can appear upon ingestion of contaminated water and it serves as an indicator of water quality in the region over decades (Efstratiou et al., 2017; Ahmed et al., 2018). However, literature on Middle eastern countries as whole is still lacking. Hence, study choose these diseases to investigate water borne diseases scenario, address research gaps with respect to neighbouring regions and determine factors susceptible to affect water quality. The study took into account the scenario for last one decade (2009-2019) owing to the fact that in this particular period Middle eastern countries was faced with conflicts (political instability, armed struggle, foreign invasions, etc.), which resulted in mass migration throughout the region testing the prevailing health and sanitation conditions of middle eastern countries. The study suggests sustainable options to address long term water security along with curbing frequent outbreaks of water borne disease incidences and sustaining public health in future.

## 2. Water borne diseases in Middle Eastern countries

Water borne diseases cause 2 million deaths worldwide. Also 4 billion cases of cholera are reported annually (El-Kowrany et al., 2016). The morbidity and mortality are mostly attributed to infectious diarrhoea. Children under age of five are the most severely affected population. Infectious diarrhoea is also responsible for 4000 deaths of children every day

under age of five globally with the majority of the cases occurring in South Asia and Middle eastern countries. Diarrhoea accounts for 4% of death as global disease burden accounting 1.8 million of deaths (UNESCO, 2016). In 2016, 7 million deaths of children under age of 5 was attributed to ingestion of unsafe water and unhygienic condition. Additionally, 400 million school children are linked with lack cognitive development problems attributed to parasitic infections (Mazzoni et al., 2018). The commonly occurring water borne diseases are bacillary dysentery, salmonellosis, typhoid fever, cholera, diarrhoea, etc. (El-Kowrany et al., 2016). Table 1. Presents the water borne disease incidence reported in literature for 2009-2019 period.

**Table 1.** Water Borne disease incidence in middle eastern countries, 2009-2019

| Disease | Country | Year | Number of cases | Reference |
|---|---|---|---|---|
| Cholera | Yemen | January, 2019 | 36062 (34 deaths) | Nuruzzaman, M., 2015 |
| Diarrhoea | Lebanon | 2019 till 23rd March | 33 | Greenarea.me, 2015 |
| Cholera | Yemen<br>Gulf of Aden | 2017-2018 | 1.1 million | Leal Filho et al., 2017 |
| *E. coli* infection | Iran | 2018 | 500, Sepidan<br>500, Kelardasht<br>400, Ramhormoz | Imamura, 1989 |
| Cholera | Yemen | October 2016 | 1698173<br>3433 (Deaths) | (WHO, 2019) |
| Cholera | Lebanon | 2015 | 105,000 Children (Syrian refugees) | Greenarea.me, 2015 |
| Dysentery | Palestine | 2014 | 11.9-14.1/100,000 | Watkins et al., 2002 |
| Diarrhoea | Iraq | 2010<br>April 28-June 4, 2010 | 360,000 in a year<br>74 confirmed cases | Berdahl & Bretz, 1997 |
| Diarrhoea | Jordan | 2000-2010 | 117,894 per year | Asaeda et al., 1996 |

### 2.1. Diarrhoea in Middle eastern countries

The second primary cause of death among children under five years is diarrhoea. Each year about 525,000 deaths among kids are attributed to diarrhoea. Globally there are about 1.7 billion cases of diarrhoea each year (Elayah, 2018). In children below five years mortality (no. of deaths) for the year 2016 in Middle eastern countries 1936 (Iraq), 870 (Iran), 117 (Jordan), 1 (Kuwait), 17 (Lebanon), 10 (Oman), 1 (Qatar), 87 (Saudi Arabia), 1519 (Syria),

67 (United Arab Emirates) and 3702 (Yemen) (Elayah, 2018). Originating from faeces of infected hosts they can be transmitted to new hosts via oral-faecal route upon contact with contaminated soil, water, feed and food.

A significant relation for based on gender, socio- economy in rural areas and animal contact role was derived (Shalaby & Shalaby, 2015). High affinity of infections was associated with tap water contamination and animal contact in urban populations (Gawad et al., 2018). Based on the zoonotic patterns of isolates, it can be identified that the mode of transmission is direct or indirect animal contact (Taghipour et al., 2011). Lebanon reported molecular analysis as an important tool to identify mode of transmission (Osman et al., 2016). Kuwait reported genetic condition of parasites plays important role in human (Iqbal et al., 2011). Report from Jordan identified human to human transmission (Hijjawi et al., 2016).When there is no significant demographic variation then modes of transmission can be ingestion of contaminated water, and human or animal contacts (Iqbal et al., 2001). Identification of the transmission routes will help in adopting mitigation measures. Hence, preventing spread of infection is most suitable and sustainable policy (Abd El Kader et al., 2012). However, zoonotic transmission cannot be eradicated from Middle eastern countries as whole region practices animal husbandry owing to extreme conditions prevailing in most of the region rendering animals as sustainable source of food and other products thereof. Lack of awareness, personal hygiene and sanitation facilities, poverty, indiscriminate eating habits are favourable infestation conditions for infections. The prevalence of Diarrhoea, is higher in developing countries as compared to developed countries (Efstratiou et al., 2017; Ahmed et al., 2018).

Nevertheless, majority of the studies identified water contamination as primary source of diarrhoea and cholera outbreaks. The improper wastewater disposal, old and lacking water supply and sanitation facilities, or facilities destroyed owing to conflicts have led to sewage mixing with water supply and causing outbreaks throughout Middle eastern countries from time to time.

### 2.2. Cholera in Middle eastern countries

Cholera is an acute form of diarrhoeal infection capable of causing death within hours in absence of medical treatment. Annually 1.3 – 4 million cases of cholera are reported globally. Around 21,000 – 143,000 deaths are attributed to cholera. A worldwide strategy was adapted to diminish cholera by 90% (Ali et al., 2015; Azman et al., 2013). Cholera is one the most widely reported water borne disease in Middle eastern countries. Yemen is currently most affected country in Middle eastern countries with frequent outbreaks of cholera and diarrhoea

over last one decade. Yemen reported 55,200 cholera cases in just four weeks. Over 124,000 cases are reported from which half are reported for children (Kummer, 2017). Around 384,000 suspected cases (cholera and acute watery diarrhoea) and around two million malnourished children are reported in Yemen. Around 923 people were reported dead since April-June 2017 (UNICEF, 2018). Since the beginning of an outbreak till September 2, 2018 number of cases reached 1.1 million (Kummer, 2017). In Palestine, diarrhoea rate was already doubled among children aged below three years (1483 cases in March – 3713 in June 2017) (https://www.unicef.org/mena/press-releases/amid-scorching-heatwave-access-water-and-electricity-down-one-third-gaza-strip). When water borne diseases in Gaza were studied, in case of dysentery in Wadi Gaza and A-Mograqa 14.1 and 11.9 infections were reported for every 100,000 population. In Iraq, polluted water supply and lack of hygiene awareness led to 360,000 diarrhoea cases in only first six months of 2010 (Aenab & Singh, 2012). In 2015, Iraq confirmed around 3000 cases of cholera outbreak from 15 of 18 governorates (https://www.unicef.org/mena/press-releases/efforts-against-killer-disease-in-iraq). Iran reported microbial outbreak in first month of spring 2018, affecting 500 inhabitants, within interval of few weeks. Another viral outbreak was experienced infecting 500 people and in late June 400 people were affected by ingesting *Escherichia coli* contaminated water (WHO, 2018a). Figure 2, presents some of the major water borne outbreaks in middle eastern countries over the last decade.

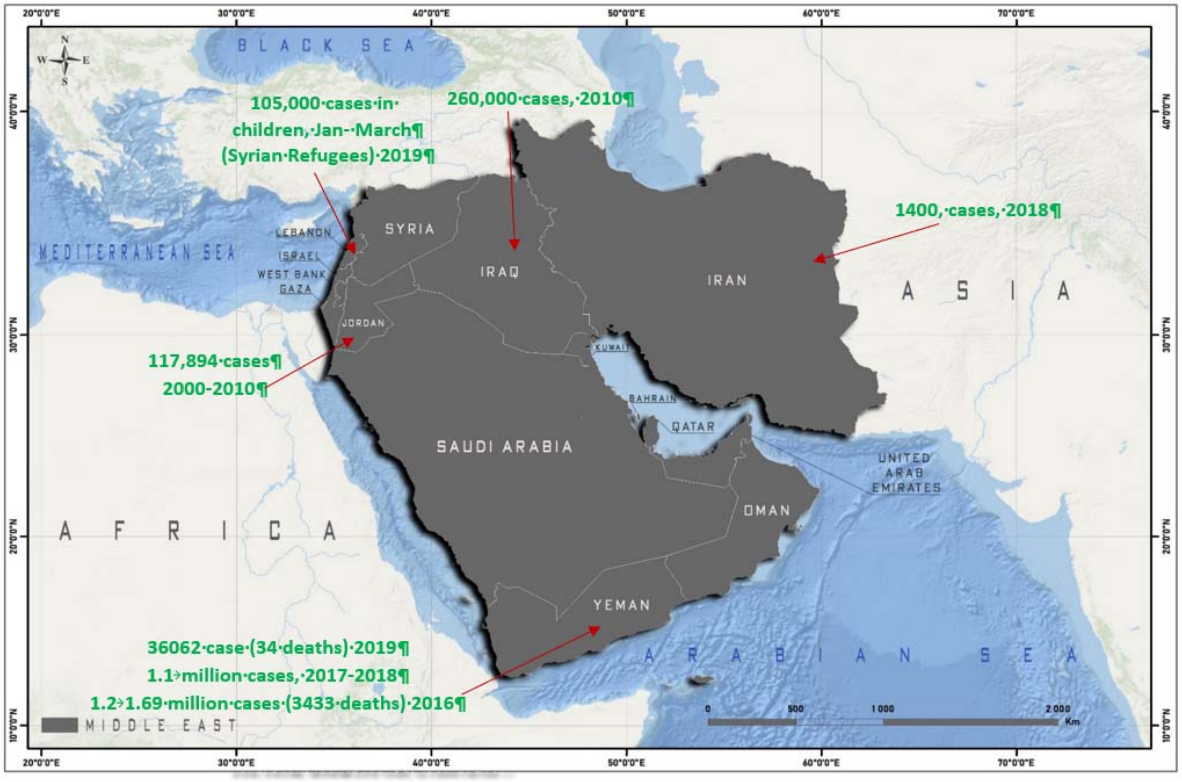

**Figure 2.** Cholera and Diarrhoea Outbreak in Middle eastern countries in last 10 years (2009-2019): blue - water bodies, sea, ocean etc.; light grey - land mass; dark grey - study area

### 2.3. Hepatitis A

Approximately 1.4 million Hepatitis A viral (HAV) cases occur worldwide each year (Melhem et al., 2014). About 425 million HAV infected population belongs to Middle East (ME) and East Mediterranean Region (EMR) (Safiabadi et al., 2017). Hepatitis A virus infection is usually transmitted through faecal-oral route, via contaminated food or water or close contact associated with poor sanitary conditions and low socioeconomic status like war and famine (Bawazir et al., 2010; Miri & Alavian, 2017). The seroprevalence in Middle East region is presented in Table 2 for the period of 2009-2019. Iran reported higher number of studies across various sections of its population. Hepatitis A was reported hyperendemic in Iran. Among soldiers the seroprevalence rate was reported as high as 80.3% (Izadi et al., 2016). Among children six months to 1.9 years group prevalence rate was reported 61.5%, between 2 to 5.9 years it was 51.7%, between 6 - 10.9 years age group it was 52.9%, between 11-15.9 years 65.2% and 85% for age group between 16-20 years in 2010 (Sofian et al., 2010). Similar results were reported in another study of 2016 where overall seropositivity was reported 64%, at age of 10 it was reported 14.8% (95%, CI 7-23), at age of 13 it was 72.9% (95% CI 68-78) with no significant improvement at 18 years of age. Also no significant differences were found based on gender and demographic conditions (Hoseini et al., 2016).

**Table 2.** Literature on Hepatitis A scenario in Middle Eastern countries

| Country | Seropositivity (%) | Age | Area and year of study | References |
|---|---|---|---|---|
| Iran | 14.8-72.9 | 10-18 | 27 provinces of Iran, 2015 | Hoseini et al., 2016 |
| | 80.3 | 18-34 | Tehran Iran 2014-15 | Izadi et al., 2016 |
| | 8.4 - 15.8 | 1-25 | Sari Iran 2007 | Alian et al., 2017 |
| | 61.5 -51.7 | 0.5-20 | Tehran 2009 | Sofian et al., 2010 |
| | 5.7 -9 | 0-30 | Mazandaran, North Iran 2010 | Saffar et al., 2012 |
| Iraq | 91.3 - 96.8 | 1-40 | Iraq 2005–2006 | Turky et al., 2011 |
| | 96.35 | -- | Iraq 2017 | Safiabadi et al., 2017 |
| Lebanon | 54.97 | -- | -- | Safiabadi et al., 2017 |
| Qatar | 162 cases 1.9/10000 | 0-35 | 2002-2006 | El Minshawy, 2011 |

| | | | | |
|---|---|---|---|---|
| Saudi Arabia | 33.1 | -- | Jeddah | Sabir et al., 2013 |
| Syria | 95 | 15 | Nationwide, 2000 | Alhalabi et al., 2012 |
| Yemen | 86.6 | 0-18 | Aden | Bawazir et al., 2010 |

Studies from other middle eastern countries also reported seroprevalence of HAV infection. Two studies from Iraq in 2011 and 2017 revealed high seroprevalence rate as high as 96% with so difference based on gender reported (Turky et al., 2011). Lebanon reported very sharp rise in HAV infection mainly attributed to influx of Syrian refugees especially during the period of 2013-2014. Between year 2005 and 2017, 10400 cases were reported, however, literature on HAV is very scarce from Lebanon (Bizri et al., 2018).The incidence rate of 1.9/10,000 population was reported in Qatar. Highest seroprevalence rate 72.3% was reported in children below 15 years of age. The infection rate was reported to be declining in Qatar nationals, while increasing in foreign workforce in Qatar. Also, infection was strongly affected by gender and age of the patients (El Minshawy, 2011). In Saudi Arabia seroprevalence of anti HAV IgG was undertaken in general population and seroprevalence rate was 18.6%, significant decline from 90-100% reported two decades ago. It is mainly attributed to improved water supply, and sanitation facilities. The seropositivity increase with age, also was increasing with the nationality, when compared with Saudi nationals and foreign workforce in the kingdom (Sabir et al., 2013). This is in positive relation with results reported for Qatar (Sabir et al., 2013). In Palestine HAV prevalence rate was reported for in Al Burajas 0.14 per 100,000 populations was reported. In 2016 international workers in Syria diagnosed 31,460 cases of HAV infection. This sharp rise in HAV infection is attributed to ongoing internal conflicts, which have damaged water supply and rendered sanitation facilities to the least standards possible. In the conflict area 70% of the population does not have access to safe drinking water, which has made it a breeding ground for water borne diseases (Miri & Alavian, 2017). Covering 538 participants in Yemen for antibodies age-standardized seroprevalence was 86.6 % for anti HAV (95%, CI 83.7-89.5). The viral hepatitis was reported to be hyperendemic in Yemen. This necessitates improvement in water supply condition, sanitation facilities, hygienic food and create public health awareness in regards with contracting the infection (Bawazir et al., 2010). Overall, a high prevalence was reported in countries of Middle eastern countries experiencing conflicts (armed struggle, internal conflicts and political instability).

Iran reported high HAV seroprevalence among children under 5, Qatar and Saudi Arabia reported high seroprevalence among foreign workforce as compared to nationals. Iraq,

Lebanon, Syria and Yemen reported sharp rise in HAV infection mainly attributed conflict in the region and influx of refugees. Contamination of water supply, accessibility to safe water supply, socioeconomic and hygienic condition, insufficient sanitation facility, lack of vaccination and travelling to endemic area are the primary reasons identified for HAV infection in Middle eastern countries based on the literature available. The high prevalence rate of HAV seropositivity will require mass vaccination of children as an counter measure to curb Hepatitis A (Hoseini et al., 2016). The shift in age group for HAV prevalence is mainly attributed to enhanced quality of drinking water, improved sanitation and hygiene condition along with improvement in socioeconomic conditions (Alhalabi et al., 2012). Establishment of clean and healthy water supply, improved sanitation and efficient wastewater treatment are responsible for low prevalence of HAV infection (Safiabadi et al., 2017; Ataei et al., 2009). Figure 3 presents seropositivity of HAV in Middle eastern countries.

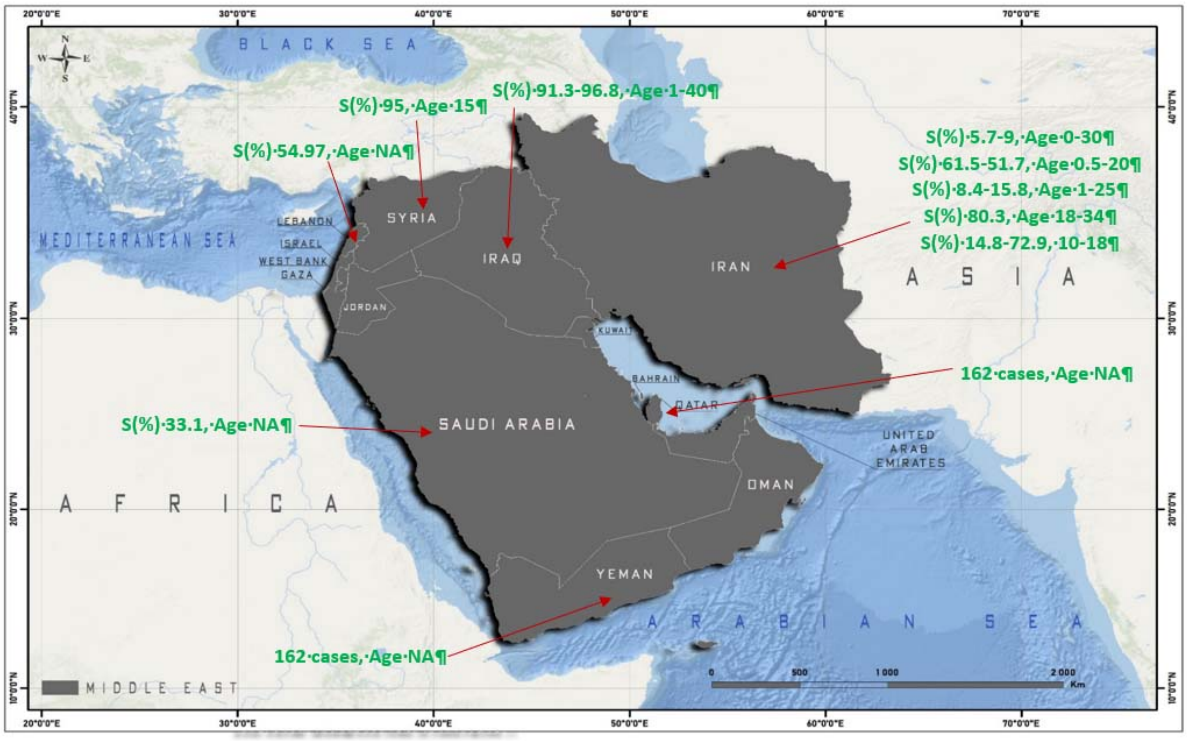


**Figure 3.** Hepatitis A seropositivity (%) in Middle eastern countries (NA=not available, S = seropositivity, in countries where seropositivity is not available it has been reported as no. of cases, blue - water bodies, sea, ocean etc.; light grey - land mass; dark grey - study area)

### 2.4 Hepatitis E

Hepatitis E is a lung infection caused by virus known as hepatitis E virus (HEV). An estimated 20 million HEV infections are reported worldwide with an estimated 3.3 million symptomatic cases of hepatitis E. As per WHO in 2015, 44,000 deaths are attributed to HEV which accounts for 3.3% mortality by hepatitis virus. Regional instability (social, political,

economic and security) leading to deterioration of basic infrastructure required for adequate and safe water supply and sanitation can lead to waterborne epidemics with HEV outbreaks (Al-Nasrawi et al., 2010). Table 3, present the HEV seroprevalence in Middle eastern countries for past 10 years. Iraq reported two studies each for hepatitis E seroprevalence. In Iraq jaundice patients were examined for HEV infection for IgM antibodies and reported 38.1% of seropositivity. Low chlorine concentrations, unsafe water, disruption in sanitation and water supplies as most likely cause for seropositivity (Al-Nasrawi et al., 2010). Other studies evaluated acute viral hepatitis patients reported HEV IgM seropositivity of 19.4%, while for hepatitis E-IgG antibodies it was 20.3% (95% CI 19.4-21.2%). The seropositivity increased with age but no significant difference was reported based on sex (Turky et al., 2011). Obaidat and Roess (2018) first reported on hepatitis infection for Jordan population and reported that youngest age group under 14 years and oldest age group over 60 years were among the highest HEV seropositivity.

**Table 3.** Hepatitis E seroprevalence in Middle East region

| Country | Seroprevalence (%) | Genotype/Anti HEV | Age | Area and duration | Reference |
|---|---|---|---|---|---|
| Egypt | 60 | | <10 | Nile Delta | Fix et al., 2000 |
| | 76 | | <20 | Upper Egypt | |
| | 60 | | <80 | | |
| | 26.8 | IgG | Male | 2010-2011 | El-Tras et al., 2013 |
| | 50.8 | | Female | | |
| Iraq | 38.1 | IgM | 0-40 | Baghdad, 2005 | Al-Nasrawi et al., 2010 |
| | 45.5 | | >40 | | |
| | 12.9 | | <10 | | |
| | 19.4 | IgM | | Nationwide 2005-2006 | Turky et al., 2011 |
| Jordan | 30.9 | IgG | 0-80 | | Obaidat and Roess, 2018 |
| | 45.5 | | <14 | | |
| | 20.2 | | 20-29 | | |
| | 15.2 | | 30-39 | | |
| | 53.2 | | 60-80 | | |
| Tunisia | 5.4 | IgG | Adults | 2007-2008 | Houcine et al., 2012 |
| | 2.2 | | <30 | | |
| | 8 | | >30 | | |
| Yemen | 0-53 | | Infants | 2009, Aden | Bawazir et al., 2010 |
| | 15.3-100 | | >18 | | |

Iraq and Yemen reported age group less than 20 years for HEV seropositivity. However, single reports from Jordan put over 30 years and 60 years as of highest seropositivity respectively. The major routes of transmission was identified as zoonotic, ingestion of contaminated food (undercooked meat) and water (water supply mixed with sewage), lack of sanitation and hygienic condition, which has high affinity with rural and poor living conditions (Bawazir et al., 2010; Al-Nasrawi et al., 2010; Obaidat & Roess, 2018; El-Tras et al., 2013). Figure 4 presents the seroprevalence of HEV in Middle Eastern countries.

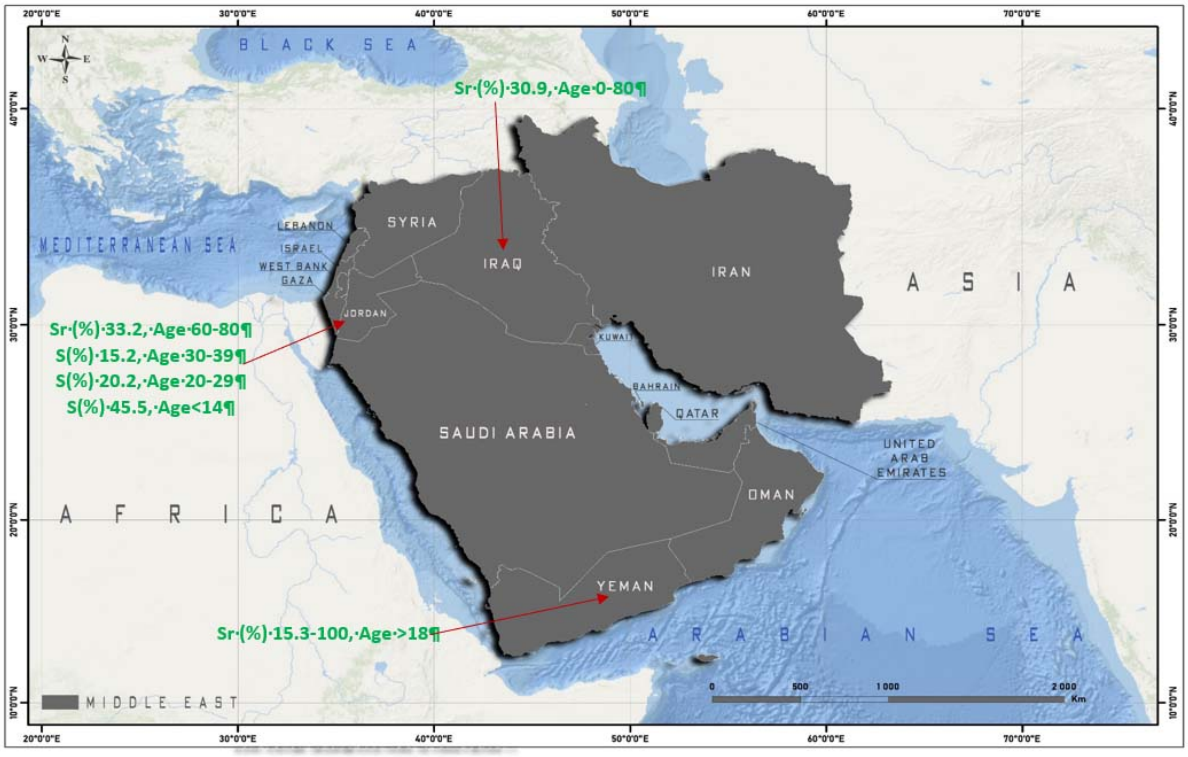


**Figure 4.** Hepatitis E Seroprevalence (%) in Middle eastern countries (blue - water bodies, sea, ocean etc.; light grey - land mass; dark grey - study area)

## 2.5 Typhoid

Typhoid fever is a dangerous disease caused by bacterium Salmonella typhi. Ingestion of contaminated food or water is primarily responsible for its occurrence. Around 128,000-161,000 deaths are attributed to typhoid worldwide while 11-20 million contract the infection annually (WHO, 2018b). Typhoid fever is endemic owing to hot weather conditions, regular electricity and water supply interruption (Sadeq & Rasha, 2017). This renders Middle eastern countries highly susceptible to typhoid infection. Table 4 presents the literature available for typhoid cases in Middle eastern countries. There are three studies each reported for Iran and Iraq (Khezzani & Bouchemal, 2016; Dworkin et al., 2014).

**Table 4.** Typhoid cases in MENA countries

| Country | Cases | Age Group | Region/Duration | Reference |
|---|---|---|---|---|
| Iran | 133.4/100000 to 0.52/100000 | -- | 1962-2001 Iran | Asl et al., 2013 |
| | 21/100000 | – | May-September 2011, Sulaimania Iraq | Dworkin et al., 2014 |
| Iraq | 7.4 % (Male) 8.7 % (Female) | 1-5 | Al Samawah, Iraq | Nahab et al., 2018 |
| | 11.1 % (Male) 13 % (Female) | 6-10 | | |
| | 14.8 % (Male) 17.4 % (Female) | 11-15 | | |
| | 26 % (Male) 26.1 % (Female) | 16-20 | | |
| | 11.1 % (Male) 8.7 % (Female) | 21-25 | | |
| | 7.4 % (Male) 0 % (Female) | 26-30 | | |
| | 7.4 % (Male) 8.7 % (Female) | 31-35 | | |
| | 7.4 % (Male) 8.7 % (Female) | 36-40 | | |
| | 0 % (Male) 8.7 % (Female) | 41-45 | | |
| | 7.4 % (Male) 0 % (Female) | 46-50 | | |
| | 36,208 | -- | 2007 (Iraq) | Sadeq & Rarha, 2017 |
| | 58,247 | | 2008 (Iraq) | |
| | 49113 | | 2009 (Iraq) | |
| | 49139 | | 2010(Iraq) | |
| Qatar | 354 | Average Age 29 | 2005-2012 Qatar | Ahmedullah et al., 2018 |

In a five-decade study in Sulaimania province of Iran, one third of reported infection was found in age group below 15 years. In adults, incidence rate was 21/100,000 and in children it was reported to be 24/100,000 (Asl et al., 2013). Iran has shown gradually decline in typhoid incidence over a period of 1969-1996 (10-100/100,000) reporting 10/100,000 for period from 1996 till now. Lowest incidence rate was reported in 0.5/100,000 in 2011 (Dworkin et al., 2014). In Iraq, typhoid incidence rate was reported as 21/100,000 patients/year and typhoid was also concluded as a considerable public health challenge (Dworkin et al., 2014). Al Zahra and Gaza Wadi in Palestine reported 5.4 and 1.9 people were infect with typhoid for every 100,000 population. For three successive years (2004-2006) Libya reported incidence rate of 7/100,000, 21/100,000 and 16/100,000 (Zorgani & Ziglam, 2014). While Qatar reported number of cases of duration 2005-2012 as follows: 42 (in 2005), 48 (2006), 39 (2007), 44 (2008), 46 (2009), 47 (2010), 52 (2011) and 36 (2012) (Ahmedullah et al., 2018). The study from Qatar identified travelling to endemic areas as source of infection. Also,

higher rate of infection was reported in foreign workers than in Qatari nationals and was also higher in rural areas. The improvement in water supply, personal hygiene and sanitation condition was identified as counter measure to curb typhoid successfully. Studies in Iraq identified most prone age group between 6-20 years for Typhoid (Nahab et al., 2018). Figure 5 presents the Typhoid cases in Middle eastern countries as reported in literature.

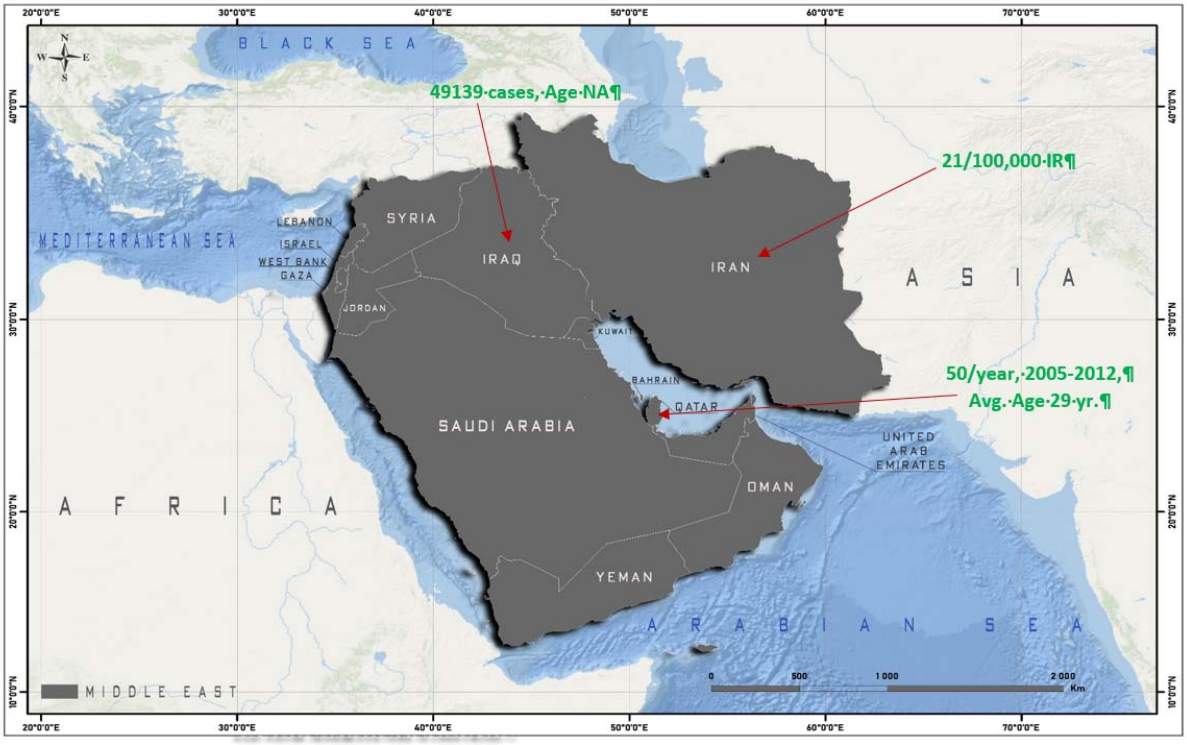


**Figure 5.** Number of cases and incidence rate of Typhoid in Middle eastern countries (IR = Incidence rate, blue - water bodies, sea, ocean etc.; light grey - land mass; dark grey - study area)

## 3. Waterborne diseases management

The water quality scenario along with water borne diseases in Middle eastern countries summarizes need for providing region with sustainable water supply facilities. Water borne diseases can be effectively controlled and managed through adopting treated and clean water supply, efficient hygiene and sanitation practices (Husain et al., 2023). However, Middle eastern countries exist in water scarcity zone which makes it difficult for sustainable water supply and management facilities. Especially in countries facing conflicts (political instability, armed struggle, etc.) supply of water facilities has been targeted which throws the basic human needs in abyss leading to frequent and large scale outbreaks of water borne diseases in Middle eastern countries (Moustakbal, 2009; WHO, 2019; Zolnikov, 2013; WBG, 2009). Even, if Middle eastern countries is experiencing conflicts (armed struggle, political instability etc.) still its high water scarcity situation keeps the outbreak of water borne

diseases lurking around all the time (El-Kowrany et al., 2016). The uncontrolled disposal of raw sewage in natural water bodies are mainly responsible for water contamination along with frequent outbreaks of water borne diseases. However, installation of wastewater treatment plants has shown successful reduction in water borne infections and diseases owing to reduced contamination of water resources (Khezzani & Bouchemal, 2016). The installation of wastewater treatment facilities, disinfection of water supply, effective maintenance of sanitation and hygiene condition are the primary factors in curbing outbreak of water borne diseases (Mazzoni et al., 2018; Moustakbal, 2009; WHO, 2019; Zolnikov, 2013; Aziz et al., 2017).

Additionally, region also loses in economic in term of GDP, Iran 0.5% (2.15 billion US Dollars), Iraq 2.9% (5.57 billion US Dollars), Jordan 0.4% (0.16 billion US Dollars), Kuwait 0.6% (0.72 billion US Dollars), Lebanon 0.2% (0.10 billion US Dollars), Oman 0.9% (0.63 billion US Dollars), Qatar 0.3% (0.5 billion US Dollars), Saudi Arabia 0.79% (5.42 billion US Dollars), United Arab Emirates 0.6% (2.29 billion US Dollars) and Yemen 6% (1.40 billion US Dollars). Since it can be clearly deduced water is a basic human need, disruption of water supply and its contamination is not only a threat to human life, but also affects economy of the country. This has led the decision and policy makers to adapt to sustainable approach in addressing water demand, its utilisation and conserving the water resource for future generation.

This study calls for policies and measures to be adapted to bring in collective thinking for water conservation for sustainable water and health security measurement in Middle eastern countries. Several initiatives have been adopted in Middle eastern countries at local, institutional and national levels for water and health security. However, these measures are more focussed on solving current issues and lacking to address future issues at the same time. The major challenge that study has to overcome arises due to significant differences in water resources availability, economy, social factors, and population. This hinders any assessment to be applicable for Middle eastern countries accurately. The second difficulty is faced owing to conflicts (war, political instability, etc.) going on in Middle eastern countries which leads to limited data availability from respective countries. A serious consideration has to be given to political scenario in middle eastern countries before adopting any general strategy, otherwise it will lead to further complication in adaptation, further deteriorating current scenario.

## 4. Conclusions

Middle eastern countries belong to most water scarce area in the world. The quality of water affects the human health directly on consumption. However, reduced water supply (quantity) results in lack of hygiene and water sanitation facilities also affecting human health directly. Children under five years were reported as highly prone to diarrhoea and cholera in Middle eastern countries. Also, HAV seroprevalence was reported to be highest in children under five years of age. While HEV seroprevalence was reported to be highest for age group under 20 years of age. Additionally, typhoid was also reported to be prevailing among age group of 6-18 years in Middle eastern countries. The water borne diseases affects in majority children which makes them a national concern. Preserving their health will also preserve future of a country and economy. The zoonotic transmission route is a major concern as region is deeply rooted with animal husbandry as source of food and other products since ancient times owing to environmental and climatic condition.

The varying detection methodologies and non-uniform reporting policies makes it difficult to present general overall scenario of water borne diseases in Middle eastern countries. All water borne diseases in Middle eastern countries are directly related to water supply and lack of hygiene and sanitation conditions. However, countries such as Syria, Yemen, Palestine, Iraq, Libya ongoing conflicts are primarily responsible for deterioration of water supply and sanitation facilities leading to frequent outbreaks of diseases. This can be validated from the fact that neighbouring GCC (Saudi Arabia, Qatar, Kuwait, Bahrain, Oman, United Arab Emirates) countries have not reported any recent outbreaks especially for diarrhoea and cholera, which countries facing conflicts are reporting from time to time and at mass level. Also, these countries have reported continuous decline in cases of diarrhoea, which is the indicator of improving water supply and sanitation facilities. Additionally, shift in seroprevalence in age group is also attributed to improved water supply and sanitation condition.

The study would recommend adaptation of policies and strategies to restore and generate renewable water resources in the region, adopt uniform reporting of any outbreak of diseases, implement uniform water supply, personnel hygiene and sanitation practices throughout the Middle eastern countries in various segment of society, to address future water and health security in Middle eastern countries.

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