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Review

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## Abstract

**Background**: Water-borne parasitic infections are caused by pathogenic parasites found in water. These parasites are often not well-monitored or reported, therefore, there is an underestimation of their prevalence.

**Aims**: We systemically reviewed the prevalence and epidemiology of water-borne diseases in the Middle East and North Africa (MENA) Region, which has a population of about 490 million people distributed over 20 independent countries.

**Methods**: Online scientific databases, mainly PubMed, ScienceDirect, Scopus, Google Scholar, and MEDLINE were searched for the main water-borne parasitic infections in MENA countries during 1990–2021.

**Results**: The main parasitic infections were cryptosporidiosis, amoebiasis, giardiasis, schistosomiasis, and toxocariasis. Cryptosporidiosis was the most frequently reported. Most of the published data were from Egypt, the country with the highest population in MENA.

**Conclusions**: Water-borne parasites are still endemic in many MENA countries, however, their

incidence has reduced dramatically due to the control and eradication programmes in countries that could afford such programmes, some with external support and funding.

Keywords: water-borne parasites; parasitic infections, MENA Region, distribution, frequency

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## Introduction

Drinking safe water contributes significantly to establishing the quality of human life (1). The holy Quran, in Surah Al-Anbiya (20:30), states: “We made from water every living thing”. This was emphasized by the Secretary-General of the United Nations, Ban Ki-moon, at the opening session of the 2014 High-Level Meeting on Sanitation and Water for All, when he said “Water is life” (2).

Water-borne parasitic infections are caused by pathogenic parasites in water. The infections can be acquired not only through the consumption of infected water but also through bathing, washing and eating food exposed to contaminated water (3,4). These parasites are important public health and economic problems throughout the world in general and the developing countries particularly. Although little is known about the burden and nature of water-borne diseases in most regions, they are directly related to environmental contamination and deterioration (4,5).

WHO estimates that more than 3.4 million people die as a result of water-related diseases every year, making it the leading cause of disease and death worldwide. Among these deaths, about

1.4 million are children (6). Poor sanitation and lack of clean, safe drinking water are the main causes of death among humans, ranking them above war, terrorism and weapons of mass destruction combined (2). Water-borne diseases such as diarrhoea, gastrointestinal disease and systematic illnesses (5,7,8) cause an estimated annual economic losses worldwide of about US$ 12 billion (9). In the developed countries, diarrhoeal outbreaks have commonly been attributed to protozoan parasites such as Cryptosporidium spp., Giardia spp. and Entamoeba spp. (3,10). Cryptosporidium and Giardia are the 2 most common causes of water-borne parasitic infections leading to diarrhoea (11,12).

This review focuses on the main causes of water-borne parasitic diseases in the Middle East and North Africa (MENA) Region. These include protozoal infections: amoebiasis (Entamoeba spp.), cryptosporidiosis (Cryptosporidium spp.) and giardiasis (Giardia spp.), and helminth infections: particularly schistosomiasis (Schistosoma spp.) and toxocariais (Toxocara spp.).

There are 20 independent countries in the MENA region: Algeria, Bahrain, Djibouti, Egypt, Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Palestine, Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates and Yemen, with around 490 million inhabitants (13). The country with the largest population (> 100 million) is Egypt, followed by the Islamic Republic of Iran with more than 84 million (14,15).

## Methods

The search was conducted during July and September 2021. Published articles on water-borne parasitic diseases in humans were obtained from the online scientific databases, mainly PubMed, ScienceDirect, Scopus, Google Scholar and MEDLINE. English language original articles, reviews, short research communication, books and certified online references were included. Data were gathered on the prevalence and geographical distribution of water-borne parasites (Cryptosporidium spp., Entamoeba spp., Giardia spp., Schistosoma spp. and Toxocara spp.) in the MENA Region from research work and prevalence data published during 1990–2021. Up-to-date data and research were collected as much as possible. A combination of search words was used, including the name of each water-borne parasite or the infection caused and the name of each of country.

Duplicate records were removed. Titles and abstracts were then screened and evaluated for their relevance to the scope of the review, and on the basis of the entire document. Full texts, including relevant citations, were retrieved where possible and evaluated. Data were also obtained from articles not captured in the literature database searches, and these were included if they confirmed the presence of water-borne parasites in a MENA country.

## Results

### Diagnosis

Diagnostic methods used in the reports were mainly microscopic examination of stool samples, and in some cases water samples. Serological methods and polymerase chain reaction (PCR)-based tools were used sometimes to confirm the diagnosis (3). Table 1 shows the number of articles reviewed for each water-borne parasite in the MENA countries.

### Cryptosporidiosis

The US CDC describes cryptosporidiosis as the leading etiologic pathogen of water-borne parasites (16). Globally, cryptosporidiosis has been ranked as the sixth most important food-borne parasitic infection of humans and domestic animals (17). The disease may occur without the parasite being detected, but the infected individual can be a carrier of the infection and transmit it to others (18).

Cryptosporidium spp. are protozoan parasites that have several different species, of which C. parvum is primarily responsible for clinical illnesses (18). The genus name, Cryptosporidium, was proposed for the first time by Tyzzer in 1910 for the protozoan parasite that was frequently detected in the gastric glands of laboratory mice. In 1976, 2 independent groups reported the first cases of human cryptosporidiosis (19).

This protozoan organism infects the epithelial cells of the stomach or intestine, causing diarrhoeal diseases (20,21). Several Cryptosporidium spp. can cause cryptosporidiosis (22), in which the oocysts have a ubiquitous presence in the environment (23).

From 2010 to 2017, water-borne Cryptosporidium spp. were responsible for causing the highest number of cases (24). Infection is associated mainly with the consumption of raw animal food and water-borne outbreaks (25,26). About 40 species of mammals are known to be reservoirs of the pathogens (27,28). The spherical shaped (and highly resistant) oocyst is the infective stage of this protozoan, which contains sporozoites (29,30). Although Cryptosporidium mainly causes mild symptoms such as diarrhoea, nausea, vomiting and fever, it can be life-threatening in immunocompromised people (31,32). In Middle Eastern countries, the most often affected sectors of the population were children under 5 years old, immunocompromised patients and people living in poverty. The prevalence among boys was greater than among girls (33).

Water-borne outbreaks caused by Cryptosporidium spp. have been documented all over the world in contaminated swimming pools, recreational and public water supplies (11), drinking water reservoirs and contaminated food (12). Cryptosporidiosis occurs in up to 7.0% of children diagnosed with diarrhoea in developed countries, and up to 12.0% in developing countries (21). The prevalence of cryptosporidiosis in the MENA countries is illustrated in Table 2 .

**Amoebiasis**

Amoebiasis ranks as the 3rd leading parasitic cause of death worldwide (24,35). Although it is a public health problem that occurs throughout the world, affecting tens to hundreds of millions of people annually, it is more common in developing countries (36,37).

Amoebiasis is caused by Entamoeba histolytica, a pathogenic amoeba associated with intestinal and extra-intestinal infections. Other morphologically identical Entamoeba spp. are generally not associated with disease (38). The trophozoite form of this protozoan parasite was described by Lösch in 1875 from organisms in a faecal sample taken from a patient with chronic dysentery (39). In Saudi Arabia, E. histolytica was the most common cause of gastroenteritis and diarrhoea, reaching a prevalence of about 20.0% (36). Neither age nor sex have been considered significant risk factors for amoebiasis (37). The prevalence of amoebiasis in some MENA countries is illustrated in Table 3 .

**Giardiasis**

The first report describing the causative parasite of this infection was by Lambl in 1859 (39). In developing countries, Giardia is one of the most prevalent enteric pathogens to infect children under 10 years old, with a prevalence of 15.0–20.0% in children (18). It is considered the most common protozoan parasite infecting the human intestine worldwide (10,18).

Giardia lamblia (also called G. duodenalis or G. intestinalis) is believed to be the most frequent cause of diarrhoeal disease and the most frequent intestinal parasite in humans worldwide (18,40). It accounts for more than 250 million symptomatic human infections annually, with the less-developed countries being the most afflicted (41). The disease is included in the WHO neglected diseases initiative because of its burden and its association with poverty (11). Giardiasis has been associated with several water- and food-borne outbreaks worldwide (3,42). The parasite is transmitted through the faecal–oral route, frequently through ingestion of contaminated water and food (43).

In a 2021 study, the prevalence of giardiasis in Middle Eastern countries was higher in boys

than in girls; the infection was also more prevalent in children under 5 years old and in the older population (33). Prevalence commonly ranges from 20.0% to 30.0% in developing countries and 3.0% to 7.0% in developed countries (44). The prevalence of giardiasis in the MENA countries is illustrated in Table 4 .

**Schistosomiasis**

Schistosomiasis represents one of the major communicable diseases of public health importance and has socioeconomic significance in the Eastern Mediterranean Region (45). It has been estimated that 300 million people worldwide are affected (12,46). In the MENA Region alone, it has been reported that 12.7 million individuals are infected (47). The link between poverty and high prevalence is evident, with approximately 10 million infected individuals clustered in Egypt and Yemen (47).

Schistosomiasis is caused by infection with parasitic blood flukes. It is also known as bilharziasis after Theodor Bilharz, who first identified the parasite in 1852 (48). The infection is recognized as a neglected tropical disease that is caused by several species of the genus Schistosoma, particularly S. mansoni, S. haematobium, or S. japonicum (49–51).

Schistosoma spp. live in certain types of freshwater snails. The infectious form of the parasite, known as cercariae, emerge from the snail into the water, and the infection occurs when the skin comes in contact with contaminated fresh water (50,51). In the body, the larvae develop into adult schistosomes. Adult worms live in the blood vessels, where the females release their eggs. Some of the eggs are passed out of the body through faeces or urine to continue the lifecycle of the parasite. Others become trapped in body tissues, causing immune reactions and progressive damage to organs (49). Most affected are areas with poor sanitation and the school-age children living in those areas, who are often most at risk because they tend to spend time swimming or bathing in water containing infectious cercariae (50,51).

It is estimated that at least 90.0% of those requiring treatment for schistosomiasis live in Africa (52). Schistosomiasis control programmes have been implemented in several MENA countries, including Egypt, Islamic Republic of Iran, Jordan, Morocco, Oman, Saudi Arabia, Sudan, Tunisia and Yemen (52).

Schistosomiasis was endemic in ancient Egypt: the causative agent has been identified in mummies 3000, 4000 and 5000 years old (53). Before the National Schistosomiasis Control Programme was initiated in the Nile Delta, the prevalence of schistosomiasis reached more than

30.0% (53). By the end of 2010, only 20 villages had a prevalence ranging from 3.5% to 10.0% (49). The number of cases in Egypt was reported to be about 7.2 million in 2012 (54). In the same report, the number of cases in Yemen, Algeria and Libya was 2.9 million, 2.3 million, and 0.3 million, respectively (54). In the White Nile river basin in Sudan, one in every 2 schoolchildren reportedly tested positive for schistosomiasis (55).

Previously, the prevalence of schistosomiasis in some parts of the Islamic Republic of Iran was greater than 90.0%, but in recent years, and after the implementation of appropriate measures through a national programme for schistosomiasis control, this infection has been eliminated from the country (45,56). Schistosomiasis has also been eliminated from Lebanon, Oman and Tunisia, and the transmission has been greatly reduced in Egypt, Iraq, Jordan, Morocco, Saudi Arabia and Syria (47). The prevalence of schistosomiasis in MENA countries is illustrated in Table 5.

### Toxocariasis

Toxocariasis is a neglected parasitic infection; it is reported worldwide but the prevalence is underestimated (57,58). Toxocariasis has been reported as the second most common helminth infection in developed countries (59,60).

Among a total of 21 species within the genus Toxocara, 2 are of significant public health concern, T. canis and T. cati, which are highly prevalent nematodes infections of dogs and cats (61). Toxocara eggs are shed to the environment through the faeces of infected animals. Within 2–4 weeks, the larvae develop inside the eggs and become infectious (62). The eggs themselves are very resistant to various environmental conditions due to the strong protective layer surrounding them, allowing them to survive in the environment for months or even years (62,63). Humans can be infected accidentally by ingesting Toxocara eggs in raw contaminated food and polluted drinking water. After ingestion, the larvae hatch in the small intestine and penetrate the gut wall; they are then transported to the liver and lungs via the blood circulation (61). Although there is no information on the specific sources of human infection with toxocariasis, the main problem indicated in many countries was the presence of stray dogs and cats, which may serve as uncontrolled sources of toxocariasis (64). The prevalence of toxocariasis in some MENA countries is illustrated in Table 6.

## Discussion

Human intestinal protozoan and helminth infections are still major public health problems in many parts of the world (6,65). There is an important connection between social and economic conditions and the rate of water-borne infections (33). Lack of awareness, poor personal

hygiene, poor sanitation services, poverty and indiscriminate eating habits are determining factors for these infections (33).

The problem with water in the MENA Region is the inadequate supply of potable water. Taking into consideration the population growth, poorly maintained infrastructure and the lack of appropriate sanitary facilities, conditions are eminently suitable for the parasites to live, grow and continue to pose a threat to human health (5,66).

There is also the clear role of certain animals in the transmission of some of these diseases. High rates of infection were clearly related to contamination of tap water and contact with animals in urban areas (67). Direct transmission of infections from some animals to humans is possible.

Several other factors can contribute to the spread of water-borne diseases, including heavy rains, agricultural residues which transfer the parasites to water surface from the soil (32), and climate change (68). Water-borne protozoal diseases, including cryptosporidiosis and giardiasis, are mainly associated with seasonality, daily maximum temperatures and precipitation (68).

In some MENA countries, especially those around the Persian Gulf, immigrants comprise the majority of the workforce (reaching 80.0%). Many of these immigrants originated from countries endemic for these parasitic infections, including Bangladesh, India and Pakistan (12). Although these parasites are considered the main water-borne parasites in the MENA Region, other parasites have been reported in some countries, such as in the Islamic Republic of Iran (69,70). The same can be said for Cryptosporidium spp.; even though it was the main water-borne parasite found in the MENA Region as a whole, it was quite rare in some investigations, whereas Entamoeba spp. and Giardia spp. were ubiquitous (69).

It should be noted that the sensitivity and the specificity of the detection methods used may have a major influence on the mitigation and prevention of water-borne diseases, and can affect the outcome of water safety and hygiene (5). Some detection methods had low sensitivity and specificity: this may result in false negatives. For some methods, there may be cross-reaction with other parasites, which will certainly affect the recorded prevalence rate of each parasite studied. The specificity, sensitivity and reproducibility of results are the most important requirements for a reliable analysis (71). Diagnosis and identification of the parasites was usually accomplished using staining methods, occasionally confirmed using another sensitive method such as serology or PCR to give a definitive diagnosis (23,69,70).

This review had some limitations. One was the few number of studies published on many water-borne parasites in the MENA Region and the limited

information on the burden and distribution of the majority of the diseases. Additionally, there was a lack of coordination in the published investigations in describing the wide-ranging disease patterns of regional importance of these diseases.

## Conclusion

In order to control and prevent water-borne parasitic diseases, drinking water sources and sanitation facilities must be improved. This includes proper treatment of drinking water and proper wastewater treatment. The principles of sanitation and hygiene should be introduced and supported, as well as the propagation and promotion of hygiene programmes in communities, schools and universities.

Water-borne diseases are still endemic in many parts of the MENA Region, which calls for particular attention to be paid to control and prevention measures. The shortage of financial resources in the developing countries is a major factor contributing to the high incidence of these diseases, which also can have a huge negative economic influence, especially in low-income countries.

Many countries in the MENA Region have already implemented eradication and control programmes and have succeeded in reducing and preventing a number of water-borne diseases.

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**Competing interests**: None declared.

## Analyse systématique de la fréquence et de la distribution géographique des parasites d'origine hydrique au Moyen-Orient et en Afrique du Nord

## Résumé

**Contexte** : Les infections parasitaires d'origine hydrique sont causées par des parasites pathogènes présents dans l'eau. Ces parasites ne font souvent pas l'objet d'un suivi adéquat ou ne sont pas signalés et leur prévalence est donc sous-estimée.

**Objectifs** : Nous avons analysé de manière systématique la prévalence et l'épidémiologie des maladies à transmission hydrique dans la Région Moyen-Orient et Afrique du Nord, qui compte environ 490 millions d'habitants répartis dans 20 pays indépendants.

**Méthodes** : Des bases de données scientifiques en ligne, principalement PubMed, ScienceDirect, Scopus, Google Scholar et MEDLINE, ont été consultées pour déterminer les principales infections parasitaires d'origine hydrique dans les pays de cette Région entre 1990 et 2021.

**Résultats** : Les principales infections parasitaires étaient les suivantes : cryptosporidiose, amibiase, giardiase, schistosomiase et toxocarose. La cryptosporidiose était la plus fréquemment signalée. La plupart des données publiées provenaient d'Égypte, le pays le plus peuplé du Moyen-Orient et d'Afrique du Nord.

**Conclusions** : Les parasites d'origine hydrique sont toujours endémiques dans de nombreux pays de la Région Moyen-Orient et Afrique du Nord. Cependant, leur incidence a considérablement diminué grâce aux programmes de lutte et d'éradication mis en place dans les pays qui en ont les moyens, dont certains bénéficient d'un soutien et d'un financement extérieurs.

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