Review article

A review of worldwide distribution of Acanthamoeba from drinking water sources

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Abstract

Acanthamoeba species are free-living amebae (FLA) that inhabit a diversified environmental source such as air, soil, and water. These FLA can also act as an opportunistic pathogen to cause infections in both healthy and immunocompromised individuals, including granulomatous encephalitis, keratitis, cutaneous lesions, and sinusitis. Thus, information's about Acanthamoeba distribution in environmental samples is very important in parasitology research. Therefore, this review aimed to analyze the incidences of Acanthamoeba in different types of water sources that are open to public accesses every day of life. Besides, this review endorses safety measures to avoid Acanthamoeba contamination in water.

Keywords:
acanthamoeba, trophozoites, cysts, drinking water, granulomatous amebic encephalitis

الملخص

خلفية:
تتبع انواع الاكانثاميبا جنس الطلائعيات وهي من الاميبات الحرة وتتواجد في مصادر بيئية متنوعة مثل الهواء والتربة والمياه. يمكن أن تعمل هذه الانواع أيضًا كممرضات انتهازية لإحداث التهابات في كل من الأفراد الأصحاء والذين يعانون من نقص المناعة، بما في ذلك التهاب الدماغ الحبيبي والتهاب القرنية والامراض الجلدية والتهاب الجيوب الأنفية. وبالتالي، تعد المعلومات المتعلقة بتواجد هذه الانواع في العينات البيئية مهمة جدًا في أبحاث الطفيليات. لذلك، تهدف هذه المراجعة البحثية إلى تحليل تواجد مثل هذه الأنواع المختلفة في مصادر المياه المتاحة للبشر والتي تستخدم كل يوم في حياتنا اليومية. بالإضافة إلى أن هذه المراجعة البحثية تدعم تدابير السلامة لتجنب تلوث الماء بأنواع الاكانثاميبا.

كلمات مفتاحية:
الاكانثاميبا ، التروفوزويت، الطور المتكيس ، مياه الشرب ، التهاب الدماغ الأميبي الحبيبي.

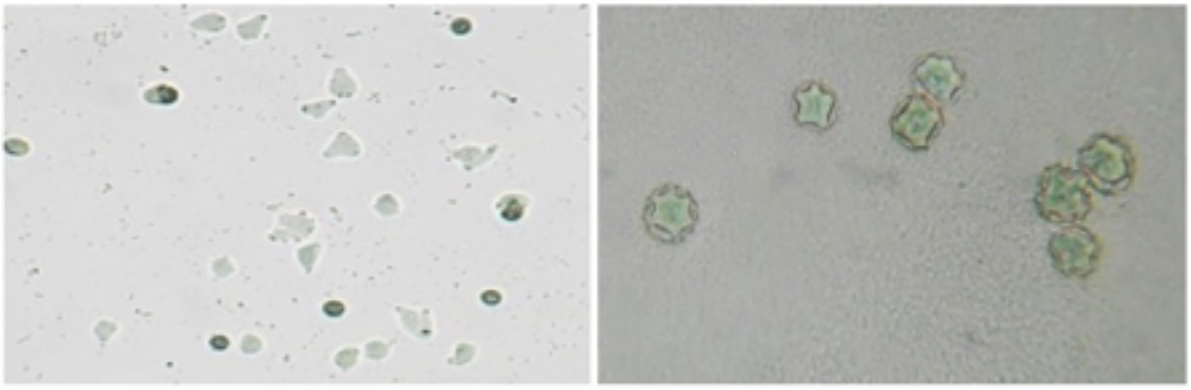
Introduction

Microbial contamination in water sources is one of the significant problems concerning the proper sourcing of water reservoirs used for drinking water supply, recreational facilities, and harvesting seafood due to possible contamination by pathogenic bacteria, protozoa, and viruses. In the past three decades, there had been intense contamination of drinking water by pathogenic parasites, transferred by water, which is causing many diseases in humans [1]. Free-living amoebae (FLA) are one of the protozoa most common habitants in the environment, such as water, sewage water, air, soil, dust, sewage water, and sediments [2]. The genera of free-living amoeba include Naegleria fowleri, Acanthamoeba spp, Balamuthia mandrillari, Sappinia diploidea, which cause a dangerous infection in human [3].

Even though there are many parasites in water samples, Acanthamoeba is considered to be the most important protozoan pathogen because of its opportunistic nature. This opportunistic parasite can be found in diversified natural environments such as dust, soil, ambient air, potable water sources, sea, and recreational facilities (home aquaria, swimming pools) sources [2,5]. The bacteria-phagocytosing protozoa has been proved as one of clinical free-living amoeba not only present in the natural soil and water bodies, and it is also found in the man-made environment as a

secondary decomposer. It was found that the abundance of Acanthamoeba is more common in water sources such as water systems, rivers, and swimming pools to which humans are frequently exposed [6]. Acanthamoeba has adopted to withstand diverse environmental conditions by switching their phenotype (infective trophozoites form and resistant cyst form) (Figure 1) [7]. The infection occurs to humans by inhalation of contaminated water or dust particles containing trophozoite and cyst. The infective trophozoites can infiltrate to the respiratory tract and cause nasopharyngeal infections and also skin infections. Particularly some pathogenic strains cause serious diseases in humans, such as keratitis in the eye and granulomatous amebic encephalitis

Figure 1. Acanthamoebae cysts isolated from water samples



[8, 9]. The existence of Acanthamoeba in aquatic sources could be a dual danger because some of these are pathogenic and could also harbor pathogenic microorganisms such as Legionella, Pseudomonas, and Helicobacter [10]. Thus, parasitologist must know the distribution of Acanthamoeba in water samples and their control measures. Hence, the aim of this review is to analyze the distribution of Acanthamoeba incidence, especially in drinking water samples reported worldwide.

History of Acanthamoeba

Acanthamoeba is a unicellular parasite with bearing centrosome, in Order of Acanthopodida, Class Centramoebia, Phylum Discosea, Amoebozoa clade in Amorphea domain of Eukaryotic organisms. In Greek, expressing the term "Acanth" is 'spike' which represents noticeable sub-pseudopodia while "amoeba" implies alteration, which represents change their shapes often. Acanthamoeba spp. Was first documented as a microbial culture contaminant along with Cryptococcus pararoseus by Castellani in 1930. Initially, the organism was named Hartmannella castellanii, and subsequently, a year later, it was renamed as Acanthamoeba spp. As of its irregular ectocyst appearance with double-wall nature, which is distinct from Hartmannella spp (round & smooth cyst wall) [11].

Acanthamoeba – adaptations

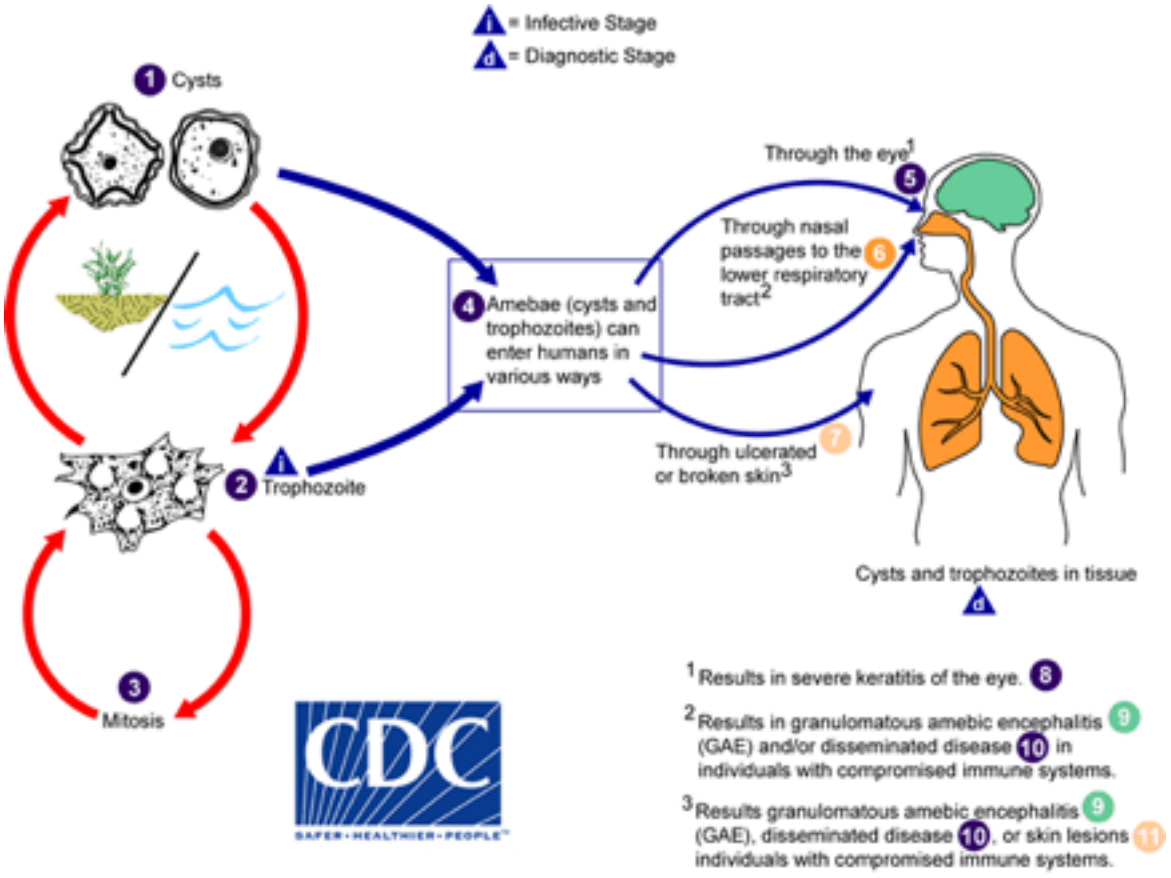
Acanthamoeba spp. Exhibits two different forms of life cycle (Figure 2). In rich nutrient conditions, in growing stat is in the form of trophozoites, and later in the dormant stage, it changed into cyst form. The size of Trophozoite is 25 to 40 μm, and it is an infectious stage with amoeboid motility. The size of this FLA's cyst roughly 13 to 20 μm is a dormant stage against tough environments such as high temperature and pH imbalance, malnutrition, or the presence of anti-amoebic agents [12]. Anwar et al. analyzed the cell wall biochemical characteristics and found that one-third of the

strength of the cyst wall might come from a polymer of glycosidic linkages between saccharides while another 2/3 are protein and other components, respectively [13]. Various researchers reported Acanthamoebae adaptations, and it acts as a possible source or vector of human-pathogenic bacteria, fungi, or viruses while endosymbiont and Acanthamoeba-resistant organisms also are identified [12,14]. Lately Corsaro et al. described more than 25 species were documented in NCBI taxonomy database, and 20 genotypes were published, which T4 is a major genotype associated with human infections [15].

Epidemiology of Acanthamoeba in drinking water samples

Acanthamoeba species can transmit through waterborne, especially acquired through forceful inhalation of surface waters from poorly maintained swimming pools and other aquatic sources. Even though there are many reports available in various water sources worldwide, this review concentrates only on drinking water sources. Acanthamoeba, a protozoan parasite, is most found in soil and water environments throughout the world [2]. These FLVs have been isolated from a variety of sources, including water sources from the Antarctic [16], packaged drinking water, swimming pools [17], and even from dust in the atmosphere [18]. Prevalence of Acanthamoeba in various types

Figure 2. Life cycle of Acanthamoeba and waterborne infections
(Image credit: Centers for Disease Control and Prevention, Atlanta, Online access from : https://www.cdc.gov/parasites/images/acanthamoeba/Acanthamoeba_LifeCycle.gif)



of water sources reported worldwide listed in Table 1. The rate of prevalence varying based on region-wise, sample size, and sources. Go´rnik and Kuz´na-Grygiel from Poland found that at least 50% of the swimming pools contaminated with Acanthamoeba. This high frequency being recognized not only to the amoebae's resistance to chlorination but also transfer by humans. In studies carried out on various water sources in Jamaica, amoebae with pathogenic potential were detected in 26.4%, 36.1%, and 49.6% of the samples of river water, tap water, and seawater, respectively, clearly representing a health risk [19]. Recently Tanveer et al. (2015) reported that pathogenic Acanthamoeba predominantly

Table 1: Prevalence of Acanthamoeba in different types of water in worldwide

Country	Year	Type of water source	Number of samples processed	Prevalence of *Acanthamoeba*	Authors
USA, Oklahoma	1995	Pond, running water	2016	63%	John and Howard [19]
Saudi Arabia	1998	River water	40	36.7%	Al-Herrawy *et al*., [20]
Thailand	2001	Water samples	95	18.9	Nacapunchai et al. [21]
USA	2003	James river water	330	7%	Ettinger *et al*.,[6]
Malaysia	2003 2010	Domestic tap water Swimming pool	42 840	2.4% 46.2%	Anisah et al. [22] Init et al. [23]
Poland	2004	Swimming pools	NA	59.7%	Gronik *et al*., [24]
Jamaica	2005	Tap water & sea water	2004	43.3%	Lorenzo-Moraes *et al*. [25]
Brazil, Porto alegre	2009	Swimming pools	13	20%	Caumo *et al*., [17]
Iran	2010	Cold and warm water	94	45%	Bagheri et al., [26]
Brazil, Rio Grande do sul	2011	Tap water	136	9.5%	Winck *et al*.,[27]
Turkey	2012	Fountains, hot springs, wells	250	4.4%	Ozçelik et al., [28]
Pakistan	2013	Drinking water	35	92%	Tanveer *et al*., [5]
Turkey	2013	Tap water	150	22%	Coskun *et al*.,[29]
Egypt	2013 2014	Nile river Swimming pools	NA NA	56 % 60%	Al-Herrawy *et al*., [30] Al-Herrawy *et al*., [31]
Iran	2014	Environmental water Tap water	34 59	73.5 45.16	Mohammadi Manesh et al., [32]
The Philippines	2014	Tap water	3	33.3	Onichandran et al. [33]
India	2015	Tap water	100	14%	Khurana et al., [34]
Uganda	2016	Tap water	84	42.9	Sente et al [35]
Pakistan	2017	Drinking water supplies	20	35%	Yousuf et al [36]
Saudi Arabia	2018	Drinking water, fountains, well water	57	17.5%	Vijayakumar [37]
Malaysia	2019	Tap water	181	24.9%	Gabriel et al. [38]

NA – Not available

present in various water sources in Pakistan and pointed that Acanthamoeba as a potential transmission vehicle of pathogenic bacteria in different environmental sources and causes an additional threat to humans [20]. There are various authors published many research studies in the distribution of Acanthamoeba in water samples and their pathogenicity [21-39]. The prevalence of Acanthamoeba in water samples varies worldwide, in the literature search noticed in the range of 2.4% to 90%. The variation of percentage of Acanthamoeba is due to the sampling method, culture processing, and changes in ecological factors.

Very recently, Bunsuwansakul et al. documented a review on the prevalence of pathogenic Acanthamoeba among the Southeast Asian Nations and recognized a different range of certain supporting determinants such as distribution, the demographic profile of the patients, potential source of the parasite, method of transmission and treatment [40].

Effects of Acanthamoeba contamination in drinking water

Acanthamoeba has adopted to withstand diverse environmental conditions by switching their phenotypes, and it can grow in the water at various temperature and also act as a carrier for different microorganisms to humans, working as a medium for the circulation of pathogens between the environment and humans (Huws et al., 2008). Dry Acanthamoeba cysts can persist to many years and are isolated frequently from natural water sources, swimming pools, soil, sewage, freshwater fish, brackish water, ocean sediments, dust, air, and even packaged mineral water, or contact lens cleaning and soaking solutions. Therefore the public can easily access the Acanthamoebic infections by accidentally and forcibly inhaling water.

The major infection by Acanthamoebic cysts contaminated water is corneal ulcer/keratitis. Acanthamoeba keratitis recognized as a vision-threatening corneal infection and can occur in healthy persons but most often reported in contact lens wearers [41]. These infections are repeatedly a result of direct eye exposure to contaminated water or solutions such as contact lens soaking and cleaning fluids. However, commensal bacteria present on the eyelids, the conjunctiva may have an additional role in the pathogenesis of Acanthamoeba corneal infections. Kilvington et al. investigated and proved that domestic tap water could be a source for Acanthamoeba, causing keratitis. The study revealed that the domestic tap water outlets of almost 89% (24 of 27) of patient homes, of which eight samples contained Acanthamoeba, indicated that this is a significant source of these organisms [42]. Another study by Vesaluoma and his associates analyzed the swimming pool water sample in Finland revealed the high possibility of amoebic and bacterial keratitis linked with swimming or bathing in properly cleaned public pools. Subsequently, they recommend that the contact lens wearers should not swim or bath in public pools with contact lenses, which may increase the chances chance of getting Acanthamoeba keratitis [43]. Additionally, Acanthamoeba may occur as a commensal in the nasopharynx of apparently healthy normal individuals [42]. The infiltration of the amoebae into the central nervous system (CNS) is possibly by hematogenous spread from a primary focus in the lower respiratory tract, skin, or open wounds, but the amoebic trophozoites or cysts can reach the CNS directly through the olfactory neuroepithelium.

Regarding the brain infection, A. polyphaga is the first species that causes granulomatous amoebic encephalitis, which leads to hemorrhagic and necrotic encephalitis that is generally seen only in debilitated or immunodeficient persons. Early symptoms include

drowsiness, intense headaches, nausea, vomiting, fevers, and coma. Additionally, cutaneous acanthamoebiasis is a Cutaneous infection caused by Acanthamoeba and is most common in patients with AIDS, with or without CNS involvement [44].

Pathogenic Species

Currently, about 25 species of Acanthamoeba have been described, and eight of them frequently linked with eye infections, the most prevalent Acanthamoeba genotype from clinical and environmental samples are the T4 genotype [45]. As mentioned before, Acanthamoeba has mostly been linked with granulomatous amoebic encephalitis (GAE), amoebic keratitis (AK), cutaneous lesions, and sinusitis in people. Eight species of Acanthamoeba (A. castellanii, A. polyphaga, A. culbertsoni, A. hatchetti, A. rhysodes, A. lugdunensis, A. quina and A. griffini) have been previously reported by researchers as causative agents in Acanthamoeba keratitis which is very common in individuals using dirty contact lenses as well as those washing and bathing with contaminated water. [41,42,46]

Control Measures

The most influencing factors that lower the consequences of Acanthamoeba contamination and infections to public health are proper hygiene practices, availability of sufficient good quality water, appropriate sanitary conditions, and suitable disposal of human and animal excreta.

Various authors suggested effective control measures of 'Acanthamoeba' infection by water exposure which are collectively listed below

1. Good personal hygiene: As per CDC guidelines, people can protect themselves against waterborne Acanthamoebic infections by following proper personal hygiene, which includes frequent hand-washing prior cooking and consuming food, after using the restroom, after changing diapers, and before and after attending to someone who is sick [47].

2. Proper storage and use of water: Due to the ubiquitous nature of Acanthamoeba, water can be easily polluted by users at the household level through inappropriate use. Therefore, the water tanks shoud be kept clean and covered; it is also necessary to cleanse and disinfect them routinely [48,49].

3. Avoid long term storage water: Water stored in the water tanks for household usage should not be stored for a long time, and also proper cleaning and disinfection should be done for each refilling and avoid exposure/touching of hand to the water [50].

4. Public awareness: According to the US EPA Office of groundwater and drinking water, the public should be aware of how necessary it is to protect the source of water supply from the contamination of pathogenic protozoa. They should also accept liability for the safety of the water they utilize. It is highly essential to dispose of human waste matters and sewage materials away from any sources of water supply and construction of lavatories according to the requirements to avoid any possible contamination [51].

5. Filtering water by a water purification system is one of the important aspects of hygiene and plays an significant role in preventing the entry of Acanthmoeba at a household level. If people do not afford purification system, boiling is the most reliable way of getting water that is free from microbial pollution. The boiling of drinking water is one of the commonest methods to avoid microbial infections in many developed countries. Most importantly, after boiling, the water must be stored in a clean, germ-free container with a tight cover, and refrigerated [52,53].

6. The ophthalmologist should instruct their patients to follow appropriate hygiene practices while using and handling contact lenses to

avoid Acanthamoeba keratitis [54].

7. While Acanthamoebic trophozoites are considered to be susceptible to many chemical agents, however the cysts shown resistant to many chemicals. It has been documented in several research studies that the cysts exhibited tolerance to quaternary ammonium compounds, biguanides, chlorine & chlorine dioxide, and hydrogen peroxide. Only a few studies documented the strategies to control Acanthamoebic cysts by effective disinfection and investigated their virulence factors [55].

Conclusion

The literature review indicates that there is a limited number of epidemiological surveys of Acanthamoeba infections that occurred worldwide, especially the local incidences from water sources. However, based on the available information, there is a steady increase in the number of infections caused by Acanthamoeba. Therefore, the local epidemiological survey on the occurrence of Acanthamoeba in drinking and public access water sources worldwide is a need of the hour.

Key Point box

• Acanthamoeba is considered important because it is an opportunistic protozoan pathogen, is ubiquitous in nature
• Acanthamoeba cysts can withstand several years in water and adapt both trophozoites and cyst in extensive environmental conditions
• Acanthamoeba is the causative agents of granulomatous amoebic encephalitis, a fatal disease of the central nervous system, and amoebic keratitis, a painful sight-threatening disease of the eyes.
• This review highlighted the occurrences of Acanthamoeba in various aquatic environments in particular drinking water sources worldwide.
• This review recommended the control measures of Acanthamoebic infections by contaminated water.

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