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Summer Recreational Water Tourism: A Deadly Human Encounter with *Naegleria fowleri*

Said M Ladki* and Jad Abdul Samad

Adnan Kassar School of Business, Lebanese American University, Lebanon

Abstract

This paper reports about a pathogenic free-living organism that's affecting the quality of recreational waters in the three states. *Naegleria fowleri*, multiplies in fresh water during warm seasons which coincides with peak outdoor tourism activities. The deadly organism is acquired while swimming, during which it easily enters the nostrils and reaches the brain. If the recreational water supply of a destination were to be compromised, the whole tourism cycle may be at risk. Swimming in freshwater and untreated pools increases the threat. There are no established standards for controlling the occurrence of *Naegleria fowleri* in fresh water. The ideal method of preventing infection is by refraining from engaging in recreational activities in fresh bodies of water during summer months.

Keywords: Tourism; Recreation; Fresh water; Deadly disease; *Naegleria fowleri*

Introduction

This paper reports about a pathogenic free-living organism that's affecting the quality of recreational waters in three states. Domestic and international travelers consider lakes, hot springs, spas, and swimming pools as escape places and important stress alleviators. However, environmental changes and extreme temperatures during hot summer months are compromising recreational water qualities. Though Texas enjoys a healthy tourism industry [1], the death of several vacationers while enjoying water related tourism activities has generated some uncertainties about the safety of recreational waters in the state [2].

"Swimming with death" or "Brain eating creatures" may possibly explain the current situation in Texas. The tragic story of a 14 year old Houston teen sheds light on a new threat affecting Texas tourism industry. Michael John Riley, who is an athletic Houston teen died after swimming in Sam Houston Park. Michael died of "Primary Amoebic Meningoencephalitis (PAM)", a life-threatening infection of the brain [3]. *Naegleria fowleri,* which is a free-living pathogenic amoeba protist, is the main cause of PAM [4]. According to the Center of Disease Control, more than half of PAM cases have occurred in Florida and Texas [5].

Being a thermophylic single-celled microbe, *Naegleria fowleri*, multiplies in fresh water during the warm season of the year which coincides with peak outdoor tourism activities [6].The aggressiveness of this organism is in its ease of transmission. It is acquired while swimming, during which it easily enters the nostrils and reaches the brain. Once the pathogen is in the brain, it causes PAM. PAM is a fatal brain infection whereby the *Naegleria fowleri* organisms consume the brain cells leading to rapid deterioration in the mental status of the victim within three days and death usually occurs in seven after the infection [7].

Despite advances in current antimicrobial therapy, there is limited availability of resilient antimicrobial therapy capable of combating *Naegleria fowleri* inside the brain tissue. The lack of resiliency makes the disease generally fatal. As a matter of fact; there were four cases where individuals have survived the infection in North America. The first case was reported in the US in 1978 [8], the second in Mexico in 2003 [9]. The remaining two cases were reported in 2013 in the US [2]. To alleviate brain swelling, the medication "Amphotericin B" continues to be PAM's most used treatment. A breast cancer medication "Miltefosine" is being investigated as a potential PAM treatment because it has saved the lives of two patients [10]. The two US PAM surviving individuals received Miltefosine in addition to other medications [2]. Miltefosine appears to be a promising therapy for killing *Naegleria fowleri* when used with other antibiotics.

If the recreational water supply of a destination were to be compromised, the whole tourism cycle may be at risk. Tourism, travelers and families may be at higher risk if they were to swim in *Naegleria fowleri* infected waters. Consequently, states that lack proper recreational water monitoring systems may be at increased risk of losing their tourists' base. Since tourism is a family engaging activity, no state desires to be perceived as the place where family members have lost their lives while on vacation at one of the famous lakes, rivers or swimming pools of commonly known resorts.

Literature Review

Destination safety and hygiene continue to be important discriminate variables when selecting one destination over the other. Tourism becomes sustainable if the tourist and destination enjoy good health [1]. The close relationship between tourism and health dates back to the Roman times. In Europe, water resorts were developed after the utilization of pools and health clubs. Water, other than its daily uses and its healing abilities, is an indispensable source of life. Since ancient epochs, Balneotherapy which is the use of natural and thermal mineral water to treat diseases had been one of the earliest curative therapies. Ancient Greeks believed in the supernatural therapeutic ability of hot springs and regarded them as the dwelling places of Gods [11]. Resorts that have maintained high level of health standards have attracted many visitors and became sustainable [7].

***Corresponding author:** Said M Ladki, Adnan Kassar School of Business, Lebanese American University, Lebanon, Tel: +961 1 786 456; E-mail: sladki@lau.edu.lb

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Primary identification of *Naegleria fowleri* dates back to 1965 in Australia when it was first defined by Fowler and Carter [12].A year later, Florida had witnessed three fatal cases. Whether in Australia or Florida, all cases were acquired by swimmers. Additionally, warm and fresh water of ponds, lakes, pools, streams and hot springs had been the culprit because they shelter *Naegleria fowleri*. Since Amoeba is a free living organism, it can be present in clean or contaminated waters. *Naegleria fowleri* has not only infected United States tourists but also tourists who have visited aquatic environments in Japan, Italy, Thailand, New Zealand, Belgium England, Californian hot springs and the United States freshwater lakes [7].To better understand the spread of *Naegleria fowleri*, one has to first understand the biology of this single celled microbe, its pathogenic mechanism in addition to the disease it causes which is primary amoebic meningoencephalitis. *Naegleria fowleri* is a species of phylum Percolozoa. The genus *Naegleria* consists of more than 40 species but only *Naegleria fowleri* species infects humans. It is a thermophylic free living single celled microbe and most active in temperatures that exceed 86˚F and can tolerate a temperature of over 113˚F [6].As a result, the proliferation of the amoeba reaches its peak during the summer season when local residents and tourists seek recreational water activities.

Naegleria fowleri nourishes from fresh water bacteria.and.debris. The amoeba exists in three forms: the trophozoite form; the flagellate form; and the cyst form. The sole infective stage is the amoeboid trophozoite which is ten to thirty five micrometers in length with a single nucleus and a granular appearance. The optimum growth of *trophozoite* occurs at a temperature 107.6˚F. Upon changes in environmental conditions such as change in PH or diminished food supply, the trophozoite can change, within few hours, into a non-feeding, temporary flagellated stage and revert back to the trophozoite stage when the stressful conditions are alleviated. For the trophozoites to survive cold environments, it evolves into a spherical shape hard cyst that ranges from seven to fifteen micrometers in diameter. The cyst form is more resistant than the trophozoite form to extreme environment conditions. The cyst form can survive and stabilize at a temperature of 149 ˚F. The trophozoites are rapidly killed in cold environment while the cyst can survive for months at above freezing cold temperature. That's why; it is difficult to control *Naegleria fowleri* availability in fresh waters of rivers and lakes [13]. It is worth mentioning that the trophozoite infective form is seen in the brain tissue and cerebrospinal fluid. Flagellate forms of the protist are found occasionally in the cerebrospinal fluid while Cysts are not found in the brain tissue [10].

Naegleria fowleri is normally found in the body of healthy organisms but PAM occurs in children and adults after their exposure to the amoeba in untreated freshwater of resort pools, lakes, hot springs and rivers. The amoebacan also grow in public and private water pipes and tanks when there is lack of proper disinfectants (like chlorine or chloramine) and thus enter the human host upon nasal rinsing [14]. Additionally, *Naegleria fowleri*can also be found in soil, untreated water supplies for domestic use and hot water ejections from electric power generating plants. This life threatening amoeba survives best at higher temperatures up to 45˚C rendering water heaters as its suitable host [6].

One simply can't get *Naegleria fowleri* by drinking amoeba contaminated waters. The amoeba penetrates the human body through the nasal cavity once a person swims, scubadives, or engages in any other activity in infected waters. Once the amoeba enters the disrupted nasal mucosa, it invades the olfactory membrane then rises to the olfactory nerve until it reaches the victim's olfactory bulb of the subarachnoid space which is highly vascularized and thus aids in the dissemination of the trophozoites to other parts of the brain [6]. Once in the nervous system, it causes a severe hemorrhagic and necrotizing inflammation called primary amoebic meningoencephalitis. The symptoms of PAM start by a high grade fever, headache, nausea and vomiting. Thereafter, the victim experiences rapid progression to seizures, hallucination, comas and death within 3-7 days [7].

The department of health in US Virginia Islands reported the first isolated case of PAM related human loss in November 2012 [15]. It is the case of a 47 year old male whose only exposure to fresh water was tap water frequent use for nasal rinsing as part of daily hygiene. One month later, USVI department of health and Center for Disease Control conducted an investigation to identify the source of *Naegleria fowleri* in the victims' house. Water samples tested from the water heater and shower nozzle were positive for *Naegleria fowleri* suggesting that the amoeba has infected the victim's plumbing system and entered the victim's body through nasal rinsing. Nasal rinsing with infected water is a risk factor for contracting *Naegleria fowleri*, however, the most common PAM infections occur in victims of infected recreational waters [16].

Global warming and increased recreational water's temperature are aggravating the spread of the disease [4]. PAM cases were usually restricted to warm fresh waters of countries and states during the hot summer season. The increase in temperature due to global warming effect is creating a suitable environment for the multiplication of the amoeba and therefore creating more densities in water used for recreational and other purposes. Few cases have been reported beyond the southern belt states and as far north as Minnesota suggesting a possible change in the epidemiology of *Naegleria fowleri* [7]. Additionally, climate change is causing Amoeba to spread to new countries such as Pakistan where no previous exposures or cases were reported before [4,17].

Methods

This paper reports the results of two studies conducted to assess the recreational water qualities in the states of Texas, Virginia and Florida.

Of all the fresh water lakes in Virginia, Lake Anna is considered one of the largest. The lake is 72 miles south of Washington D.C. It covers an area of 13,000 acres and it is considered one of the most popular lakes used for recreational purposes by locals and tourists. It is almost 17 miles long. The lake has a public and private side. The public side is also known as the cold side. It provides water to decrease the temperature of the generators. The private side, in contrast, collects warm water from the power plant which is warmer than the public side making it unsuitable for swimming especially at the discharge point. Due to the various water activities, Lake Anna has gained popularity as a main tourists' attraction and a second home vacation choice for many others [18].

Lake Lyndon B Johnson, also known as Lake LBJ, is a reservoir on the Colorado River and considered to be another source of *Naegleria fowleri* where a 12 year old victim passed away in 2007 after spending his summer camp on the lake. It is 21 miles in length and 10,800 feet in width. It is considered a main source of recreational activities attracting tourists from different areas in Texas and the US to enjoy the various activities it offers [19].

In 2007, a $10,000 fund has been provided by Lake Anna Civic Organization to Virginia Commonwealth University to identify any existence of *Naegleria fowleri* in the lake [20]. Samples on three

different dates were collected from several sites of the lake and tested using Polymerase Chain Reaction (PCR). PCR is specific and sensitive to identify the amoeba [21]. In June 2007, eight samples were collected and tested. Six out of eight samples were positive for *Naegleria fowleri* using analysis which is specific and sensitive to *Naegleria fowleri* DNA in water. Samples at positive sites had a temperature ranging between 85 to 95 degrees Fahrenheit which is a favorable environment for the multiplication of the amoeba. In addition, 6 of the 16 samples obtained on September 2nd and five out of the six samples obtained on September 20th had been taken in sites with temperatures ranging between eighty-ninety six degrees Fahrenheit were also positive [20].

Similarly, a study was initiated in January 1975 in Florida as an attempt to identify *Naegleria fowleri* in Florida lakes [22]. A polluted lake which gets cooling water expelled from an electric power plant and other freshwater lakes in Orlando had been sampled. The latter were chosen because they were suspected as sites of exposure for PAM cases. As the study progressed, additional lakes throughout Florida were randomly selected for study. As a result, twelve of the twenty sampled lakes indicated the presence of the amoeba. Of the five routinely sampled lakes during the hot summer months, three had levels of one amoeba in 25 ml. This study further appears to validate the presence of *N. fowleri* at a high rate in the hottest sites of the lake.

Discussion

No adequate and well evidenced data exists to accurately identify those at risk of PAM. A large number of locals and tourists visit swimming places in the United States and it is still not clear why some people get infected with *Naegleria fowleri* while many others do not even though they were swimming in the same water. Several efforts were done to properly define the minimum concentration of amoeba necessary for infection, but no standardized method of measurement currently exists to measure the exact count of amoeba in water [23]. Such complexity makes it cumbersome for public health authorities to set specific safety standards to guard human health. Although risk of infection remains low, contaminated water compromises human life and imposes destination risk.

Though the number of reported PAM infections is not statistically significant, 133 cases have been reported between 1964 -2014 in the United States. Florida and Texas reported 34 and 32 cases respectively [5].Several studies have attempted to isolate *Naegleria fowleri* which proved to be the cause of the lethal brain infection, PAM. One of these studies aimed at isolating *Naegleria fowleri* in Lake Anna.

Though *Naegleria fowleri* induced PAM is a rare infection and the rate of infection after exposure is unknown, fatality rate is certain in infected victims and the number of reported cases is on the rise [4]. Travel medicine experts are being challenged to identify treatment that stops the effects of *Naegleria fowleri* on unknowing tourists who are engaged in water related activities.

PAM infections have affected people of all age groups. Eighty four percent of the infections occurred in children with an average age of 11 years and more than 75% of those infected were males [13]. Literature on Naegleria fowleri has also reported cases of PAM infections in cattle [24]. Given the progressive course of the disease, medical professionals are challenged to early diagnose PAM infections. Likewise, the National Park Service, the Environmental Protection Agency are challenged to test the quality of recreational waters for being PAM free.

Medical diagnosis requires specific lab tests only available in few states. As a matter of fact, it is very difficult to differentiate PAM from other types of bacterial meningitis. In addition, the only definitive diagnostic tool is the identification of trophozoites in culture which can take a few days (time that is very critical for such a progressive disease) and 75% of diagnosed cases are confirmed after the patient's death. That is why; the current diagnosis relies on the history of the patient and whether the patient has been exposed to warm bodies of water [2].

Although one possible preventive measure would be testing untreated rivers and lakes for the presence of *N. fowleri*, the CDC doesn't recommend such practice as there is no strong correlation between the amoeba's infection risk and its specific levels in water [25].

Though the most common source of infection originates from *Naegleria fowleri* in fresh water; several deaths from PAM have been witnessed in victims using tap or faucet water from unchlorinated private and public tanks contaminated with the amoeba [14,26]. To minimize the risk of such exposure and make sure hydrophilic germs are removed, resort operators should use especially designed filters. Chlorine is another powerful disinfectant agent against *Naegleria fowleri*. Unchlorinated contaminated swimming pools may host the amoeba. Strict disinfection and testing policies should be implemented for all recreational waters. Whenever disinfection is mentioned, it means the use of Chlorine at a dose ranging from one to three parts per million sustained at a PH of 7.2-7.8 [25].

Educational campaigns should be initiated prior to each summer season to remind water recreational tourists about the risk of infection. Other campaigns should be specifically developed to target healthcare professionals to acquaint them ahead of time of the risks, diagnosis, and treatment of PAM [27,28].

Conclusion

Tourists of different ages carry a risk of amoeba infection which leads to PAM fatality. Bathing and swimming in freshwater and untreated resort pools increases the threat. As there are no established standards for controlling the occurrence of *Naegleria fowleri* in fresh water, risk prevention becomes difficult. The ideal method of preventing infection is refraining from engaging in recreational activities in fresh bodies of water during summer months' periods of high temperature. For those who find it difficult to refrain from water activities in the summer, an important method of reducing the risk of infection is by minimizing the entry of water into the nose which can be achieved by applying several precautions. First, it is of great value to shut the nose by using clips and keep the head at all times above the level of water while swimming or performing other water related activities. It is crucial to refrain from burrowing in the sediment and moving it up the soil while engaging in recreational water activities in freshwater regions [25]. The presented recommendations are prevention tools and do not emanate from evidence based medicine. The relatively low numbers of infections make it difficult to figure out whether these recommendations help in reducing the chance of contracting the infection. The final essential recommendation calls for extra care for children who may play with hoses, sprinklers, ponds and accidentally squirt water into their nose may increase their exposure of being infected.

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