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Review Article

Amoebic Meningoencephalitis - A Review in the Context of Aggravating Case Incidences in Kerala, India

R Rajendran[1], K Regu[2], M S Sasi[3], S N Sharma[4]

[1]Former Joint Director and Consultant, National Centre for Disease Control, Ministry of Health and Family Welfare, Government of India, Thiruvananthapuram, Kerala, India
[2]Former Additional Director and Consultant, National Centre for Disease Control, Ministry of Health and Family Welfare, Government of India, Kozhikode, Kerala, India
[3]Former Assistant Director, Directorate of Health Services, Government of Kerala, India
[4]Former Joint Director and Consultant, National Center for Vector Borne Diseases Control, Ministry of Health and Family Welfare, Government of India, Delhi, India
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INFO

Corresponding Author:
R Rajendran, National Centre for Disease Control, Ministry of Health and Family Welfare, Government of India, Thiruvananthapuram, Kerala, India
E-mail Id:
rajendran061@gmail.com
Orcid Id:
https://orcid.org/0000- 0003-2080-9723
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ABSTRACT

Amoebic meningoencephalitis (AME), a rare yet deadly infection of the central nervous system, is caused by free-living amoebae found in soil and warmer freshwater bodies such as lakes, rivers, ponds, and swimming pools. The infection manifests in two forms: primary amoebic meningoencephalitis (PAM) and granulomatous amoebic encephalitis (GAE). PAM is typically caused by *Naegleria fowleri,* and GAE is primarily caused by *Acanthamoeba* species and *Balamuthia mandrillaris*, and occasionally by *Sappinia pedate*. Since 1962, a total of 488 PAM cases have been reported globally. Between 2016 and April 2026, about 345 cases of AME were reported in Kerala, resulting in 82 deaths. The data reveal an alarming recent spike; 2025 alone accounted for over 58 % of all cases and 57% of the fatalities reported during the period under review. The unique agent, environmental, host and medical factors contributing to the near-epidemic rise in AME infection in Kerala have been discussed. Necessary primary and secondary measures essential for prevention and control of AME have also been dealt with in this brief review.

Keywords: Amoebic Meningoencephalitis, *Naegleria fowleri*, Central nervous system infection

Introduction

Amoebae are a group of protists that move using pseudopods and feed by phagocytosis. These versatile organisms can be found in a variety of environments, including water, soil and air. Amoebae are important contributors to ecosystem dynamics, but they can also pose potential hazards to human well-being.[1] Based on their lifestyles, amoebae can be categorised into two main groups: Free-living Amoebae (FLA) and Parasitic Amoebae (PA). FLA are ubiquitous microorganisms found in natural environments as well as man-made water systems. Among the four main genera of amoebae, *Naegleria*, *Acanthamoeba*, *Balamuthia*, and

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Sappinia are mostly implicated in human amoebic diseases. There are also FLAs such as *Vermamoeba* (*Hartmanella*) *vermiformis* that have occasionally been linked to human illness. [2,3]

Pathogenic Amoebae: Biological Action

Amoebic encephalitis is a rare but lethal central nervous system (CNS) infection caused by FLA. Two types of amoebic encephalitis are primary amoebic meningoencephalitis (PAM) and granulomatous amoebic encephalitis (GAE). PAM is a disease caused by the microscopic amoeba *Naegleria fowleri*, commonly known as "brain-eating amoeba". PAM is often found in immunocompetent children and young adults due to exposure to water contaminated with the amoeba. Initial symptoms of PAM are indistinguishable from those of bacterial meningitis, whereas symptoms of GAE can mimic a brain abscess, encephalitis, or meningitis that is common in bacterial and other infections. These infections are uniformly fatal, with only a few survivors as reported worldwide.[4]

N. *fowleri* is the sole pathogenic species of *Naegleria* and is the causative agent of PAM. It is commonly found in freshwater sources, including rivers, lakes, ponds, hot springs, domestic water supplies, sewage, heating and ventilation units, and swimming pools.[5,6,7] During summer, when the water is warm, most cases of *N. fowler*i infections have been associated with bathing in contaminated freshwater bodies. Less frequently, nasal irrigation is also reported as a route of infection.[8] Infection begins when *N. fowleri* in the trophozoite stage enters the nasal passages. The amoebae then attach to the olfactory mucosa along the olfactory nerves and ultimately cross the cribriform plate to reach the brain. After the amoebae reach the brain, the resulting repercussions can lead to brain inflammation, herniation of the brain artery, and ultimately death.[9,10] *Acanthamoeba* are widespread free-living amoebae (FLA) that can cause a range of infections in humans, including granulomatous amoebic encephalitis (GAE), keratitis, pneumonitis, and cutaneous infections. GAE is a slowly progressing, opportunistic, and often fatal disease caused by several species of this amoeba.[2] *Balamuthia* amoebic encephalitis (BAE), caused by the amoeba *Balamuthia mandrillaris*, can affect both healthy and immunocompromised people. Contact with contaminated soil is a significant risk factor for infection. The amoeba can enter the body through the skin or respiratory tract and then spread to the central nervous system (CNS) via the bloodstream [11,12]. A sole known human *Sappinia* encephalitis case has been reported in a 38-year-old male from Texas in 1998.[13,14] *Sappinia* species are found in soil, plant litter, standing decaying plants, and freshwater ponds. It has also been detected in the faeces of various animals, including horses, lizards, bison, elk, buffalo, and dogs.[15]

Amoebic Meningoencephalitis: Global Scenario

From 1961 to 1965, Malcom Fowler and his team at the Adelaide Children's Hospital in Australia investigated a series of fatal infections, identifying an amoeba as the cause of primary amoebic meningoencephalitis.[16] Since 1962, a total of 488 PAM cases have been reported globally. Recently researchers have identified the highest numbers of these cases in the U.S., Pakistan, and Australia.[17] The United States, Australia, Pakistan, India and the Czech Republic have reported the highest number of *N. fowleri* cases among the 39 countries where infections have occurred. This is likely because their warm climate and freshwater bodies are ideal for the pathogen's growth and replication.[17] Historically, the United States has recorded the most cases of PAM, with most infections occurring in the southern states due to their warm climates.[18] However, cases have also been documented in northern states, including Minnesota in 2010 and both Kansas and Indiana in 2011 and 2012, respectively.[19] Contaminated swimming pools and other freshwater bodies are the primary sources of these infections, corroborated by poor water management practices and climate change.[20,21] Between 1962 and 2024, the United States reported 167 cases of PAM, making it the most affected country globally.[22] In 2023, Pakistan had emerged as the largest hotspot for *N. fowleri* infections with 155 cases, most of which were from Karachi.[23] In Pakistan, initial cases of PAM were linked to contact with contaminated water. However, closer investigation revealed that a significant number of these infections resulted from vigorous nasal irrigation during ablution and showering.[24] In Pakistan, the transmission of PAM caused by the pathogenic amoebae, *N. fowleri*, is significantly influenced by the forceful inhalation of contaminated tap water during ritual practices, rather than by swimming in contaminated water.[24,25]

AME infection has been reported from Latin American countries such as Mexico, Peru, Venezuela, Argentina, Brazil, and Chile, as well as in the Middle East and Asia-Pacific countries such as China, Japan, India, Thailand, South Korea, and Australia. A few cases have been reported in the UK, Portugal, and the Czech Republic.[26] Infections from *Balamuthia* are concentrated in the Americas and Asia, whereas *Vermamoeba* are more widespread, typically found in sewage-related environments worldwide. Over 200 *Balamuthia madrillaris* encephalitis (BME) cases have been reported globally since 1991, with a majority occurring in South America and the United States, and nine cases have been reported from Japan.[27,28]

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Amoebic Meningoencephalitis: Indian Scenario

Primary Amoebic Meningoencephalitis (PAM) due to *N. fowleri*

Despite significant advances in antimicrobial chemotherapy and supportive care, the fatality rate of PAM in India remains alarmingly high, exceeding 95%.[29] India's tropical climate, characteristically hot and humid, creates conditions that are conducive to the growth of various free-living amoebae. *N. fowleri* infections become more common during the monsoon and post-monsoon seasons due to a combination of factors. The warm, humid conditions and stagnant water pools created by heavy rainfall provide an ideal environment for the amoeba to thrive. Concurrent to more people participating in water-related recreational activities, there is an increased likelihood that the amoeba will enter the nose from contaminated water.[30] The amoeba has also been detected in a variety of water sources, including public water distribution systems, swimming pools, rainwater tanks, tap water and well water.[31,32,33] In India, PAM due to *N. fowleri* was first reported in Kolkata, West Bengal, in 1971. Since then, 25 confirmed PAM cases have been documented, with most occurring in the northern states of India[11,34].

A study of PAM cases due to *N. fowleri* reported in India from 1971 to 2023 revealed a striking gender disparity, with 84% of infections occurring in males.[11] A significant portion of the infected persons, 40%, were children under the age of 10, and half of these young patients were infants less than one year old. In India, nearly 50% of PAM cases have an unknown source of infection. Most published works are case reports focusing on clinical symptoms, vital signs, and diagnostic findings, with little reference to the source of infection, which poses a significant challenge for effective disease prevention and control.

After being exposed, symptoms of PAM can show up anytime from one to twelve days. The timing depends on the size of the inoculum and how virulent the strain is. Most patients succumb within 3 to 7 days following the onset of symptoms. The average duration between onset of symptoms and death is 5.3 days. Infections by *N. fowleri* are thought to be frequently misdiagnosed and underreported. This is likely because there is inadequate information about the disease's pathology, and patients often die before a definitive diagnosis can be made.[11, 35]

To prevent death and minimise long-term complications, early diagnosis and prompt treatment are essential.[36,37] A review of case histories of *Naegleria* - infected individuals in India over the past five decades shows only a 50% fatality rate. It is likely that numerous cases have gone unnoticed or undiagnosed.

Acanthamoeba Granulomatous Amoebic Encephalitis

Acanthamoeba are widespread, free-living amoebae and are isolated from natural environments and from places like swimming pools, sewage, domestic tap water, and contact lenses.[38,39] In India, between 1972 and 2021, there were 42 reported cases of *Acanthamoeba* -related encephalitis. [11,40,41,42] Among them, 17 cases were reported from hospitals in Delhi. The remaining cases were reported from Chandigarh (7), Maharashtra (6), Karnataka (4), Tamil Nadu (3), Andhra Pradesh (2), and one case each from Pondicherry, Punjab, and Uttar Pradesh. Subsequently, a total of 14 GAE cases caused by *Acanthamoeba* were reported from West Bengal [43, 44, 45, 46, 47,48]. *Acanthamoeba* can infect parts of the body by entering through cuts and wounds in the skin, being inhaled into the lungs or nostrils, or infecting the eyes through contact lens use.

Balamuthia Amoebic Encephalitis (BAE)

In India, the first reported case of *Balamuthia* amoebic encephalitis occurred in 2008 when a 22-year-old male was admitted to AIIMS, Delhi. Subsequently, three more cases have been reported from different areas, all involving males who also died while undergoing treatment.[11] The clinical presentations of BAE include systemic symptoms like fever and headache, along with neurological issues such as vomiting, seizures, altered sensorium, slurred speech, right-side weakness, and vertigo.

The Alarming AME Situation in Kerala

The first case of AME due to *N. fowleri* was reported in Kerala from the Alappuzha district in a 16-year-old male in 2016.[49] Even though Kerala had a relatively belated report of AME incidence as of 2016, it emerged to widespread infections since then, amounting to a total of 345 cases as of April 2026 (Table 1). The first case of AME due to *Acanthamoeba* was reported in a 15-year-old boy from Trikarpur, Kasaragod district, in 2023. The patient's daily ritual of bathing in the temple pond posed a potential exposure risk for *Acanthamoeba* infection; the child succumbed to the infection. Out of the reported cases of amoebic meningoencephalitis (AME) in Kerala, only 10% were attributed *to N. fowleri*; the vast majority of the remaining cases (90%) were encephalitis caused by *Acanthamoeba.*[50] However, the source of infection mostly remains uncertain, particularly those caused by *Acanthamoeba*, which has characteristically an incubation period that can range from a few days to almost a year. While *N. fowleri* has a shorter incubation period and is almost always linked to recent water exposure, establishing an epidemiological link for *Acanthamoeba* mostly eluded confirmation. The year 2025 witnessed an epidemiological

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rise of AME infection in Kerala, i.e., 201 cases, amounting to 58.26% of total infections up to the time.

A study of the Regional Institute of Ophthalmology, Thiruvananthapuram, Kerala (2013), corroborated a link between unhealing corneal ulcers and amoebic keratitis caused by *Acanthamoeba*, where household wells were identified as the source of infection.[51] In an effort to identify free-living pathogenic amoebae in disease-affected areas, the Kerala State Health Department conducted molecular PCR testing on water samples taken from sources such as household wells, storage tanks, piped water, public wells, ponds, and swimming pools. The test confirmed the presence of free-living pathogenic amoebae in these water bodies.[52]

Table 1.Reported cases of Amoebic meningoencephalitis in Kerala (2016 to April 2026)

Year	Number		District	Month	Diagnosis
	Cases	Deaths			
2016	01	01	Alappuzha	March	Positive for *N. fowleri*
2019	01	01	Malappuram	May	Positive for *N. fowleri*
2020	02	02	Malappuram Kozhikode	June	Positive for *N. fowleri*
2021	02	02	Malappuram Thrissur	November Not Known	Positive for *N. fowleri*
2022	01	01	Thrissur	August	Positive for *N. fowleri*
2023	02	02	Alappuzha Kasargod	June October	*N. fowleri, Acanthamoeba*
2024	39	09	Thiruvananthapuram [Case-22; Death-02]	July,August, September October	*Acanthamoeba*
			Kollam [Case-05]	October	-
			Thrissur [Case-01]	June	*Vermamoeba vermiformis*
			Palakkad [Case-01; Death-01]	June	*Vermamoeba vermiformis*
			Malappuram [Case-04; Death-03]	May	*Vermamoeba vermiformis*
			Kozhikode [Case-03; Death-01]	June, July	*N. fowleri* & *Vermamoeba vermiformis*
			Kannur [Case-02; Death-01]	May, July	*Vermamoeba vermiformis*
			Kasargod [Case-01; Death-01]	September	*Vermamoeba vermiformis*
2025	201	47	Thiruvananthapuram Kollam Kozhikode Malappuram Wayanad Palakkad Ernakulam	August September	*Vermamoeba vermiformis, Sappinia pedata**, *N. fowleri, Acanthamoeba*
2026 (up to April 2026)	96	17	Kasargod , Alappuzha Thiruvananthapuram, Kollam, Kozhikode, Malappuram, Ernakulam, Alappuzha	-	*N. fowleri, Acanthamoeba, Vermamoeba vermiformis*

*In August 2025, the Kozhikode district reported the first confirmed case of a rare amoeba variant, *Sappinia pedata*, in the State

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Increased ambient temperatures and rising water pollution in the state could be attributed as potential factors boosting the concentration of amoebae in water bodies and thereby contributing to the growing incidences of amoebic meningoencephalitis in those using the water. Free-living amoebae thrive in contaminated or stagnant water pools when the water temperature rises. This could be the possible cause of amoebic infection among those using the water for recreation activities.

Outbreak of AME in Kerala in 2025 – '26: Epidemiological overview

Kerala has seen an alarming rise in AME cases, recording an unprecedented 201 infections and 47 deaths in 2025. The epidemiological data available from the Directorate of Health Services (DHS), Kerala, showed that amoebic meningoencephalitis cases observed a wide age range from infants to young to advanced age in both males and females.[53] While infection is occurring in both adults and children, children could be more vulnerable due to fragile anatomical features. Official data indicate that underlying immunocompromising conditions could be a significant risk factor in aged adults. Between January and April 2026, the state reported 96 new AME cases and 17 deaths, signalling a critical epidemiological shift in the disease's progression.[53] AME cases are being reported most frequently from Thiruvananthapuram, Kollam, Alappuzha, Kozhikode and Malappuram districts. The infection trends indicate that the disease is subsequently being spread to other districts as well.[54]

In Kerala, only nine cases of AME were reported between 2016 and 2023, all of which were fatal (case fatality rate [CFR] of 100%), and except for one case, all other cases were attributed to *N. fowleri*. However, a sharp surge occurred between 2024 and April 2026, with a total of 336 AME cases and 73 deaths reported in the state. Notably, the CFR dropped to 21.73% during this latter period. The sudden spike and lower fatality rate are linked to a change in the underlying pathogens. While *N. fowleri* remains the most lethal species, recent infections have been primarily driven by *Acanthamoeba* and *Vermamoeba vermiformis*, which generally present lower mortality rates. Because *N. fowleri* is exceptionally fatal, rapid and precise diagnosis is absolutely vital to patient survival. Consequently, further research is urgently needed to understand the shift from *N. fowleri* to *Acanthamoeba* and *V. vermiformis.* Specifically, studies should investigate the ecology of these pathogens, changes in human behaviour, and the impact of climate change on their breeding potential in Kerala's aquatic environments.

Host factors

Human infection occurs through nasal entry or wounds following exposure to contaminated water from sources such as household water supplies, ponds, and lakes. High-risk activities include exposure to untreated water sources, viz., for swimming, diving, or bathing in them. The risk of infection typically increases during the post-monsoon period when different water bodies swell up due to torrential rain and mostly become contaminated with overflowing flood water. It is not uncommon that people resort to throw away household wastes in fresh water bodies that are used as sources of drinking water as well. It is also to be observed that in many places, household drainages are emptied into nearby water bodies. It has to be averred that penal actions by authorities are not effective enough to forbid this public behaviour. This contributes to severe sanitary and public health issues; AME incidence is typical among them.

The prevalence of coliform bacteria, stemming from sewage and waste contamination across Kerala's aquatic environments such as wells, pools, ponds and rivers, provides a nutrient source for pathogenic free-living amoebae. High concentrations of amoebae in water bodies, including domestic tanks, significantly increase the incidence of amoebic meningoencephalitis infection. High incidence of AME is likely exacerbated by conducive environmental factors, combined with human behavioural aspects. Water bodies contaminated with sewage and biowastes provide for profuse growth of coliform bacteria that are fed upon by free-living pathogenic amoebae in such water bodies, contributing to their large-scale multiplication and thriving. It is also to be found that there are many places in Kerala where drinking water wells and septic tanks are in close proximity, paving the way to contamination of the former with coliform bacteria and likely presence of free-living pathogenic amoebae that feed upon them. The high population density and adjacent construction of house buildings invariably aggravate the situation.

Indifferent attitudes from health authorities, along with lukewarm responses from local governing bodies and other concerned government departments, make the situation highly vulnerable in favour of pathogen proliferation and infection episodes. Effective management of amoebic meningoencephalitis in Kerala hinges on a dual strategy: (1) implementing public health measures for disinfecting water sources through proper and effective water treatment measures, and (2) conducting enhanced disease surveillance for prompt detection and prophylactic responses. To prevent infection, individuals should avoid contact with untreated, stagnant freshwater and refrain from bathing, diving or swimming in such water bodies. If unavoidable, nose plugs should be used or the nose should be pinched shut. Furthermore, maintaining clean and chlorinated swimming pools and water sources is essential. Public health officials must maintain and enforce chlorination standards,

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conduct regular water testing, conduct widespread public awareness campaigns and ensure public safety.[55]

The outbreak of AME in Kerala over the past decade serves as a stark reminder of how pathogenic amoebae can leverage ecological niches and human behaviour. It simultaneously emphasises the vital importance of intensified diagnostics, heightened clinical suspicion, and a rapid public health response.[56,57]

The widespread presence of pathogenic amoebae in both natural and artificially created environments poses significant exposure risks. Because traditional disinfection methods show limited efficacy against them, emerging concepts and applications are urgently required to reduce amoeba viability. Nevertheless, a critical gap persists in the early detection and monitoring of these pathogens. Future research must prioritise developing integrated strategies under the “One Health Approach” - explicitly linking human health with environmental and ecological dimensions - while simultaneously advancing innovative control strategies to limit transmission. Given the rising incidence of amoeba-related disease, proactive public health surveillance and swift intervention efforts are more urgent than ever.

Conclusion

Amoebic meningoencephalitis is a devastating and often fatal brain infection caused by free-living amoebae. Although rare, the disease poses significant challenges because of its rapid progression, difficulty in diagnosis, limited treatment options and high fatality. The prevention and control of pathogenic free-living amoebae demand strong public health measures. These must include fostering greater primary health and secondary health education about the disease within the medical community, along with promoting grassroots-level community preventive awareness. Public education must essentially cover disease epidemiology, risk factors, and necessary preventive measures. Effective public health interventions and disease management rely on prompt clinical case reporting, public health reporting, and timely sharing of experimental and field data. A coordinated effort among public health and research departments, NGOs, community organisations and a concerned public is crucial to contain and mitigate the threat of this fatal disease.

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