

‘Don’t put your head under water’: enteric viruses in Brazilian recreational waters

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Abstract

Like in many other countries, virologic analyses are not routinely performed in Brazil in monitoring water quality for recreational purposes. We surveyed current research regarding viral contamination of recreational water environments in Brazil. Among the enteric viruses studied in Brazilian recreational waters, we highlight adenoviruses, rotaviruses, enteroviruses and noroviruses. Although there has been relatively little research on outbreaks related to bathing in recreational water environments in Brazil, noroviruses and adenoviruses are the viruses that are most often related to outbreaks. Better surveillance of the occurrence of enteric viruses in water could improve the assessment of risk to human health as well as indicate the sources of contamination and thus demonstrate the importance of adequate environmental sanitation.

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Introduction

The release of untreated domestic sewage is one of the main modes of contamination of recreational water environments, causing damage to the environment and to public health [1,2]. According to large data sets available about sanitation conditions in Brazil [3], only 44.92% of Brazil's sewage is treated before being discharged into water bodies, and more than 100 million inhabitants do not have access to sewage collection [4]. The release of sewage without adequate treatment transmits several pathogens associated with diseases such as gastroenteritis [5–7]. This is worrying because tourist income is an important component for the economy of many Brazilian cities.

The monitoring of water quality is evaluated through parameters such as temperature, salinity, chlorophyll, turbidity,

pH and dissolved oxygen, but currently there is no international regulation to evaluate the presence of viruses in recreational waters [8,9]. The evaluation of the quality of recreational waters depends on bacteriologic markers such as *Escherichia coli* and *Enterococcus*, mainly because of low-complexity and inexpensive detection methods [10,11]. However, the lack of correlation between the presence of faecal coliforms and enteric viruses is well established in the literature; in addition, enteric viruses are more stable in the environment than faecal coliforms and may be used as markers of faecal contamination of water [12,13].

In Brazil, Ministry of Health ordinance 1469, dated 29 December 2000, affirms the need to include enteric viruses in the evaluation of water quality [14]. However, to date there is no legislation in the country that includes such viruses in the analysis of water samples. Among the possible reasons for not including virologic evaluations are the high cost of analysis, difficulties in standardization of methodologies and lack of reliability of results considering the problem of establishing if viruses detected in the samples are infectious [15].

This study was an effort to survey the studies of enteric viruses carried out in Brazilian recreational water environments. We surveyed studies involving adenoviruses (AdV),

enteroviruses (EV), rotaviruses (RV) and noroviruses (NoV); biological information; the frequency of detection in Brazilian recreational water environments in other countries; and outbreaks in recreational waters.

Enteric Viruses

The increase of population results in greater environmental pressure and consequently greater demand for natural resources, increasing the amount of waste generated and aggravating the insufficiency of basic sanitation. Thus, these elements contribute to the increase of waterborne diseases [16–18]. Among the pathogens related to waterborne diseases, we highlight the enteric viruses, which are transmitted via the faecal–oral route and can cause asymptomatic infections as well as serious diseases [19]. Among the viruses that can be transmitted by recreational waters, we highlight AdV, EV, RV and NoV.

Adenoviruses

AdV are nonenveloped double-stranded DNA viruses with icosahedral capsid, measure between 60 and 100 nm in diameter and belong to the *Adenoviridae* family [20,21]. This family consists of five genera; we highlight the genus *Mastadenovirus*, which includes the human *Mastadenovirus* (HAdV), which is considered one of the most abundant enteric virus groups in water [12,22]. HAdVs comprise 86 genotypes subdivided into seven species (from A to G) [21].

AdV is one of the few viruses that are on the US Environmental Protection Agency list of drinking water contaminants candidates [23]. In addition, the list contains caliciviruses, EV and hepatitis A virus (HAV). However, there is a preference for AdV because of its high frequency in many aquatic environments and its greater stability under adverse conditions, including variations in temperature, pH, and physical and chemical treatments [24]. In addition, viruses of double-stranded genomes such as AdV are less susceptible to UV inactivation [25]. As already demonstrated by Hara *et al.* [26], AdV may be 60 times more resistant than EV (single-stranded RNA) when exposed to low-pressure UV radiation. All HAdVs are excreted in faeces for an extended period of time even if diarrhoea is not present [27].

HAdVs carried by recreational waters have been reported in different regions of Brazil [28–32]. Vieira *et al.* [33] conducted a study in Rio Negro, located in the Amazônica basin, and reported that 91.9% of the samples were positive for HAdV. In the state of Rio de Janeiro (southeastern Brazil), studies

conducted at Olympic venues showed 25.3% and 93.1% of positive samples respectively for HAdV-F and HAdV-C [28]. Studies carried out in the Lagoa do Peri (Santa Catarina, in the south of the country) found all samples to be positive for HAdV [29]. In the state of Rio Grande do Sul (southern Brazil), studies in Lake Guaíba showed about 78% positive samples for AdV [30]. In this same state, Girardi *et al.* [31] detected 42.8% of samples contaminated by species C, E and F of HAdV. High risk of infection ($9.99\text{e-}01$) for HAdV has recently been reported in recreational freshwaters of southern Brazil [32]. In other countries, AdV in recreational waters has also been detected. In Singapore, HAdV was detected in 60% of samples [34], in the United States (Ohio) 40% [35], in Europe 36% [36] and in Taiwan 28.1% [37].

Rotaviruses

RV are double-stranded RNA, have an icosahedral capsid, measure approximately 100 nm in diameter, are nonenveloped, belong to the *Reoviridae* family and are classified into eight species, A through H [38,39]. RV infections can range from asymptomatic to presentation of symptoms such as diarrhoea, vomiting, fever, dehydration and abdominal pain [22]. RV of species A (RV-A) is the main aetiological agent of diarrhoeal disease in children and is recognized as an important contaminant in aquatic environments [40]. Globally, RV is still responsible for 215<thinsp>000 deaths in children under 5 years of age; however, 22% of these deaths occurred in India. These data are unacceptable because there are two live attenuated oral RV vaccines, Rotarix (derived from a single common human RV strain) and RotaTeq (a reorganized bovine–human rotavirus) [41]. Rotarix vaccine was introduced in Brazil's national immunization programme in 2006. After immunization, a time-series analysis from 2007 to 2009 showed that immunization was associated with declines in diarrhoeal deaths and hospital admissions in childhood. In addition, the study showed that the vaccine benefits those children living in areas with limited access to healthcare, who are more susceptible to death [42]. A problem related to immunization against RV is an increased risk of intussusception, which can lead to death. However, the safety profile of current RV vaccines is acceptable. The benefits of vaccination far outweigh the risks, particularly in poor countries where RV infection remains a major cause of mortality among children [43].

We found few studies about RV in recreational waters of other countries. Probably because of its being the main cause of diarrhoeal disease in children under 5 years of age, several studies are related to stool samples from children hospitalized for acute diarrhoea [44]. In Argentina (Córdoba), RV was

detected in 100% (Suquia River) and 18.7% (Xanaes River) of the samples evaluated [45]. In Brazil, in studies conducted in southern waters (Florianópolis, SC), 25% of RV-A-positive samples [46] were detected. Miagostovich et al. [47] evaluated water samples from the Manaus watershed (Amazonas) and detected RV in 44.2% of the samples. Analysis of water samples from urban beaches in Rio de Janeiro showed an RV-A contamination in 37% [48].

The beaches in Rio de Janeiro and Florianópolis are among the most visited in Brazil throughout the year, by both tourists from other countries and Brazilians. Thus, we highlight studies such as this that indicate the need for the inclusion of virologic analyses of recreational waters, mainly during rainy events, a period when RV-A detection is higher.

Enteroviruses

EV belong to the family *Picornaviridae*, are positive-sense single-stranded-RNA and have a capsid that measures between 15 and 30 nm in diameter. These viruses can cause asymptomatic infections as well as a wide variety of diseases that may be of short duration or more severe, such as meningitis [49–51].

Maurer et al. [30] evaluated recreational waters in the south of the country and found about 22% of samples contaminated by EV. In coastal waters of Rio de Janeiro, Staggemeier et al. [28] reported the presence of EV in 26.7% of the samples evaluated. In other countries such as the United States (Ohio), EV was detected in 17% of the samples [35]. In Hawaii, it was detected in all the samples evaluated [11].

Noroviruses

NoV belong to the family *Caliciviridae*, are nonenveloped, have a genome that is single-stranded RNA and are subdivided into 29 groups under five genogroups, of which NoV GI and GII are commonly associated with human diseases [52,53]. NoV causes substantial morbidity in community settings, such as cruises. Factors such as the need for only a small inoculum required to produce an infection (100 virus particles) increase the transmissibility of NoV [52]. Research to develop and validate infectivity assays has been performed [54]. However, to date, the detection of NoV in the environment depends on molecular techniques. GII has been reported in epidemics since 1995 in countries such as the United States [55], Australia [56], the United Kingdom [57] and New Zealand [58]. Factors such as increased environmental stability, transmissibility and virulence are among the factors that contribute to GII predominance [59].

NoV, originally called Norwalk-like virus, was first described in 1968 after an outbreak of gastroenteritis at a school in Norwalk, Ohio, USA [60]. In Brazil, the first NoV detection report was in the mid-1990s from stool samples of children with and without acute diarrhoeal symptomatology [61].

Moresco et al. [62] evaluated NoV contamination in marine waters of 11 beaches in Florianópolis (southern Brazil) and found 4.5% of samples to be positive for NoV-GII and 7.5% for NoV-GI. Studies carried out in an urban lagoon in the city of Rio de Janeiro showed contamination in 18.8% of the samples evaluated [63]. In Rio Negro (Amazon), 7.4% of the samples evaluated were positive for NoV [33]. In other countries, NoV detection has been higher. In Singapore, NoV was detected in 75% of the water samples evaluated (NoV-GI in 35% and NoV-GII in 65% of samples) [34]. In samples from French waters (Meurthe River–Maxéville), NoV-GI and -GII were detected in all samples evaluated [64]. In South Africa, NoV was detected in 50% (GI) and 74% (GII) of the samples evaluated [65].

Disease Outbreaks Related to Recreational Waters

According to the US Centers for Disease Control and Prevention, a disease outbreak is the occurrence of disease cases in excess of normal expectancy in a particular location or in a group of people over a given period. In Brazil in January 2018, the municipal health department of Rio de Janeiro reported 92 cases of HAV, with 75 confirmed in a period of 45 days. In total, ten points were evaluated and HAV was detected in three, mainly in Vidigal (southern zone) and in São Conrado Beach. A shower had to be removed because of confirmation of HAV [66,67].

In recreational waters, enteric viruses are a considerable cause of waterborne diseases. However, factors such as the wide variety of diseases that they cause, and especially the limitations of prior detection, make it difficult to document them. According to Sinclair et al. [68], the main enteric viruses associated with outbreaks were AdV, coxsackievirus, echovirus, HAV, NoV and astrovirus, and the highest percentages of outbreaks were for NoV (45%) and AdV (24%). In addition, studies have shown that the occurrence of outbreaks is greater after a period of extreme rainfall [69,70]. This may be related to the fact that the incidence of enteric viruses such as AdV and RV is greater after long periods of precipitation [31,49]. The lack of required reporting and lower water quality are among the main factors contributing to disease outbreaks in recreational waters.

However, in Brazil, it is difficult to get information about water-related illness outbreaks, especially because the population tends not to go to the hospital, and when they do go, it is

difficult to detect the pathogen that caused the infection. This is just one of many variables that occur in other countries as well. Hlavsa *et al.* [71] highlight the main factors for underreporting outbreaks: mild disease; small outbreak size; long incubation periods; wide geographical dispersion of sick swimmers; transient nature of the contamination; establishment of place of exposure to outbreaks (eg, residential backyard pool); and potential lack of communication between those responding to outbreaks of chemical aetiology and those who generally report outbreaks.

Final Considerations

It is clear that the lack of basic sanitation is primarily responsible for contamination in aquatic environments. The shortage of virus analyses in recreational waters in the current political climate is associated with factors such as the lack of qualified professionals and the need for access to monitoring systems and exploratory methodologies. Thus, although these limitations exist, our results provide confirmatory evidence of the importance of including virus monitoring. Virus analyses inserted into routine monitoring protocols could contribute to measures to prevent outbreaks related to recreational waters that affect public health.

Conflict of Interest

None declared.

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