ORIGINAL ARTICLE

‘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.

Keywords: Adenovirus, enterovirus, enteric viruses, escherichia coli, norovirus, outbreaks, recreational waters, rotavirus, water quality
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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, chlorophyl, 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),

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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 (9.99e-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 aetiologic 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% (Suquía 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 another 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 predominancy [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, 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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References

[1] Gu X, Tay QXM, Te SH, Saeidi N, Goh SG, Kushmaro A, et al. Geospatial distribution of viromes in tropical freshwater ecosystems. Water Res 2018;137:220–32.

[2] Mackowiak M, Leifels M, Hamza IA, Jurzik L, Wingender J. Distribution of *Escherichia coli*, coliphages and enteric viruses in water, epilithic biofilms and sediments of an urban river in Germany. Sci Total Environ 2018;626:650–9.

[3] Treats Brazil and National Sanitation Information System. Available at: http://www.tratabrasil.org.br/saneamento/principais-estatisticas/no-brasil/esgoto.

[4] Prado T, Miagostovich MP. Environmental virology and sanitation in Brazil: a narrative review. Cad Saude Publica 2014;30:1367–78.

[5] Brown J, Cairncross S, Ensink J, Jeroen HJ. Water, sanitation, hygiene and enteric infections in children. Arch Dis Child 2013;98:629–34.

[6] Prüss-Ustün A, Bartram J, Clasen T, Colford Jr JM, Cumming O, Curtis V, et al. Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. Trop Med Int Health 2014;19:894–905.

[7] Jagai JS, DeFlorio-Barker S, Lin CJ, Hilborn ED, Wade TJ. Sanitary sewer overflows and emergency room visits for gastrointestinal illness: analysis of Massachusetts data, 2006–2007. Environ Health Perspect 2017;125:129003.

[8] Jovanović Galović A, Bijelović S, Milošević V, Hrnjaković Cvjetkovic I, Popović M, Kovačević G, et al. Testing for viral material in water of public bathing areas of the Danube during summer, Vojvodina, Serbia. Euro Surveill 2016;21(15).

[9] World Health Organization. Guidelines for safe recreational water environments. Coastal and fresh waters, Volume 1. Geneva: World Health Organization; 2003.

[10] Verani M, Federigi I, Donzelli G, Cioni L, Carducci A. Human adenoviruses as waterborne index pathogens and their use for quantitative microbial risk assessment. Sci Total Environ 2019;651:1469–75.

[11] Updyke EA, Wang Z, Sun S, Connell C, Kirs M, Wong M, et al. Human enteric viruses—potential indicators for enhanced monitoring of recreational water quality. Virol Sin 2015;30:344–53.

[12] Adefisoye MA, Nwodo UU, Green E, Okoh AI. Quantitative PCR detection and characterization of human adenovirus, rotavirus and hepatitis A virus in discharged effluents of two wastewater treatment facilities in the Eastern Cape, South Africa. Food Environ Virol 2016;8:262–74.

[13] Peteffi GP, Fleck JD, Kael IM, Girardi V, Bündchen R, Krajeski DM, et al. Caffeine levels as a predictor of human *Mastadenovirus* presence in surface waters—a case study in the Sinos River basin—Brazil. Environ Sci Pollut Res 2018;25:15774–84.

[14] Ministério da Saúde Brasil. Portaria n° 1469 de 29 de dezembro de 2000. Norma da Qualidade da Água para Consumo Humano. Capítulo IV Do Padrão de Potabilidade. Brasília: Diário Oficial da União; 2 January 2001.

[15] Girones R, Ferru MA, Alonso JL, Rodriguez-Manzano J, Calgua B, Corrêa AA. Molecular detection of pathogens in water—the pros and cons of molecular techniques. Water Res 2010;44:4325–39.

[16] Tucci EMC. Gestão integrada das águas pluviais urbanas: o desafio da integração e da sustentabilidade. In: Cordeiro BS, coordinator, editors. Brasil. Ministério das Cidades. Lei Nacional de Saneamento Básico: perspectivas para as políticas e a gestão dos serviços públicos, Volume 2. Brasília: Editado pelo Programa de Modernização do Setor Saneamento—PMSS; 2009. p. 334–44.

[17] Gleick PH. Water in crisis: paths to sustainable water use. Ecol Appl 1998;8:571–9.

[18] Pimentel D, Cooperstein S, Randell H, Filiberto D, Sorrentino S, Kaye B, et al. Ecology of increasing diseases: population growth and environmental degradation. Hum Ecol 2007;35:653–68.

[19] Wyn-Jones AP, Sellwood J. Enteric viruses in the aquatic environment. J Appl Microbiol 2001;91:945–62.

[20] McConnell MJ, Imperiale MJ. Biology of adenovirus and its use as a vector for gene therapy. Hum Gene Ther 2004;15:1022–33.

[21] Santos NSO, Soares CC. Viroses entéricas. In: Santos NSO, Romanos MTV, Wigg MD, editors. Virologia humana. 3rd ed. Rio de Janeiro: Guanabara Koogan; 2015. p. 189–231.

[22] International Commitee on Taxonomy of Viruses. Adenoviridae. Available at: https://talk.ictvonline.org/ictv-reports/ictv_9th_report/dsdna-viruses-2011/w/dsdna_viruses/93/adenoviridae.

[23] United States Environmental Protection Agency. Office of Water. Fact sheet: drinking water contaminant candidate list 4—draft. 2015. Available at: https://www.epa.gov/sites/production/files/2015-02/documents/epa815f15001.pdf.

[24] Fong TT, Lipp EK. Enteric viruses of humans and animals in aquatic environments: health risks, detection, and potential water quality assessment tools. Microbiol Mol Biol Rev 2005;69:357–71.
[25] Thurston-Enriquez JA, Haas CN, Jacangelo J, Riley K, Gerba CP. Inactivation of feline calicivirus and adenovirus type 40 by UV radiation. J Appl Environ Microbiol 2003;69:577–82.
[26] Hara J, Okamoto S, Minekawa Y, Yamazaki K, Kase T. Survival and disinfection of adenovirus type 19 and enterovirus 70 in ophthalmic practice. Jpn J Ophthalmol 1990;34:421–7.
[27] Rodríguez-Lázaro D, Cook N, Ruggeri FM, Sellwood J, Nasser A, Nascimento MS, et al. Virus hazards from food, water and other contaminated environments. FEMS Microbiol Rev 2012;36:786–814.
[28] Staggemeier R, Heck TMS, Demoliner M, Ritzel RGF, Röhnelt NMS, Girardi V, et al. Enteric viruses and adenovirus diversity in waters from 2016 Olympic venues. Sci Total Environ 2017;586:304–12.
[29] Fongaro G, Padilha J, Schissi CD, Nascimento MA, Bampi GB, Viancelli A, et al. Human and animal enteric virus in groundwater from deep wells, and recreational and network water. Environ Sci Pollut Res 2015;22:20060–6.
[30] Maurer CP, Simonetti AB, Staggemeier R, Rigotto C, Heinzelmann LS, Spilki FR. Adenovirus, enterovirus and thermotolerant coliforms in recreational waters from Lake Guaíba beaches, Porto Alegre. J Water Health 2015;13:1123–9.
[31] Girardi V, Demoliner M, Rigotto C, Schneider VE, Paesi S, Spilki FR. Assessment of diversity of adenovirus DNA polymerase gene in recreational waters facilitated by ultracentrifugal concentration. J Water Health 2018;16:102–11.
[32] Girardi V, Mena KD, Albino SM, Demoliner M, Gularte JS, de Souza FG, et al. Microbial risk assessment in recreational freshwaters from southern Brazil. Sci Total Environ 2019;651:298–308.
[33] Vieira CB, Corrêa AA, Jesus MS, Luz SLB, Wyn-Jones P, Kay D, et al. Viruses surveillance under different season scenarios of the Negro River Basin, Amazonia, Brazil. Food Environ Virol 2016;8:57–69.
[34] Vergara GGRV, Rose JB, Gin KYH. Risk assessment of noroviruses and human adenoviruses in recreational surface waters. Water Res 2016;103:276–82.
[35] Lee CS, Marion J, Wang Q, Saif L, Lee J. Occurrence of human enteric viruses at freshwater beaches during swimming season and its link to water inflow. Sci Total Environ 2014;472:757–66.
[36] Wyn-Jones AP, Carducci A, Cook N, D'Agostino M, Divizia M, Fleischer J, et al. Surveillance of adenoviruses and noroviruses in European recreational waters. Water Res 2011;45:1025–38.
[37] Shih Y, Tao C, Tsai H, Huang W, Huang T, Chen J, et al. First detection of enteric adenoviruses genotype 41 in recreation spring areas of Taiwan. Environ Sci Pollut Res 2017;24:18392–9.
[38] International Commitee on Taxonomy of Viruses. Reoviridae. Available at: https://talk.ictvonline.org/ictv-reports/ictv_9th_report/dsrna-viruses-2011/w/dsrna_viruses/188/reoviridae.
[39] da Silva M, Miagostovich M, Victoria M. Rotavirus and astroviruses. In: Rose JB, Jiménez-Cisneros B, editors. Global water pathogens project; 2016. Available at: http://www.waterpathogens.org/book/rotavirus.
[40] Parashar UD, Gibson CJ, Bresee JS, Glass RI. Rotavirus and severe childhood diarrhea. Emerg Infect Dis 2006;12:304–6.
[41] World Health Organization. Rotavirus, immunization, vaccines and biologicals. Available at: https://www.who.int/immunization/diseases/rotavirus/en/; 2016.
[42] Carmo GMI, Yen C, Cortes J, Siqueira AA, Oliveira WK, Cortez-Escalante JJ, et al. Decline in diarrhea mortality and admissions after routine childhood rotavirus immunization in Brazil: a time-series analysis. PLoS Med 2011;8:1–11.
[43] Clark A, Jit M, Andrews N, Atchisond C, Edmunds WJ, Sanderson C. Evaluating the potential risks and benefits of infant rotavirus vaccination in England. Vaccine 2014;32:3604–10.
[44] Palihawadana P, Kang G, Navaratnasingam J, Galagoda G, Abeynayake J, Gunasekera M, et al. Rotavirus infection among hospitalized children under five years of age with acute watery diarrhea in Sri Lanka. Vaccine 2018;36:7846–50.
[45] Prez VE, Gil PI, Temprana CF, Cuadrado PR, Martínez LC, Giordano MO, et al. Quantification of human infection risk caused by rotavirus in surface waters from Córdoba, Argentina. Sci Total Environ 2015;538:220–9.
[46] Rigotto C, Victoria M, Moresco V, Kolesnikovas CK, Corrêa AA, Souza DSM, et al. Assessment of adenovirus, hepatitis A virus and rotavirus presence in environmental samples in Florianopolis, South Brazil. J Appl Microbiol 2010;109:1979–87.
[47] Miagostovich MP, Ferreira FFM, Guimarães FR, Fumian TM, Diniz-Mendes L, Luz SLB, et al. Molecular detection and characterization of gastroenteritis viruses occurring naturally in the stream waters of Manaus, Central Amazônia, Brazil. Appl Environ Microbiol 2008;74:375–82.
[48] Victoria M, Fumian TM, Rocha MS, Dalmao F, Leite JPG, Girones R, et al. Gastroenteric virus dissemination and influence of rainfall events in urban beaches in Brazil. J Appl Microbiol 2014;117:1210–8.
[49] Hyypiä T, Hovi T, Knowles NJ, Stanway G. Classification of enteroviruses based on molecular and biological properties. J Gen Virol 1997;78:1–11.
[50] Nikonov OS, Chernykh ES, Garber MB, Yu E. Nikonova. Enteroviruses: classification, diseases they cause, and approaches to development of antiviral drugs. Biochemistry (Moscow) 2017;82:1615–31.
[51] International Commitee on Taxonomy of Viruses. Enterovirus. Available at: https://talk.ictvonline.org/ictv-reports/ictv_online_report/positive-sense-rna-viruses/picornavirales/w/picornaviridae/681/genus-enterovirus.
[52] Robilotti E, Deresinski S, Pinsky BA. Norovirus. Clin Microbiol Rev 2015;28:134–64.
[53] International Commitee on Taxonomy of Viruses. Caliciviridae. Available at: https://talk.ictvonline.org/ictv-reports/ictv_9th_report/positive-sense-rna-viruses-2011/w/posrna_viruses/253/caliciviridae.
[54] Takanashi S, Hashira S, Matsunaga T, Yoshida A, Shiota T, Tung PG, et al. Detection, genetic characterization, and quantification of *Norovirus* RNA from sera of children with gastroenteritis. J Clin Virol 2009;44:161–3.
[55] Widdowson MA, Cramer EH, Hadley L, Bresee JS, Beard RS, Bulens SN, et al. Outbreaks of acute gastroenteritis on cruise ships and on land: identification of a predominant circulating strain of *Norovirus*—United States, 2002. J Infect Dis 2004;190:27–36.
[56] Bull RA, Eden JS, Rawlinson WD, White PA. Rapid evolution of pandemic noroviruses of the GII.4 lineage. PLoS Pathog 2010;6:1000831.
[57] Green J, Gallimore CI, Norcott JP, Lewis D, Brown DW. Broadly reactive reverse transcriptase polymerase chain reaction for the diagnosis of SRSV-associated gastroenteritis. J Med Virol 1995;47:392–8.
[58] Tu ET, Bull RA, Greening GE, Hewitt J, Lyon MJ, Marshall JA, et al. Epidemics of gastroenteritis during 2006 were associated with the spread of *Norovirus* GII.4 variants. Clin Infect Dis 2008;46:413–20.
[59] Karst SM. Pathogenesis of noroviruses, emerging RNA viruses. Viruses 2010;2:748–81.
[60] Kapikian AZ, Wyatt RG, Dolin R, Thornhill TS, Kalica AR, Chanock RM. Visualization by immune electron microscopy of a 27-nm particle associated with acute infectious nonbacterial gastroenteritis. J Virol 1972;10:1075–81.
[61] Timenetsky MCST, Kisielius JJ, Grisi SJFE, Escobar AMU, Ueda M, Tanaka I. Rotavírus, adenovirus, astrovírus, calicivírus e 'small round virus particles' em fezes de crianças, com e sem diarreia aguda, no período de 1987 a 1988, na grande São Paulo. Rev Inst Med Trop São Paulo 1993;35:275–80.
[62] Moresco V, Viancelli A, Nascimento MA, Souza DSM, Ramos APD, Garcia LAT, et al. Microbiological and physicochemical analysis of the coastal waters of Southern Brazil. Mar Poll Bull 2012;64:40–8.

[63] Vieira CB, Mendes ACO, Guimarães FR, Fumian TM, Leite JPG, Gaspar AMC, et al. Detection of enteric viruses in recreational waters of an urban lagoon in the city of Rio de Janeiro, Brazil. Mem Inst Oswald Cruz 2012;107:778–84.

[64] Sedji MI, Varbanov M, Meo M, Colin M, Mathieu L, Bertrand I. Quantification of human adenovirus and norovirus in river water in the north-east of France. Environ Sci Pollut Res 2018;25:30497–507.

[65] Abel NV, Mans J, Taylor MB. Quantitative microbial risk assessment to estimate the health risk from exposure to noroviruses in polluted surface water in South Africa. J Water Health 2017;15:908–22.

[66] Outbreak of hepatitis A virus in Brazil. Available at: https://oglobo.globo.com/rio/chuveirinho-com-agua-contaminada-com-virus-da-hepatite-e-retirado-da-praia-de-sao-conrado-22275242.

[67] Outbreak of hepatitis A virus in Brazil. Available at: https://oglobo.globo.com/rio/tres-pontos-de-coleta-de-agua-no-vidigal-estao-contaminados-com-virus-da-hepatite-e-serao-fechados-22273487.

[68] Sinclair RG, Jones EL, Gerba CP. Viruses in recreational water-borne disease outbreaks: a review. J Appl Microbiol 2009;107:1769–80.

[69] Hofstra N. Quantifying the impact of climate change on enteric waterborne pathogen concentrations in surface water. Curr Opin Environ Sustain 2011;3:471–9.

[70] Jiang SC, Chu W, He JW. Seasonal detection of human viruses and coliphage in Newport Bay, California. Appl Environ Microbiol 2007;73:6468–74.

[71] Hlavsa MC, Roberts VA, Kahler AM, Hilborn ED, Mecher TR, Beach MJ, et al. Outbreaks of illness associated with recreational water—United States, 2011–2012. MMWR Morb Mortal Wkly Rep 2015;64:668–72.