Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Journal of Hazardous Materials Advances 8 (2022) 100149

Contents lists available at ScienceDirect

Journal of Hazardous Materials Advances

journal homepage: www.elsevier.com/locate/hazadv

Study of the correlation between Covid-19 cases and deaths and basic sanitation in Brazil: Is this a possible secondary route of virus transmission?

Mateus Guimarães da Silva*, Alessandra dos Santos Carniel

Environmental Modeling & Monitoring Laboratory (LAMMAM), Federal University of Pampa, UNIPAMPA, R. Pedro Anunciação 111, 96570-000, Caçapava do Sul, RS, Brazil

ARTICLE INFO

Keywords:
Coronavirus
Fecal-oral transmission
Residual waters
Water supply

ABSTRACT

People with COVID-19 may excrete viable SARS-CoV-2 virus through urine and faeces, which has raised concerns about the possibility of transmission of COVID-19 via water contaminated or sewage. These concerns are especially exacerbated in underdeveloped countries like Brazil, where untreated sewage is usually discharged to surface water or soil. Because of that, a hypothesis emerged that was addressed in this study, which seeks to understand whether access to basic sanitation services can influence the proliferation of the virus. A correlation study was carried out between the cases of COVID-19 and the indicators of basic sanitation from all regions of Brazil. The results showed that there was a correlation only with the water supply indicator. A hypothesis that would explain the presented correlation would be the inefficiency of the water treatment systems in Brazil, not totally inactivating the virus, or possible contamination of the water distribution networks by sanitary sewage. In general, the data presented reinforce the need to expand and monitor basic sanitation services, especially to ensure the effective and efficient disinfection of drinking water. This monitoring could be useful for early warning surveillance of the spread of the virus.

1. Introduction

The first cases of COVID-19 were confirmed in Wuhan, China, at the end of 2019. Subsequently cases of covid-19 appeared in several countries, through people who have been to Wuhan city or who have had contact with someone who has been there (World Health Organization, 2020). The SARS-CoV-2 virus mainly attacks the respiratory system and the gastrointestinal system (Wong et al., 2020) and, in many cases, symptoms are not even felt (Zhang et al., 2020a). The main route of transmission of the virus is through contact with infected people, both symptomatic and asymptomatic, or through surfaces where the virus may have accumulated through sedimentation of droplets expelled in coughs, sneezing, speaking or breathing by infected people (Prather et al., 2020; Kampf et al., 2020). However, there may be secondary transmission routes such as drinking water and mainly sanitary sewage, since the presence of SARS-CoV-2 viral RNA has already been confirmed in feces from patients with severe COVID-19 (Zhang et al, 2020b), as well as from presymptomatic and asymptomatic individuals, and found in wastewater from several countries (Ahmed et al., 2020; Wurtzer et al., 2020; Ferreira, 2020). Because of that, a hypothesis emerged that was addressed in this study, which seeks to understand whether access to basic sanitation services can influence the proliferation of the virus. Patients with COVID-19 can shed the virus in their stool for days after all respiratory symptoms have disappeared (Heller et al., 2020; Wu et al., 2020). The persistence of viable SARS-Cov-2 in water and sewage has not yet been determined, however a study with other coronaviruses showed a 99.9% die-off of 10 days in tap water at 23°C and 100 days at 4°C (Gundy et al., 2009).

There are several environmental viral routes from faeces to the mouth, surfaces, water or environments where insect vectors are present. Through these routes, viruses may reach the mouth and infect the respiratory and intestinal tracts of a sensitive individual (Heller et al., 2020). In highly vulnerable environments, monitoring of basic sanitation conditions could help balance sampling biases and contact tracingbased human testing for COVID-19, in addition to being able to preemptively indicate epidemic outbreaks and determine the exact risk of community transmission via the faecal-oral route (Odih et al., 2020; Hendriksen et al., 2019; Murakami et al., 2020).

Around 2.2 billion people worldwide do not have access to safe drinking water and 4.2 billion to basic sanitation (Heller et al., 2020). In Brazil, the average rate of sewage system coverage is 53.2%, while the rate of sewage collection in urban areas is 61%, with a sewage treatment rate of 46% (ITB, 2018). There are already more than 33,5 million confirmed cases of Covid-19 in Brazil, being the third country with the most cases in the world, behind only the USA and India and almost 676 thousand deaths from the disease (Brasil, 2022). Preventing the rapid

* Corresponding author.
E-mail address: mateussilva@unipampa.edu.br (M.G. da Silva).

https://doi.org/10.1016/j.hazadv.2022.100149
Received 13 April 2022; Received in revised form 15 August 2022; Accepted 17 August 2022
Available online xxx

spread of COVID-19 still remains a global challenge (Al Qahtani et al., 2021). Monitoring of basic sanitation services may be a potential indicator of the spread of COVID-19 and, in this sense, spatio-temporal pattern analysis are important tools to clarify the spread of the disease and identify some risk factors. Therefore, the objective of this study was to investigate the correlation between basic sanitation indicators (water supply, sewage collection and sewage treatment indicator) and the number of cases of COVID-19 (accumulated cases COVID-19, incidence in 100 thousand, accumulated deaths and accumulated deaths in 100 thousand) in all regions of Brazil, to identify possible high-risk transmission clusters.

1.1. Fecal-oral transmission

One of the ways in which the viral agent responsible for COVID-19 proliferates is in the human gastrointestinal system (Gao et al., 2020). According to Jones et al. (2020), about 5 to 20% of patients experience some gastrointestinal discomfort while infected by the virus. After analysis carried out in a hospital in Wuhan in contaminated patients, the presence of viral RNA SARS-CoV-2 was confirmed in fecal samples and anal smears (Zhang et al., 2020b), even in patients who did not present gastrointestinal symptoms (Lin et al., 2020) or in asymptomatic cases (Xu et al., 2020). Huang et al. (2020) state that the best method of detecting SARS-CoV-2 RNA is through lower respiratory samples, whose correct diagnoses are 100%, while in fecal samples only 69% of cases were detected. Wu et al. (2020) tested 74 patients in a hospital in Zhuhai, China, of which 55% tested positive for SARS-CoV-2 RNA in the fecal samples and they remained positive for an average of 27.9 days, this results in a mean approximately 11.2 days longer than respiratory samples. Furthermore, Wu et al. (2020), through statistical analyses, suggest the possibility of the duration of viral shedding in feces to occur for up to 5 weeks after the respiratory samples show negative results.

Many viruses attack the gastrointestinal system and use it as the main route of transmission, such as rotaviruses, noroviruses, astroviruses, among many others (Rovida et al., 2013). As for the behavior of viruses from the same family as COVID 101 19, both SARS-CoV and MERS-CoV were characterized by the presence of gastrointestinal symptoms and viral RNA in stool samples (Isakbaeva et al., 2004; Goh et al, 2013), and for Goh et al. (2013) fecal-oral transmission would explain the spread of MERS-CoV. According to Goh et al. (2020), SARS-CoV-2, as well as other CoV, have intermediate levels of potential for fecal-oral transmission, but it presents a differential compared to others, since its outer layer is more resistant, thus having the permanence in the environment and its contagion. However, there is still no proof of the feasibility of permanence and contamination of the virus in the environment (Yeo et al., 109 2020). If confirmed, fecal-oral transmission can enhance and justify the number of cases of COVID-19, especially in places with poor access to basic sanitation, such as in places of open defecation, without water treatment and poor management of infectious solid waste (Gwenzi, 2021).

1.2. Contamination of rivers and drinking water

The survival of viruses in water depends on a series of environmental factors such as sunlight, presence of organic matter or microorganisms, but the main one is temperature (Pinon and Vialette, 2018). Casanova et al. (2009) observed the survival and infection of coronaviruses and other viruses in water for long periods at low temperatures or environments. Gundy et al. (2009) concluded that coronaviruses remain in public water supplies for up to 10 days at room temperature (23°C) and up to 100 days at low temperatures (4°C).

The study by Guerrero-Latorre et al. (2020) was the first to record the RNA of the SARS-CoV-2 virus in urban river waters in Quito, Ecuador. High levels of viral load were quantified, which can be explained by the fact that this water body receives untreated sewage from more than 3 million people (Guerrero-Latorre et al., 2020). In Milan, Rimoldi et al. (2020) detected the presence of RNA SARS-CoV-2 in the three rivers analyzed, which may be the result of illicit discharges or malfunctioning of sewage networks. The communities most susceptible to transmission through contaminated drinking water are those residing in informal settlements, slums, urban or rural areas without access to a reliable network (Gwenzi, 2021). Data regarding coronaviruses are still scarce, but there are facts that link drinking water contamination to other outbreaks of human infections such as cholera, for example (Rebaudet et al., 2013).

2. Methodology

In this paper we investigated the bivariate correlations between the number of cases of COVID-19 (accumulated cases COVID-19, incidence per 100,000 inhabitants, accumulated deaths and accumulated deaths per 100,000 inhabitants) with indicators that reflect the sanitation (water supply, sewage collection and sewage treatment indicator). The analysis took place for all of Brazil and the sampling was delimited considering the cities with more and less cases of COVID-19, and with the best and worst rates of basic sanitation.

2.1. Study area

The study area was defined considering the following parameters: a) cities with higher levels of sanitation; b) cities with lower levels of basic sanitation; c) cities with the highest incidence of COVID-19 per 100,000 inhabitants; d) cities with the lowest incidence of COVID-19 per 100,000 inhabitants; e) cities with the highest number of accumulated cases of COVID-19; f) cities with the lowest number of accumulated cases of COVID-19; g) cities with the highest number of deaths; and h) cities with the highest number of deaths per 100,000 inhabitants. The area is represented in Figure 1 and encompasses all Brazilian regions, totaling 126 cities from 24 states and the Federal District.

2.2. Data collection

Information regarding the number of confirmed cases of COVID-19, the incidence of COVID-19 cases per 100,000 inhabitants, the number of deaths accumulated and the deaths accumulated per 100,000 inhabitants were collected in the Interactive Panel Coronavirus Brazil of the Ministry of Health (Brasil, 2020) in March 2021. The "per 100,000 inhabitants" indicators were calculated for every 100,000 inhabitants of the respective cities. These indicators are used to make it possible to compare cities with different numbers of inhabitants. Data on basic sanitation were collected from the Sanitation Information Panel (Brasil, 2019), and the indicators used were: a) Water supply index, which indicates the total portion of the population, whether urban or rural, served by the network of water supply; b) Sewage service index, which represents the portion of the population, rural or urban, served by a sewage collection network, with or without treatment; and c) Sewage treatment index, which expresses the percentage of sewage treated by water consumed. The cities with the best and worst basic sanitation indicators in Brazil were extracted from the 2020 Basic Sanitation Ranking (Instituto Trata Brasil, 2020) and their population from the reports of the Brazilian Institute of Geography and Statistics (Ibge, 2020).

2.3. Statistical analysis

Bivariate correlation analysis were performed using the Pearson or Spearman methods, with a confidence interval of 95%. Pearson's correlation method is indicated when both variables have normal behavior, while Spearman's correlation method is a non parametric technique,probabilistic distribution free.

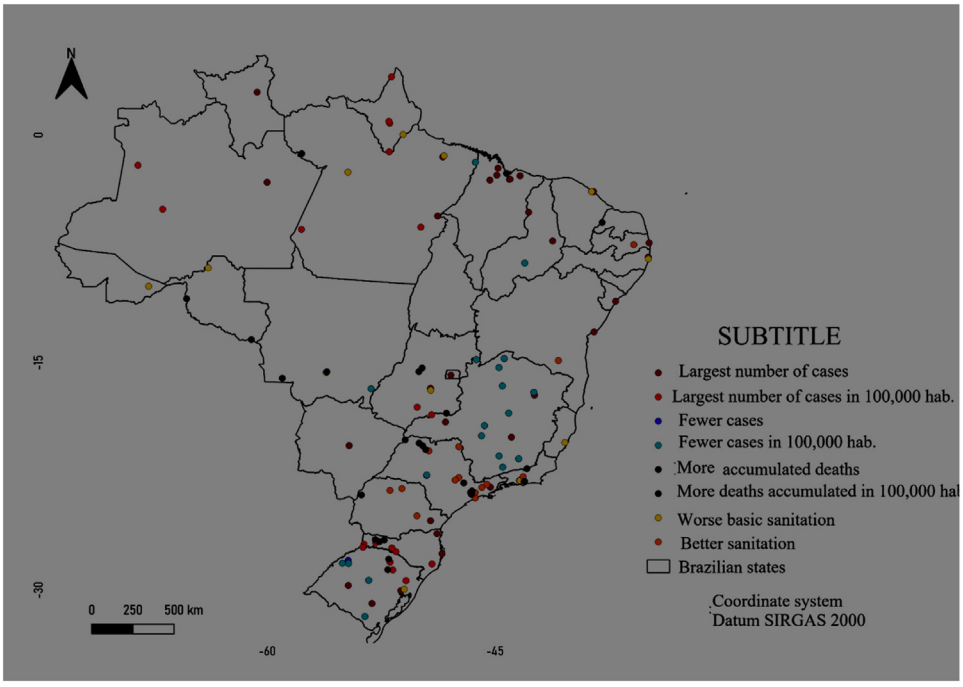

Figure 1. Location map of cities

Table 1
Correlation matrix of basic sanitation indicators and COVID-19

		Water supply	Sewage collection	Sewage treatment
Accumulated cases	*p*	< 0.001*	0.072	0.169
	r	0.391	0.205	0.157
Incidence on 100,000 inhab.	*p*	0.177	0.122	0.611
	r	0.124	-0.177	-0.058
Accumulated deaths	*p*	<0.001*	0.234	0.725
	r	0.374	0.136	0.040
Accumulated deaths in 100,000 inhab.	*p*	0.047*	0.904	0.261
	r	0.181	0.014	0.129

*Statistical significance of 95%

3. Results and discussion

The data collected showed non-normal statistical behavior, thus, the bivariate correlation method used was Spearman's (data reliability of 95%), whose results are shown in Table 1.

Analyzing the data in Table 1, they indicate that there was no statistical significance between the indicators related to sanitary sewage and the COVID-19 disease, considering the sampling period of this study, at the national level, indicating that there is no correlation between the variables. With regard to the water supply indicator, there was a correlation with three indicators of the disease, namely: accumulated cases, accumulated deaths and accumulated deaths per 100,000 inhabitants.

The correlation coefficient of the water supply indicator with the accumulated cases and accumulated deaths of COVID-19 was 0.391 and 0.374, which is considered a weak correlation. Meanwhile, the correlation between water supply and deaths accumulated in 100,000 inhabitants was considered very weak, whose value was equal to 0.181. In all cases, the coefficient had a positive value, that is, the variables are directly proportional. This fact is unexpected, as there are no records in the literature that point to this occurrence (Giacobbo et al., 2021). However Chan et al. (2011) proved that the virus can remain stable for up to three weeks in a liquid environment and viral loads of SARS-CoV-2 were detected in rivers in Ecuador and Italy (Guerrero-Latorre et al., 2020; Rimoldi et al., 2020). These concerns are especially exacerbated in underdeveloped countries like Brazil, where untreated sewage is usually discharged to surface water or soil (which ends up contaminating groundwater).

SARS-CoV-2 is a coated RNA coronavirus with a brittle exterior membrane and therefore is less environmentally stable, being deactivated by oxidants in aqueous media. A hypothesis that would explain the presented correlation would be the inefficiency of the water treatment systems in Brazil or possible contamination of the water distribution networks by sanitary sewage. Insufficient disinfection of faecal-infected drinking water allows viral transmission by consumption, inhalation or aspiration (water bathing) or by skin or eye contact (Pinon and Vialette, 2018).

In Brazil, the lack of basic sanitation overwhelmed the health system with 273,403 hospitalizations and 2,734 deaths from waterborne diseases such as diarrhea, leptospirosis, schistosomiasis and malaria in 2019 (SNIS, 2019). The incidence of hospitalizations was 13.01 cases per 10,000 inhabitants, which generated expenditures of R$ 108 million for the country that year. Hospitalizations and deaths that could have been avoided if the basic sanitation system was satisfactory. Correlation analysis was also performed for each region of the country. The only variables that showed statistical significance were the incidence of cases in 100,000 inhabitants and sewage collection in the southern region with a correlation coefficient equal to -0.561, which indicates that the correlation is moderate and inversely proportional, that is, the higher the rate of the population that is served by sewage collection, the lower is the incidence of COVID-19.

Martins et al. (2020), found moderate and inversely proportional correlation coefficients in cities in the northern region of the country, the value was -0.414, indicating that the larger the portion of the population supplied with water, the smaller the number of cases of the disease. It is noteworthy that in this study they considered the statistical significance to be 90%. In another study carried out for all Brazilian states, the results showed no statistical significance between the mortality rates of patients with COVID-19 and the indicators of water supply and sanitation (Aquino, 2020). On the other hand, Silva et al. (2020) found a significant and inversely proportional correlation between the death rate by COVID-14 and the indicators of sewage treatment and water supply, with -0.611 and -0.464, respectively; they also obtained a correlation between the incidence of COVID-19 and sanitation indicators, being -0.526 for sewage treatment and -0.631 for water supply. This study differs from the others in terms of sample size and period of analysis, most studies were carried out at the beginning of the pandemic, when there was still little data and the rules of social isolation were more correctly followed. Since then, many factors have caused the spread of the virus across the country, such as the non-use of masks, reopening of stores, lack of public policies, non-compliance with social distancing, social inequality, among many others. Thus, the data may have been influenced by these factors.

Even if it is not possible to affirm correlation and causality between the sanitation indicators and the COVID-19 disease, they can be used as tools to monitor cases, as has been done in several countries, through water-based epidemiology (WBE) (Gwenzi, 2021; Baldovin et al., 2021; Betancourt et al., 2021), this is a way to identify the real portion of the population that may be contaminated (Giacobbo et al., 2021; Wiktorczyk-Kapischke et al., 2021; Zhu et al., 2021), after all, studies have already proven the positive correlation between cases of COVID-19 and the concentration of viral RNA SARS-CoV-2 in wastewater from the same region (Weidhaas et al., 2021).

4. Conclusions

With the development of this work, a correlation was observed in three of the twelve analyzes of basic sanitation with the COVID-19 disease, all pointing to a relationship with the water supply indicator. Between this indicator and the variables of accumulated cases and accumulated deaths, the correlation was weak, with a correlation coefficient of 0.391 and 0.374. The variable deaths accumulated per 100 thousand inhabitants showed a very weak correlation with water supply, with a correlation coefficient of 0.181. The other variables did not show statistical significance in the 95% range. Although the transmission of SARS-CoV-2 through water is still under investigation, the results presented reinforce the alert for the need to expand and monitor basic sanitation services, mainly to ensure the effective and efficient disinfection of water supply. Water monitoring could be useful for early warning surveillance of the spread of the virus. Epidemiology based on water quality could help determine an upward or downward trend in the spread of SARS-CoV-2. This work was carried out using secondary data reported during the pandemic and this data source may have missing datasets and the number of COVID-19 cases in Brazil is probably under-reported. However, it is noteworthy that variables that are directly linked to the transmission and proliferation of the virus, such as social distancing, mask use and hygiene, have been neglected in Brazil since the beginning of the pandemic and that the lack of quality public policies, the huge inequality socioeconomic status and denial have made Brazil one of the epicenters of COVID-19. Because of this, it is recommended that future studies take these and other factors into account.

Formatting of funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Ahmed, W., Angel, N., Edson, J., Bibby, K., Bivins, A., O'brien, J.W, Mueller, J.F., 2020. First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: a proof of concept for the wastewater surveillance of COVID 19 in the community. Sci. Total Environ. 728, 138764. doi:10.1016/j.scitotenv.2020.138764, v.

Al Qahtani, S., Al Wuhayb, F., Manaa, H., Younis, A., Sehar, S., 2021. Environmental impact assessment of plastic waste during the outbreak of COVID-19 and integrated strategies for its control and mitigation. Rev. Environ. Health doi:10.1515/reveh-2021-0098.

Aquino, D.S., 2020. Influência do acesso a saneamento básico na incidência e na mortalidade por COVID-19: análise de regressão linear múltipla nos estados brasileiros. Revista Thema 18, 319–331. doi:10.15536/thema, v.

Baldovin, T., Amoruso, I., Fonzo, M., Buja, A., Baldo, V., Cocchio, S., Bertoncello, C., 2021. SARS-CoV-2 RNA detection and persistence in wastewater samples: an experimental network for COVID-19 environmental surveillance in Padua, Veneto Region (NE Italy). Sci. Total Environ. 760, 143329. https://www.sciencedirect.com/science/article/pii/S0048969720368601.

BRASIL, 2019. Ministério do Desenvolvimento Regional. Sistema Nacional de Informações sobre Saneamento (SNIS).

BRASIL, 2020. Ministério da saúde. COVID-19 no Brasil. Brasília.

BRASIL, 2022. Ministério da saúde. Brasília.

Casanova, L., Rutala, W.A., Weber, D.J., Sobsey, M.D., 2009. Survival of surrogate coronaviruses in water. Water Res. 43 (7), 1893–1898. doi:10.1016/j.watres.2009.02.002.

Chan, K.H., Peiris, J.S., Lam, S.Y., Poon, L.L., Yuen, K.Y., Seto, W.H., 2011. The effects of temperature and relative humidity on the viability of the SARS coronavirus. Adv. Virol. doi:10.1155/2011/734690.

Gao, Q.Y., Chen, Y.X., Fang, J.Y., 2020. 2019 Novel coronavirus infection and gastrointestinal tract. J. Digest. Dis. 21 (3), 125–126. doi:10.1111/1751-2980.12851.

Giacobbo, A., Rodrigues, M.A.S., Ferreira, J.Z., Bernardes, A.M., De Pinho, M.N., 2021. A critical review on SARS-CoV-2 infectivity in water and wastewater. What do we know? Sci. Total Environ., 145721 doi:10.1016/j.scitotenv.2021.145721.

Guerrero-Latorre, L., Ballesteros, I., Villacrés-Granda, I., Granda, M.G., Freire-paspuel, B., Ríos-Touma, B., 2020. SARS-CoV-2 in river water: Implications in low sanitation countries. Sci. Total Environ. 743, 140832. doi:10.1016/j.scitotenv.2020.14083.

Gundy, PM, Gerba, CP, Pepper, IL., 2009. Survival of coronaviruses in water and wastewater. Food Environ Virol 1, 10–14. doi:10.1007/s12560-008-9001-6.

Goh, G.K.M., Dunker, A.K., Uversky, V., 2013. Prediction of intrinsic disorder in MERS-CoV/HCoV-EMC supports a high oral-fecal transmission. PLoS Currents 5. doi:10.1371/currents.outbreaks.22254b58675cdebc256dbe3c5aa6498b.

Goh, G., Dunker, A.K., Foster, J.A., Uversky, V., 2020. Shell disorder analysis predicts greater resilience of the SARS-CoV-2 (COVID-19) outside the body and in body fluids. Microb. Pathog. 144, 104177. doi:10.1016/j.micpath.2020.104177, v.

Gundy, P.M., Gerba, C.P., Pepper, I.L., 2009. Survival of coronaviruses in water and wastewater. Food Environ Virol 1 (10). doi:10.1007/s12560-008-9001-6, vn.

Gwenzi, W., 2021. Leaving no stone unturned in light of the COVID-19 Faecal-oral hypothesis? A water, sanitation and hygiene (WASH) perspective targeting low-income countries. Sci. Total Environ. 753, 141751. doi:10.1016/j.scitotenv.2020.141751, v.

Heller, L, Mota, CR, Greco, DB, 2020. COVID-19 faecal-oral transmission: are we asking the right questions? Sci. Total Environ. 729, 138919. doi:10.1016/j.scitotenv.2020.138919.

Hendriksen, R.S., Lukjancenko, O., Munk, P., Hjelmsø, M.H., Verani, J.R., Ng'eno, E., Aarestrup, F.M., 2019. Pathogen surveillance in the informal settlement, Kibera, Kenya, using a metagenomics approach. PLoS One 14 (10), e0222531. doi:10.1371/journal.pone.0222531.

Huang, Y., Chen, S., Yang, Z., Guan, W., Liu, D., Lin, Z., Zhang, Y., Xu, Z., Liu, X., Li, Y., 2020. SARS-CoV-2 viral load in clinical samples from critically Ill patients. Am. J. Respir. Crit. Care Med. 201 (11), 1435–1438. doi:10.1164/rccm.202003-0572LE, vn.

IBGE, 2020. Instituto Brasileiro de Geografia e Estatísticas.

Isakbaeva, E., Khetsuriani, N., Beard, R.S., Peck, A., Erdman, D., Monroe, S.S., Tong, S., Ksiazek, T.G., Lowther, S., Smith, I., Anderson, L.J., Lingappa, J., Widdowson, M.A., 2004. SARS associated coronavirus transmission, United States. Emerg. Infect. Dis. 10 (2), 225–231. doi:10.3201/eid1002.030734, vn.

Jones, D.L., Baluja, M., Graham, D.W., Corbishley, A., Mcdonald, J.E., Malham, S.K., Hillary, L.S., Connor, T.R., Gaze, W.H., Moura, I.B., Wilcox, M.H., Farkas, K., 2020. Shedding of SARS-CoV-2 in feces and urine and its potential role in person-to-person transmission and the environment-based spread of COVID-19. Sci. Total Environ. 749, 141364. doi:10.1016/j.scitotenv.2020.141364, v.

Kampf, G., Todt, D., Pfaender, S., Steunmann, E., 2020. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. J. Hosp. Infect. 104 (3), 246–251. doi:10.1016/j.jhin.2020.01.022, vn.

Lin, L., Jiang, X., Zhang, Zhenlinh, Huang, S., Zhang, Zhenyi, Zhaoxiong, F., Zhiqiang, G., Liangqing, G., Shi, H., Mai, L., Lin, X., Lai, R., Li, R., 2020. Gastrointestinal symptoms of 95 cases with SARS-CoV-2 infection. Gut 69 (3), 997–1001. doi:10.1136/gutjnl-2020-321013, vn.

Martins, B., Maia, C., Feitosa, A., Dias, A., 2020. Correlação entre o acesso ao serviço de água e incidência por COVID-19 em municípios da região norte do país. 17° congresso nacional do meio ambiente 12 (1) vn.

Murakami, M, Hata, A, Honda, R, et al., 2020. Letter to the editor: wastewater-based epidemiology can overcome representativeness and stigma issues related to COVID-19. Environ. Sci. Technol. 54, 5311. doi:10.1021/acs.est.0c02172.

Odih, EE, Afolayan, AO, Akintayo, I, et al., 2020. Could water and sanitation shortfalls exacerbate SARS-CoV-2 transmission risks? Am. J. Trop. Med. Hyg. 103, 554–557. doi:10.4269/ajtmh.20-0462, 202010.4269/ajtmh.20-0462.

Pinon, A., Vialetee, M., 2018. Survival of viruses in water. Intervirology 61 (5), 214–222. doi:10.1159/000484899, vn.

Prather, K.A., Wang, C.C., Schooley, R.T., 2020. Reducing transmission of SARS-CoV-2. Science 368 (6498), 1422–1424. doi:10.1126/science.abc6197, vn.

Rebaudet, S., Sudre, B., Faucher, B., Piarroux, R., 2013. Environmental eterminants of cholera outbreaks in Inland Africa: a systematic review of transmission foci and propagation routes. J. Infect. Dis. 208 (1), 46–54. doi:10.1093/infdis/jit195, vn.

Rimoldi, S., Stefani, F., Gigantiello, A., Polesello, S., Comandatore, F., Mileto, D., Maresca, M., Longobardi, C., Mancon, A., Romeri, F., Pagani, C., Cappelli, F., Roscioli, C., Moja, L., Gismondo, M.R., Salerno, F., 2020. Presence and infectivity of SARS-CoV-2 virus in wastewaters and rivers. Sci. Total Environ. 744, 140911. doi:10.1016/j.scitotenv.2020.140911, v.

Rovida, F., Campanini, G., Piralla, A., Adzasehoun, K., Sarasini, A., Baldanti, F., 2013. Molecular detection of gastrointestinal viral infections in hospitalized patients. Diagn. Microbiol. Infect. Dis. 77 (3), 231–235. doi:10.1016/j.diagmicrobio.2013.07.020, vn.

Silva, R.R.D., Santos, M.B.D., Santos, A.D.D., Tavares, D.D.S., Santos, P.L.D., 2020. Coronavirus disease and basic sanitation: too early to be worried? Rev. Soc. Bras. Med. Trop. 53. doi:10.1590/0037-8682-0345-2020.

Weidhaas, J., Aanderud, Z.T., Roper, D.K., Vanderslice, J., Gaddis, E.B., Ostermiller, J., Lacross, N., 2021. Correlation of SARS-CoV-2 RNA in wastewater with COVID-19 disease burden in sewersheds. Sci. Total Environ. 775, 145790. doi:10.1016/j.scitotenv.2021.145790.

Wiktorczyk-kapischke, N., Grudlewska-buda, K., Wałecka Zacharska, E., Kwiecińska-Piróg, J., Radtke, L., Gospodarek Komkowska, E., Skowron, K., 2021. SARS-CoV-2 in the environment–non droplet spreading routes. Sci. Total Environ., 145260 doi:10.1016/j.scitotenv.2021.145260.

Wong, S., Lui, R., Sung, J., 2020. Covid- 19 and the digestive system. J. Gastroenterol. Hepatol. 35 (5), 744–748. doi:10.1111/jgh.15047, vn.

Wu, Y., Gui, C., Tang, L., Hong, Z., Zhou, J., Dong, X., Yin, H., Xiao, Q., Tang, Y., Qu, X., Kuang, L., Fang, X., Mishra, N., Lu, J., Shan, H., Jiang, G., Huang, X., 2020. Prolonged presence of SARS-CoV-2 viral RNA in faecal samples. Lancet Gastroenterol. Hepatol. 5 (5), 434–435. doi:10.1016/S2468-1253(20)30083-2, vn.

World Health Organization, 2020. Water Sanitation Hygiene: Economics Disponível em: <.

Wurtzer, S.; Marechal, V.; Mouchel, J.M.; Maday, Y.; Teyssou, R.; Richard, E.; Almayrac, J.; Moulin, L., 2020. Time course quantitative detection of SARS-CoV-2 in Parisian wastewaters correlates with COVID-19 confirmed cases. https://doi.org/10.1101/2020.04.12.20062679.

Xu, Y., Li, X., Zhu, B., Liang, H., Fang, C., Gong, Y., Guo, Q., Sun, X., Zhao, D., Shen, J., Zhang, H., Liu, H., Xia, H., Tang, J., Zhang, K., Gong, S., 2020. Characteristics of pediatric SARS-CoV-2 infection and potential evidence for persistent fecal viral shedding. Nat. Med. 26, 502–505. doi:10.1038/s41591-020-0817-4, v.

Yeo, C., Kaushal, S., Yeo, D., 2020. Enteric involvement of coronaviruses: is faecal–oral transmission of SARS-CoV-2 possible? Lancet Gastroenterol. Hepatol. 5 (4), 335–337. doi:10.1016/S2468-1253(20)30048-0, vn.

Zhang, S., Guo, M., Wu, F., Xiong, N., Wang, Z., Duan, L., Chen, L., Ouyang, H., Jin, Y., 2020a. Factors associated with asymptomatic infection in health-care workers with severe acute respiratory syndrome coronavirus infection in Wuhan, China: a multicenter retrospective cohort study. Clin. Microbiol. Infect. doi:10.1016/j.cmi.2020.08.038.

Zhu, Y., Oishi, W., Maruo, C., Saito, M., Chen, R., Kitajima, M., Sano, D., 2021. Early warning of COVID-19 via wastewater-based epidemiology: potential and bottlenecks. Sci. Total Environ., 145124. https://www.sciencedirect.com/science/article/pii/S004896972100190X.