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Review

A Narrative Review of the Survival of the Coronavirus Family in Feces, Urine, and Wastewater

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Abstract
Wastewater is one of the most important ways of transmitting viral and bacterial pathogens that can cause nosocomial and clinical infections in humans. Although previous studies show that there is no current evidence that active coronaviruses are present in surface or ground waters or are transmitted through contaminated drinking water, there is an urgent need for more effective preventive measures to limit the spread of infection, which depends on understanding their routes of transmission and persistence in different environments. Here is a narrative review of the survival of the coronavirus family in feces, urine, and wastewater. Articles related to the presence of SARS-CoV-1 and SARS-CoV-2 in feces, urine, and wastewater and their survival time were searched in the literature. Articles published in the last decade (2000–2021) were selected based on the PRISMA method. The literature review showed that due to the high concentration of RNA virus in blood and urine samples with positive oral and anal swabs, no positive case has been reported using respiratory tests. The main findings of this review show that the maximum survival time of the SARS-CoV-2 in feces and urine was 33 and 31 days, respectively. Moreover, environmental conditions (temperature and pH) are the most important factors in the survival of SRRS-CoV in feces, urine, and wastewater. This study provides researchers with basic and useful information for future research orientations in relation to wastewater treatment plant systems to eliminate and manage emerging viral contaminants.
Keywords: SARS COV-2, Survival, Wastewater, Feces, Urine

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1. Introduction

Pandemics are common phenomena in human life history that occur on average once every 30 years and lead to human morbidity and mortality worldwide (1). Coronavirus disease 2019 (COVID-19), which started in late 2019, has now become a global epidemic and has spread to all countries of the world (2). In 2002, acute respiratory syndrome and the recently emerging Middle East respiratory syndrome (MERS), with many communities involved, can be described as threats to human health. About 17 years ago, a new acute respiratory disease occurred in China. The first case of the disease was identified in Guangdong province, China. The patient was a 45-year-old man with respiratory symptoms and fever (3). It spread to most provinces and countries all over the world (4). Severe acute respiratory syndrome (SARS) spread from person to person in family members or health care providers (5). Accordingly, the illness affected many people in the United States, Europe, and Asia (6). The diseases can be difficult to detect if people are more likely to travel and not to observe social distance. Therefore, the availability of early diagnostic tests reduces the spread of the disease. Reverse transcription-polymerase chain reaction (RT-PCR) test is required for early detection (7). World Health Organization (WHO) and the Centers for Disease Control (CDC) provide guidelines for communities, indicating that handwashing and the use of masks can be effective strategies to prevent transmission of the virus (8). However, numerous studies indicate that Severe acute respiratory syndrome coronavirus (SARS-CoV) can survive in food, water, and wastewater for a long time (9,10). The contamination of water supplies through wastewater discharge has been historically recognized as a risk factor for human health. The water consumption of communities can cause the spread of pathogens, creating the conditions for outbreaks or sporadic cases of infectious diseases. Human pathogens such as bacteria, worms, protozoa, and viruses are often detected in water environments and are considered to be responsible for a considerable proportion of waterborne diseases. The presence of contaminants in wastewater is the reason for ongoing monitoring which can increase

the preparedness of utilities to respond to public health problems (11). Wastewater containing the Ebola virus is discharged directly into the wastewater collection system without any treatment (11). Gastrointestinal symptoms such as diarrhea, nausea, and vomiting have been reported among patients during the COVID-19 outbreak (12, 13). Literature review showed that SARS-CoV -2 is transmitted through aerosols. Transmission through water and wastewater resource has not been reported yet. Although the virus may survive in drinking water and wastewater, there is no evidence that SARS-CoV-2 can be transmitted through contaminated drinking water (13). Generally, there are more viruses in the winter than in the summer in the wastewater treatment plants, which can be mostly related to gastrointestinal diseases or poliomyelitis caused by enterovirus, hepatitis (A and E), norovirus, and other Caliciviruses (14). Some research findings indicated that SARS-CoV-1 and SARS-CoV-2 can survive for 4-72 hours and under different environmental conditions, this survival time varies from 4 hours to 31 days (15). According to Wang et al, SARS-CoV can survive for 2-14 days at 20-24°C in wastewater (16). Based on the results of the study conducted by Duan et al, SARS-CoV is stable in the environment and can survive for at least 96 hours in feces and on surfaces at room temperature. It remains in the urine for up to 72 hours at a low infectious dose. However, at 20-37°C, it remains for at least 2 hours. Radiation was reported to inactivate the virus in 60 minutes (3). Knowing the survival time of viruses in different environments can be of great importance for making decisions about control and preventive measures for the spread of contamination in human populations. The purpose of this study was to review the survival of the coronavirus family in feces, urine, and wastewater.

2. Materials and Methods

2.1. Search Strategies

PubMed, Scopus, and Web of Science databases were searched independently for articles published in English up to November 6, 2021. The keywords used in the search were "Coronavirus" and "SARS" and "Ebola" and "MERS" and "Survival" and "Water and Wastewater" and "Stool" and "Feces" and "Fecal". The main data of the articles were collected and categorized. Three data extraction tables were developed to collect data on the important finding, method of detection, and survival period of the virus in wastewater, feces, and urine. The keywords consisting "coronavirus" OR "SARS CoV" OR "Urine" OR "feces" OR "wastewater" OR "detection" AND "stool" OR "water" were used.

2.2. Paper Selection Criteria

The criterion for the selection of articles was access to original English full-text articles reporting the detection and survival of coronavirus in feces, urine, and wastewater. In addition, letters to editors, review articles, chapters, books, conferences, and duplicate papers were excluded. Country, types of environment (faces, urine, and wastewater), detection method, minimum and maximum survival times, and type of virus were considered in this study. Additionally, studies published in non-English languages were excluded from the study. Articles published in the last decade (2000–2021) were selected based on the PRISMA method. Summary of standard four-steps protocol for literature review is shown at Fig. 1.

3. Results and Discussion

All the data analyzed were related to the coronavirus family. According to the findings of the present study,

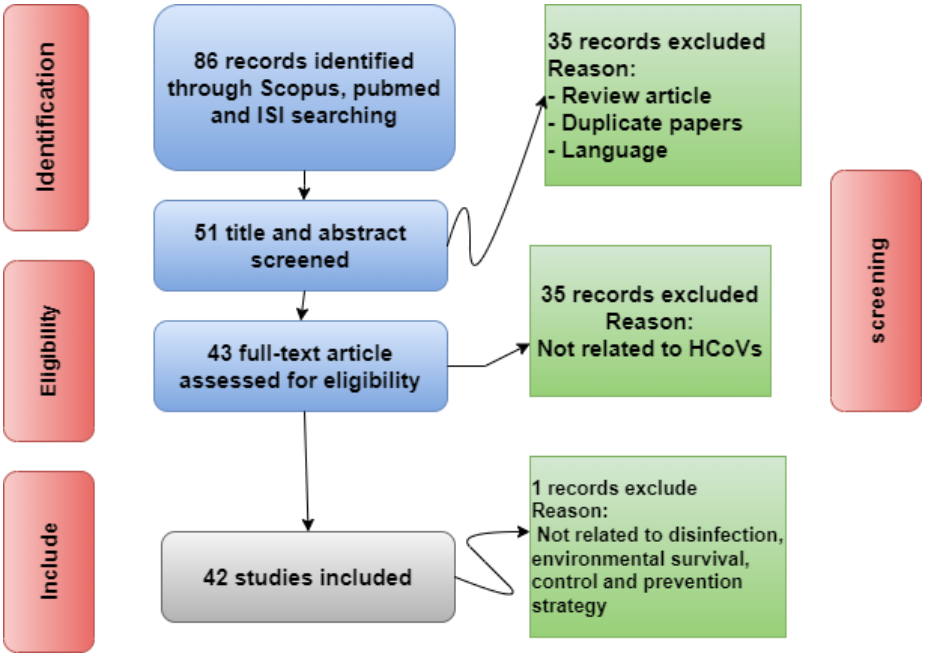

Fig. 1. Summary of a Standard Four-step Protocol for Literature Review

the half-life of these viruses varies according to their type. The coronavirus is transmitted from a person who has diarrhea and the virus is present in his/her diarrhea for 22 days and remains in the pasteurized sludge for 9 days (17). For SARS-CoV, it is 73 hours to 14 days, depending on the temperature and the laboratory environment. The survival of Ebola virus varies from 8 to 19 days in the sewers of various places and it remains in the blood serum for up to 46 days. MERS-CoV has been reported to be active in the urine for up to 13 days. It is noteworthy that with the increase of the temperature, the viability and activity of these viruses were decrease. SARS-CoV 2 survived in feces for 1-33 days and in urine for 3-22 days (Table 1) (2). In some studies, urine tests were negative despite the presence of the virus in the feces. In general, the survival of viruses varies depending on the temperature, the organic matter, and presence of antagonistic bacteria. Having complete and comprehensive information about virus transmission is vital for enhancing health in communities. The concentrations of viruses in bioaerosols of wastewater treatment plants were measured for their effect on the health of workers and residents over a 20-month

Table 1. Studies on the Survival Time of Coronavirus Family Published before COVID-19 Pandemic

Coronavirus Type	Important Findings	Source of Sampling	Reference
SARS	SARS-CoV can survive for 2-14 days in 20-24°C, respectively. The virus was inactivated after 8 days. They found that SARS-CoV cannot be alive after disinfection but it can still be detected.	Wastewater	(16)
SARS	Viruses can be active in wastewater. They may be inactivated by treatment or disinfection.	Wastewater	(27)
SARS	Generally, more viruses can be detected in the winter than in the summer in the wastewater. They have realized that pathogens may exist in wastewater. Maximum disinfection should be carried out during the swimming seasons as effluent enters the sea.	Wastewater	(28)
SARS	They found that although SARS spreads through respiratory droplets, approximately in 50% of patients infected with SARS, the virus was detected in the feces for 10 weeks.	Feces	(29)
SARS	SARS-CoV is stable in the environment and can survive at least for 96 hours in feces and on surfaces at room temperature. It remains in the urine for up to 72 hours at a low infectious dose. However, at 20-37°C, it remains for at least 2 hours. Radiation inactivated the virus in 60 minutes.	Feces, urine	(3)
SARS	They reported that SARS had a low rate of viral shedding in the early days. In fluids secreted from the upper respiratory system and feces, the virus was detected on the 14th day.	Upper respiratory tract, faces	(30)
SARS	They concluded that due to the ability of the SARS-CoV to replicate in the intestine, it was found on the 73th day.	Feces	(31)
MERS-Cov	In the sample taken from a 73-year-old, the maximum amount of MERS-CoV in the urine was detected on day 13. After the kidney failure on the 14th day, the test was negative.	Urine	(32)
Ebola	Ebola virus was inactivated at a high temperature within 7 days, and inactivation occurred at 30°C faster than 22°C.	Wastewater	(17)
SARS	SARS-CoV can survive at room temperature in alkaline feces for up to 4 days. All disinfectants reduced the virus load by > 3 log within 5 minutes.	Feces	(33)
Transmissible gastroenteritis	Coronavirus stays in water and wastewater for 22 days, it sometimes causes gastroenteritis. It remains in water at 25°C for 22 days and remains in pasteurized wastewater sludge for 9 days.	Water, waste water	(34)
SARS	In vitro experiments indicated that SARS survived in the home and hospital wastewater environments for 2 days at 4-25°C and in feces for 14-3 days at 4-25°C, respectively. At the same temperatures (4-25°C), it remained in the urine for 17 days.	Feces, urine, water.	(16)
Ebola	The survival of Ebola virus was reported to be over 18 days in hospital wastewater and human feces. Based on the results, 5 $\log_{10}$ reduction occurred on day 8. The virus was inactivated in shorter time at 37°C than at 22°C.	Wastewater, feces	(35)
Ebola	The results showed that the Ebola virus titer decreased 90% on first days, which could be due to the inactivation of the viral particles. Ebola virus was less stable than intestinal viruses.	Wastewater	(36)
Coronaviruses	Survival of coronavirus depends on the water temperature, organic matter, and the antagonistic bacteria. The virus become inactive within 10 or more than 1000 days. They found that the virus survived in wastewater for about 2-4 days.	Water, Wastewater	(19)
Ebola	The virus was inactivated after 20 seconds by adding 5-10 mg/L of sodium hypochlorite (PH increased to 11.2).	Wastewater	(37)
Ebola	Ebola virus survived in feces and urine for 19 and 30 days, respectively.	Feces, urine	(38)
SARS	SARS-CoV was detected in the feces in 6 to 90 hours.	Feces, urine	(39)
SARS	SARS-CoV was detected at room temperature in the feces and urine at least 2 and less than 24 hours, respectively.	Feces, urine	(40)
Ebola virus	Ebola virus survived in different fluids for a longer period of time, as it persists in the serum for 56 days.	Serum	(41)

period. The viral loads were significantly higher than the threshold values recommended by the U.S. Environmental Protection Agency (US EPA) (18). Gastrointestinal symptoms such as diarrhea, nausea, and vomiting have been reported among patients during the outbreak of SARS-CoV-2. Importantly, patients with a positive stool test had no gastrointestinal symptoms and this was not associated with the severity of the lung infection. The temperature and duration of wastewater reaching the municipal wastewater treatment plant are effective in detecting the virus (Table 2). According to experiments, the survival time of the virus in water at 23°C was 2-4 days, considering the effects of temperature, organic matter level, and presence of antagonistic bacteria (19). Laboratory scale studies indicate that the survival time of coronavirus can range from days to weeks. It should be kept in a clean, covered container in order to preserve treated water. In addition, filtration and disinfection can help to inactivate the virus in pandemics (20). Individuals may be infected by inhalation of virus-infected aerosols, but the risk of transmission is lower in direct contact with feces (21). Review of the literature shows that there is no strong evidence for the transmission of SARS-CoV-2 viruses through water and wastewater right now (22). So far there has been no general conclusion that contaminated wastewater can transmit the virus. In addition, there was no conclusion that wastewater causes SARS. But it is better to consider wastewater treatment lagoons for 20 days retention time rather than other critical parameters such as temperature and pH. Using disinfectants is another strategy for inactivating coronaviruses. The use of personal protective equipment is recommended to protect healthcare workers and those working in wastewater treatment plants (23). Sodium hypochlorite is used as a disinfectant in health guidelines. Based on the laboratory data, the survival of SARS-CoV at room temperature (25°C) in feces and urine was reported to be 2 and 14 days, respectively (16). As shown, the maximum survival time of SARS-CoV-2 in feces was 33 days (24). In most cases, urine tests were negative, but in the study of Zheng et al, a duration of 31 days was reported (25) (Table 3). Personnel with direct contact with infected patients should use personal protective equipment such as gowns, masks, shields, and disposable gloves. Additionally, infected persons should be prevented from entering sterile areas, diagnostic rooms, and medical equipment storage rooms (26).

4. Conclusion

Coronavirus can survive in filtered drinking water at 23°C for approximately 2-14 days. It can survive for up to 9 days in pasteurized sludge. Disinfectants can reduce SARS-CoV load by > 3 log within 5 minutes. The present study showed that SARS-CoV, MERS-CoV and Ebola virus can survive for 2-14 days in filtered drinking water at 23°. Accordingly, coronavirus can be inactivated at 23°C and 25°C within 2-12 days, respectively. Common disinfectants such as 70% ethanol and sodium hypochlorite can be used for inactivation within 1 minute. The transmission risk of the disease through the feces is low, but it can cause diarrhea and intestinal infection by swallowing. The maximum survival time of SARS-CoV-2 in feces and urine was reported to be 33 and 31 days, respectively. The findings of this review show that various factors can affect the survival time of the virus in different environments. Therefore, the survival time of the SARS-CoV in feces, urine, and wastewater has been reported to be very variable, and this time has been reported to range from a few hours to 31 days. Environmental conditions (temperature and pH) are the most important factors in the survival of SARS-

Table 2. Studies on the Survival Time of SARS-CoV-2 Published During COVID-19 Pandemic

Country	City/Region	Source	Detection Method	Type of Disinfection	Population	Year	Important Finding	Reference
Australia	Monte-Carlo	Wastewater	RT-qPCR	NR	600 000	2020	SARS-CoV-2 was detected in wastewater over 6 days in this study. Grab sampling techniques was used. Two methods including direct RNA extraction and ultrafiltration were used. The sensitivity analysis showed 10 log/g SARS-CoV-2 RNA copies in feces and wastewater.	(42)
China	Wuhan	Diarrhea, nausea, and vomiting	NR	NR	NR	2020	Gastrointestinal symptoms such as diarrhea, nausea, and vomiting have been reported among patients during the COVID-19 outbreak. The virus can be transmitted through infected hands. In this study, the use of probiotics to improve gastrointestinal symptoms and protect the respiratory system is recommended.	(12)
The United States	Snohomish County, Washington	Serum, urine and Feces samples	RT-qPCR	NR	Case study	2020	Serum and fecal samples were negative in both collection dates and positive after 7 days of illness, respectively.	(43)
China	Shanghai, Hainan, and Hefei	Urine and feces samples	Nucleic acid detection	NR	10 Cases (children)	2020	The presented study showed that in 10 identified infected children, 6 patients have been identified as positive in a fecal sample for 3 to 13 days after illness onset. Additionally, 2 patients had negative tests 10 days after the onset of the disease. Urine and serum samples were negative for 2 to 3 days after the onset of the disease.	(26)

Table 2. Continued

Country	City/Region	Source	Detection Method	Type of Disinfection	Population	Year	Important Finding	Reference
China	NR	Feces	RT-qPCR	NR	Case study	2020	Despite the negative respiratory test, the child's fecal test was positive 26 days after the onset of the disease.	(44)
China	NR	Blood and urine	RT-qPCR	NR	9 Cases (hospitalized patients)	2020	Due to the high concentration of RNA virus in blood and urine samples, no positive case has been reported using respiratory tests.	(45)
China	Wuhan	Blood and serum	qRT-PCR	NR	16 Cases (patients)	2020	Of the 15 patients with SARS-CoV-2 in this study, 8 oral tests, 4 anal tests, 6 blood tests, and 3 serum positive tests were reported on the first day. However, after 5 days, only 4 people had a positive oral test. A very interesting point in this study was that none of the patients with viremia blood had a positive oral and anal swabs.	(46)
China	Jinhua Municipal Central	Feces	Nucleic acid detection	NR	14 Cases (patients)	2020	Importantly, patients with a positive fecal test had no gastrointestinal symptoms and this was not associated with the severity of lung infection.	(26)
The United States	Tempe, Arizona,	Feces	RT-qPCR	NR	185 038	2020	The temperature and duration of wastewater reaching the municipal wastewater treatment plant are effective in detecting the virus. The half-life of SARS-CoV-2 at 20°C in most wastewater systems worldwide is reported to be approximately 4.8 and 7.2 hours, respectively.	(47)
The Netherlands	Amsterdam Airport Schiphol, Haarlemmermeer	Human wastewater	RT-PCR	NR	NR	2020	24-hour 10 L samples taken from human wastewater were tested positive for the presence of viral RNA.	(48)
Australia	Brisbane, Queensland	Untreated wastewater	RT-qPCR	NR	198 000, 505 000, and 231 000, for Plant A, B, and C, respectively	2021	From three wastewater treatment plants, 63 composite samples were taken, and 21 cases of SARS-CoV-2 were reported positive. The number of copies of SARS-CoV-2 RNA in wastewater was not related to the number of daily cases, which can be attributed to the characteristics of the basin, collection system, and duration time.	(10)
Italy	Milan and Rome	Influent wastewater	RT-PCR	NR	105 000	2020	Six of the total 24-hour composite samples (n = 12) were identified as positive effluents. It is recommended that the WHO protocol be used for wastewater treatment during the virus outbreak after appropriate modifications.	(49)
Italy	Milano and Monza e Brianza	Raw and treated wastewater	RT-PCR		480 000 population and 4.500 industrial facilities	2020	The presence of SARS-CoV-2 RNA was detected, indicating a residue at the effluent outlet confirming that secondary treatment may also have residual RNA in the effluent. The river water receiving SARS-CoV-2 was zero. Despite viral RNA in urine and feces, it cannot be infected. In addition, testing for infectivity has shown that virus pathogenicity in wastewater can be zero, whether in raw or treated samples and surface water.	(50)
China	Zhejiang	Wastewater	qRT-PCR		33 Laboratory-confirmed patients	2020	SARS-CoV-2 was positive in the samples of the patients, while the respiratory and fecal samples of the patient were positive in a room with mechanical ventilation and negative without mechanical ventilation. The risk of infection from wastewater and rivers is negligible.	(46)
Singapore	Singapore	Feces	RT-PCR	NR	3 Cases isolation rooms	2020	The patient with respiratory problems, who had not reached the pneumonia stage, had no gastrointestinal symptoms such as diarrhea but had a positive SARS-CoV-2 fecal test.	(51)
France	Parisian area	Feces, raw wastewater	RT-qPCR	NR	100 000 Cases inhabitants	2020	This study showed that the onset of SARS-CoV-2 occurred before the onset of clinical symptoms in affected individuals. In addition, the results showed that it stays in the wastewater for a long time	(52)
The United States	Massachusetts	Raw wastewater of urban origin	RT-qPCR	NR	7000 Individuals	2020	The number of positive cases of SARS-CoV-2 in wastewater is higher than the number of infected cases, which may cause transmission of the disease to healthy people. Viral titers in feces have been reported to be about 3000 times higher compared to raw wastewater samples.	(53)
Spain	Murcia	Influent, secondary and tertiary effluent	RT-qPCR	NR	100 000 Inhabitants	2020	RNA removal efficiency of SARS-CoV virus from input to secondary sedimentation and finally advanced purification has varied between 20% and 100%.	(54)

Table 2. Continued

Country	City/Region	Source	Detection Method	Type of Disinfection	Population	Year	Important Finding	Reference
Turkey	Ambarli, Pasakoy and Kadikoy	Raw wastewater	RT-qPCR	NR	600000 People	2020	SARS-CoV-2 was positive in 5 out of 7 samples taken from raw wastewater. However, all samples taken from manholes were positive. The virus titers of raw wastewater from the manhole were higher than those of the inlet of wastewater treatment plants. These amounts decreased overtime in the wastewater treatment plant.	(55)
Bangladesh	Noakhali	Wastewater	RT-PCR	NR	NR	2021	The results showed that temporal changes in the load of SARS-CoV-2 RNA in wastewater are reduced. In this study, the time interval was not measurable due to different discharge sites containing virus RNA. However, changes in the environment such as temperature fluctuations and humidity are effective in virus residues.	(56)
France	Parisian area	Raw wastewater	RT-qPCR	NR	More than 100000 inhabitants	2020	With the increase in the number of patients, the amount of SARS-CoV-2 genome has increased dramatically and the presence of SARS-CoV-2 in all municipal wastewater samples was confirmed. There were no changes in the concentration of viruses in the raw wastewater during the assessed period because of no significant rain fall.	(57)
The Netherlands	Dutch	Wastewater	qRT-PCR	NR	6 Cities	2020	Wastewater samples were positive for each assay.	(58)
Italy	Milano	Raw and treated wastewater	RT-PCR	UV	2 million persons	2020	SARS-CoV-2 RNA was detected in the incoming stream but not in the effluent. With epidemiological changes, the amount of virus genome detected decreased after 8 days.	(50)
The United States	Northern Indiana	Municipal wastewater	NR	NR	NR	2020	SARS-CoV-2 remained at room temperature in wastewater and tap water for 1.5 and 1.7 days, respectively. In this study, the virus genome remained in the high-titrated wastewater for 7 days. SARS-CoV-2 survives for 15 and 2 minutes at 50 and 70°C in wastewater, respectively. SARS-CoV-2 has been reported to survive in untreated wastewater for 20.4 and 12.6 days at 15 and 25°C, respectively.	(59)
Australia	Brisbane	Wastewater	RT-qPCR	NR	325000 People	2020	The temperature had the greatest effect on the first-order decay rate of SARS-CoV-2 RNA. SARS-CoV-2 RNA T_{90} (time required for 1 $\log_{10}$ reduction) ranged from 8.04 to 27.8 days in untreated wastewater, 5.71 to 43.2 days in autoclaved wastewater, and 9.40 to 58.6 days in tap water.	(59)
Italy	Cremona	Feces and urine	RT-PCR	NR	411 Patients	2020	SARS-CoV-2 RNA can be detected in feces and urine. In watery diarrhea, it survives for about 3 hours to 5 days. The possibility of transmitting SARS-CoV-2 through feces is very low.	(60)
Italy	Rome	Feces	RT-PCR	NR	15 Patients	2020	Fifteen days after the first positive respiratory test, 6 fecal samples from 15 infected patients were positive. Fecal samples were positive 25 days after the onset of the disease.	(61)
China	Guangzhou	Feces	RT-PCR	NR	745 'Highly suspected' children	2020	Children in this study did not need respiratory support or intensive care. Eight children had positive rectal swabs after a negative respiratory test, which increased the risk of fecal-oral transmission. Some children had a positive rectal test for up to 13 days after recovery. The probability of a positive fecal test increases.	(51)
China	Tianjin	Feces	RT-PCR	NR	3 Infected children	2020	Ten days after recovery, all patients and their families were reported to have positive fecal test results. Most children do not have acute symptoms of SARS-CoV-2.	(21)
China	Shandong University, Jinan	Feces and urine	RT-PCR	NR	10 Infected children	2020	The approximate time of negative RT-PCR test from the beginning of diagnosis for respiratory and fecal tests was 9 days and 34.43 days, respectively. After 2 weeks of discharge from the hospital, there were 7 positive SARS-CoV-2 fecal tests, while urine and respiratory samples were negative.	(62)

Table 3. Studies on the Survival Time of SARS-CoV-2 in Feces and Urine Published During Pandemic

Author	Type of Sample	Survival Time	Country	Reference
Wang et al	Feces	23.55-26.45 days	China	(63)
Chan et al	Feces	1–2 Days (at room temperature)	China	(64)
Liu et al	Feces and urine	Adult: 2 hours, child: 2 days in feces Adult: 3 days, child: 4 days in a urine sample	China	(14)
Zheng et al	Feces and Urine	22 days, interquartile range 17-31 days	China	(25)
Chen et al	Feces	6-10 Days	China	(65)
Zhang et al	Feces	10 Days	China	(66)
Xing et al	Feces	20 Days	China	(67)
Wu et al	Feces	33 Days	China	(24)
Kim et al	Feces and Urine	5-12 Days	Korea	(68)
Ling et al	Feces	11-20 Days	China	(69)
Lo et al	Feces	19.3 Days	China	(70)
Zhang et al	Feces	22.0 Days	China	(71)
Xiao et al	Feces	1 to 12 Days	China	(72)

CoV in feces, urine, and wastewater. Further studies are needed to investigate the potential presence and fate of coronavirus and other enveloped viruses in feces, urine, and wastewater, as well as drinking water

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Authors' Contribution

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Competing Interests

The authors declare that they have no conflict of interest.

Ethical Approval

The conducted research is not related to either human or animal use.

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