The following information resources have been selected by the National Health Library and Knowledge Service Evidence Virtual Team in response to your question. The resources are listed in our estimated order of relevance to practicing healthcare professionals confronted with this scenario in an Irish context. In respect of the evolving global situation and rapidly changing evidence base, it is advised to use hyperlinked sources in this document to ensure that the information you are disseminating to the public or applying in clinical practice is the most current, valid and accurate. For further information on the methodology used in the compilation of this document—including a complete list of sources consulted—please see our National Health Library and Knowledge Service Summary of Evidence Protocol.

QUESTION 57 Version 2.0

What is known about the survival of SARS-CoV-2 in open water — sea and fresh water; waste water and sewage. What are the implications to human health of recreational activities in open water such as kayaking or swimming?

What is known about the survival of SARS-CoV-2 in open water — sea and fresh water; waste water and sewage. What are the implications to human health of recreational activities in open water such as kayaking or swimming?

Main Points

1. The risk of transmission of SARS-CoV-2 from fresh or coastal waters contaminated with faeces is thought to be very low.
2. Conventional treatment by wastewater treatment plants — particularly in developed countries — should be sufficient to inactivate SARS-CoV-2.
3. SARS-CoV-2 RNA has been detected by qPCR testing in wastewater, but no samples have yet been found to contain infectious virus.
4. Coronaviruses in general are not thought to survive well in aqueous environments.

Summary of Evidence

The risk of transmission of SARS-CoV-2 from swimming or engaging in water sports in fresh or coastal waters contaminated with faeces is very low[1, 2, 3, 4, 5, 6, 7]. The risk of transmission may increase if people visiting beaches, river or pools do not practice adequate social distancing in small, crowded conditions such as changing rooms[1, 2].

Best practice wastewater treatment that is standard in developed countries should be sufficient to inactivate the virus[3, 5, 6, 7, 8, 9, 12]. The use of chlorine in waste water treatment plants has been suggested as an optimal way of inactivating the virus[5, 7, 10, 12]. It should be noted that the risk of SARS-CoV-2 being present in wastewater may be higher in developing countries with poor sanitation networks[6, 8, 10].

SARS-CoV-2 RNA has been detected by qPCR testing in wastewater[6, 10], but no samples have yet been found to contain infectious virus[6]. One study found that SARS-CoV-2 RNA was significantly more persistent than infectious SARS-CoV-2 in wastewater, indicating that detection of RNA does not confirm a risk of infection[11].

Coronaviruses, in general, are not believed to survive well in aqueous environments in comparison to other viruses[6, 7, 9, 12].

Irish and/or International Guidance

No Irish guidance specific to this question was found.

What does the World Health Organization say?

[Water, sanitation, hygiene, and waste management for SARS-CoV-2, the virus that causes COVID-19](1)
Risk of transmission of SARS-CoV-2 from fresh and coastal water or swimming pools and spas water contaminated with faeces is very low. Existing recommendations for managing the quality of bathing water apply.
The risk of transmission of SARS-CoV-2 increases where bathers and people visiting beaches, pools and spas are in small, crowded conditions including in changing rooms, toilets and showers, restaurants and kiosks. General recommendations on hand hygiene, physical distancing and the use of face masks when appropriate are recommended along with regular cleaning (once or more times a day) and maintenance of toilet facilities.

[FACT: Water or swimming does not transmit the COVID-19 virus (Social Media Update)](2)

The COVID-19 virus does not transmit through water while swimming. However, the virus spreads between people when someone has close contact with an infected person.

WHAT YOU CAN DO:

- Avoid crowds and maintain a 1-meter distance from others, even when you are swimming or at swimming areas.

- Wear a mask when you're not in the water and you can't stay distant. Clean your hands frequently, cover a cough or sneeze with a tissue or bent elbow, and stay home if you're unwell.

What do the Centers for Disease Control (CDC) and Prevention (United States) say?

Frequently Asked Questions[3]

Can the COVID-19 virus spread through wastewater systems?
SARS-CoV-2 (the virus that causes COVID-19) can be shed in the faeces of individuals with COVID-19. Genetic material from SARS-CoV-2 has been found in untreated wastewater. However, while data are limited, there is little evidence of infectious virus in wastewater, and no information to date that anyone has become sick with COVID-19 because of exposure to wastewater. Wastewater treatment plants use chemical and other disinfection processes to remove and degrade many viruses and bacteria. SARS-CoV-2 is inactivated by the disinfection methods used in wastewater treatment. At this time, the risk of transmission of the virus that causes COVID-19 through properly designed and maintained wastewater systems is thought to be low.

Can the virus that causes COVID-19 spread to people through the water in lakes, oceans or rivers?
CDC is not aware of any scientific reports of the virus that causes COVID-19 spreading to people through the water in lakes, oceans, rivers, or other natural bodies of water.
The virus mainly spreads when respiratory droplets from infected people land in the mouths or noses of others or possibly when inhaled into the lungs by others.

Drinking Water[4]

There is no evidence showing anyone has gotten COVID-19 through drinking water, recreational water, or wastewater. The risk of COVID-19 transmission through water is expected to be low.

International Literature

What does the international literature say?

[Collivignarelli et al (2020) SARS-CoV-2 in sewer systems and connected facilities [Review]][5]
Although coronaviruses' survival in the environment can differ according to the specific type, these indications allow us to formulate some preliminary considerations. Based on the above-mentioned findings, SARS-CoV-2 might be present in waste water, but its survival is likely extremely low, especially when the temperature of the waste water remains stably above 20°C. To date, the real influence of other parameters, like pH, sunlight and disinfectant agents, on survival time is still uncertain. Nonetheless, presuming a behaviour similar to that of other coronaviruses, this pathogen should rapidly be inactivated.
It has been observed that SARS-CoV can be completely inactivated in 30 min in the presence of residual chlorine greater than 0.5 mg L−1 or concentrations of chlorine dioxide equal to 2.19 mg L−1, resulting in an increased sensitivity of SARS-CoV towards chlorine in comparison to other pathogens such as *E.coli* and f2 phage. These results are confirmed by preliminary tests on SARS-CoV-2 conducted *in vitro* using 1:99 diluted household bleach. They observed that the virus was completely undetectable after 5 min of contact time.
This could suggest that the use of chlorine in waste water treatment plants would yield the complete inactivation of SARS-CoV-2.

Jones et al (2020) Shedding of SARS-CoV-2 in faeces and urine and its potential role in person-to-person transmission and the environment-based spread of COVID-19 [Review][6]

The survival of SARS-CoV-2 in faeces after release from the body is poorly understood. However, this information is important to evaluate the potential for environmental transmission. The faecal-oral route has also been implicated in disease transmission during sexual contact, however, this risk is believed to be very low in comparison to disease transmission via respiratory droplets and the oral-oral route. From the available evidence on SARS-CoV-1 it has been shown that the virus can survive for 3 h to 5 days depending on the watery nature of the diarrhea (positively related to water content), but numbers fall exponentially with time and survival rate is less than in nasopharyngeal or tracheal aspirate.

Overall, we conclude that while virus particles contained in respiratory droplets are known to be highly infectious, evidence suggests that faeces and urine probably contain low levels to no infectious particles. In comparison to respiratory particles, they are also less likely to be spread during daily life, being confined largely to toilets and other enclosed environments.

Beyond the immediate point of entry into the sewer system point, the wastewater will be further diluted in the drainage network by the addition of sewerage from non-infected households. At the peak of infection in the UK in April 2020, it was estimated that 0.25% of the population was infected. This would equate to an average community sewerage load of 1.75 × 105 gc/l reaching a centralized wastewater treatment plant. This is consistent with typical concentrations being reported in wastewater in many regions of the world ranging from 102 to 106 gc/l. At present, there are many uncertainties in the survival of SARS-CoV-2 during its passage through the sewer pipe network. CoVs are not thought to survive well in aqueous environments, especially in comparison with other viruses which can persist for months (e.g. poliovirus, norovirus). This is supported by studies in which SARS-CoV-2 RNA can be readily detected by qPCR in wastewater leaving hospitals, but which has yet to be found to contain

infectious virus. In fact, a recent study suggests that levels of infectious virus were not significant in wastewater and receiving rivers, indicating the effectiveness of wastewater treatment, combined with the natural loss of viral integrity.
If the sludge (biosolids) fraction is treated (e.g. pasteurized, heat-dried, alkali-lime treated), as per the legislative requirement in many countries, this should pose no further risk to human health.
Our critical analysis of the available evidence and potential transmission routes suggests that the possibility of faecal/urine-oral/ocular transmission of SARS-CoV-2 is extremely low to negligible except where direct person-to-person contact occurs. It should be noted that our conclusions are based on western-style sanitation networks and wastewater treatment. The risks may be higher in less economically developed countries and areas with poor sanitation. Assuming levels of SARS-CoV-2 remain relatively low in the population (<1%), our analysis also suggests that the risk of contracting COVID-19 from water supplies, wastewater, food, bathing/recreational waters, and the coastal zone remains extremely low.

La Rosa et al (2020) Coronavirus in water environments: Occurrence, persistence and concentration methods - A scoping review[7]

In the rapidly evolving picture of the scientific knowledge on COVID-19 and SARS-CoV-2, some studies have reported the presence of fragments of viral RNA in faeces or anal swabs of infected patients. Transmission of COVID-19 through the faecal-oral route, however, has not been demonstrated, nor has occurrence of SARS-CoV-2 in water environments been proved to date.
The data available suggest that: 1. CoV seems to have a low stability in the environment and is very sensitive to oxidants, like chlorine; 2. CoV appears to be inactivated significantly faster in water than non-enveloped human enteric viruses with known waterborne transmission; 3. temperature is an important factor influencing viral survival (the titer of infectious virus declines more rapidly at 23°C–

25 °C than at 4 °C); 4. there is no current evidence that human coronaviruses are present in surface or ground waters or are transmitted through contaminated drinking-water.

Langone et al (2020) SARS-CoV-2 in water services: Presence and impacts [Review][8]

In countries with a highly developed water supply system, it is difficult for viruses to overcome the existing stages of filtration and disinfection. On the contrary, in countries where water treatment is not equipped to remove viruses, its presence is unknown. Conventional centralized waste water treatment plants are able to ensure an adequate level of protection. Different treatment steps contribute to the removal or inactivation of viruses, starting from primary sedimentation, which allows to separate the virus portion associated with the suspended solids. Among the biological treatment processes, the conventional secondary activated sludge treatment ensures a significant removal of pathogens due to the combined effect of the wastewater aeration, the biological activity of biomass and the secondary sedimentation.

Kitajima et al (2020) SARS-CoV-2 in wastewater: State of the knowledge and research needs [Review][9]

A technical brief from WHO suggested that there is no evidence about the survival of SARS-CoV-2 in wastewater or drinking water. It is likely that enveloped CoVs are less stable in the environment and are more susceptible to chlorine, pH, and temperature than most of nonenveloped enteric viruses. Therefore, conventional wastewater treatment processes should inactivate SARS-CoV-2, and multiple barriers used in drinking water treatment plants should suffice to remove SARS-CoV-2 to levels of non-detect and low risks (b10-4 annual risk).

Wathore et al (2020) Understanding air and water borne transmission and survival of coronavirus: Insights and way forward for SARS-CoV-2 [Review][10]

Flushed water entering into sewerage systems may also become another carrier medium for this virus. A previous study determined that coronaviruses can survive up to 2–3 days in sewage water and up to 10 days in tap water at 23 °C; factors for survival include temperature, organic matter levels and presence of antagonistic bacteria and oxidants such as chlorine. Some of the early research in this area has suggested the presence of RNA of SARS-CoV-2 in sewage water, however, the persistence of the virus in water and sewage is yet to be determined.

Poor sanitation conditions and practices such as open defecation (which is commonly observed in rural areas or less-developed countries), coupled with unhygienic practices can potentially result in transmission via fomites as well.

Bivins et al (2020) Persistence of SARS-CoV-2 in Water and Wastewater [Laboratory Study][11]

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) RNA is frequently detected in the feces of infected individuals. While infectious SARS-CoV-2 has not previously been identified in wastewater, infectious SARS-CoV-2 has been isolated from the feces of at least one patient, raising concerns about the presence of infectious SARS-CoV-2 in wastewater. The fate and inactivation characteristics of SARS-CoV-2 in water and wastewater are unknown, with current inactivation estimates based on surrogate models. In this study, the persistence of SARS-CoV-2 infectivity and RNA signal was determined in water and wastewater. The times for 90% reduction (T90) of viable SARS-CoV-2 in wastewater and tap water at room temperature were 1.5 and 1.7 days, respectively. In high-starting titer (105 TCID50 mL−1) experiments, infectious virus persisted for the entire 7-day sampling time course. In wastewater at 50 and 70°C, the observed T90 values for infectious SARS-CoV-2 were decreased to 15 and 2 min, respectively. SARS-CoV-2 RNA was found to be

significantly more persistent than infectious SARS-CoV-2, indicating that the environmental detection of RNA alone does not substantiate risk of infection.

Cahill and Morris (2020) Recreational waters – A potential transmission route for SARS-CoV-2 to humans? [Short Communication][12]

The main route of transmission of SARS-CoV-2 between humans occurs via respiratory droplets and contact. However, concerns regarding environmental transmission and the associated public health risk are beginning to emerge. In relation to SARS-CoV-2, the risk of transmission to humans through recreational water bodies is unclear, as there have been no reports to date on the detection of or the ability of this particular virus to remain viable in such water bodies. It is believed that the SARS-CoV-2 virus may behave in similar ways to other coronaviruses, therefore, data reported on previously identified coronaviruses in relation to transmission routes and viability in the environment may be comparable to this novel virus. Although little data is available in relation to the effects of waste water treatment on SARS-CoV-2, there is no evidence to suggest that this virus behaves in a different manner to other coronaviruses. A previous study which investigated coronavirus survival following primary and secondary wastewater treatment, but before disinfection, reported reduced viability of the virus in secondary effluent. The inactivation of the closely related SARS-CoV-1 by common antiseptics and disinfectants, such as ethanol, chlorine and bleach, has been reported previously indicating susceptibility to such agents.
According to the Water Environment Federation and World Health Organization, previous studies have indicated that filtration and disinfection systems in place at municipal wastewater treatment plants should be sufficient for the inactivation of viruses. Although reports have indicated the disinfection process to be a crucial step in wastewater treatment for the reduction in viability of viruses, there is still a possibility of the virus remaining in the wastewater treatment plant effluent. However, even if the virus does enter the aquatic

environment, enveloped viruses, which include coronaviruses, are believed to have a short survival rate in such waters.

Tran et al (2021) [Review] SARS-CoV-2 coronavirus in water and wastewater: A critical review about presence and concern[13]

The presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in water and wastewater has recently been reported. According to the updated literature, the stools and masks of the patients diagnosed with coronavirus disease (COVID-19) were considered as the primary route of coronavirus transmission into water and wastewater. Most coronavirus types which attack human (possible for SARS-CoV-2) are often inactivated rapidly in water, the survival of human coronavirus 229E in water being 7 days at 23 °C. However, the survival period of coronavirus in water environments strongly depends on temperature, property of water, concentration of suspended solids and organic matter, solution pH, and dose of disinfectant used. The World Health Organization has stated that the current disinfection process of drinking water could effectively inactivate most of the bacterial and viral communities present in water, especially SARS-CoV-2. A recent study confirmed that SARS-CoV-2 RNA was detected in inflow wastewater, but not detected in outflow. Although the existence of SARS-CoV-2 in water influents has been confirmed, an important question is whether it can survive or infect after the disinfection process of drinking water. To date, only one study confirmed that the infectivity of SARS-CoV-2 in water for people was null based on the absence of cytopathic effect (CPE) in infectivity tests. Therefore, further studies should focus on the survival of SARS-CoV-2 in water and wastewater under different operational conditions, and whether the transmission from COVID-19-contaminated water to human is an emerging concern. Although paper-based devices have been suggested for detecting the traces of SARS-CoV-2 in water, the protocols and appropriate devices should be developed soon. Wastewater and sewage workers should follow the procedures for safety precaution against SARS-CoV-2 exposure.

Produced by the members of the National Health Library and Knowledge Service Evidence Team†. Current as at 10 February 2021. This evidence summary collates the best available evidence at the time of writing and does not replace clinical judgement or guidance. Emerging literature or subsequent developments in respect of COVID-19 may require amendment to the information or sources listed in the document. Although all reasonable care has been taken in the compilation of content, the National Health Library and Knowledge Service Evidence Team makes no representations or warranties expressed or implied as to the accuracy or suitability of the information or sources listed in the document. This evidence summary is the property of the National Health Library and Knowledge Service and subsequent re-use or distribution in whole or in part should include acknowledgement of the service.

The following PICO(T) was used as a basis for the evidence summary:

Population	GENERAL POPULATION ENGAGING IN OPEN WATER SPORT/ACTIVITY
Intervention	TREATED WATER
Comparison	
Outcome	

The following search strategy was used:

"covid-19" OR coronavirus OR "wuhan virus" OR "2019-ncov" OR "severe acute respiratory syndrome coronavirus 2" OR "2019 novel coronavirus" OR "2019 new coronavirus" OR MERS OR Middle East Respiratory Syndrome OR SARS or Severe Acute Respiratory Syndrome

AND sea water OR seawater OR salt water OR saltwater OR open water* OR wastewater OR waste water OR swim* OR sewage OR sewerage OR bathing OR kayak* OR canoe* OR water sport*

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