



# Searching if SARS-CoV-2 Subsists Following the Disinfection of Potable Water

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## Abstract

The manifestation of *severe acute respiratory syndrome coronavirus 2* (SARS-CoV-2) in water and wastewater has newly been revealed. The stools and masks of the patients diagnosed with coronavirus disease (COVID-19) were viewed as the key way of CoV diffusion into aquatic medium. Most CoV kinds that attack human (likely for SARS-CoV-2) are frequently demobilized quickly in water (the endurance of human CoV 229E in water being 7 days at 23°C). Nevertheless, the endurance time of CoV in water strongly follows temperature, characteristics of water, concentration of suspended solids and organic matter, solution pH, and dose of disinfectant injected. The present disinfection technique of potable water can efficiently demobilize most of the bacterial and viral communities existing in water, particularly SARS-CoV-2 (more vulnerable to killing agent such as free chlorine). Scientists affirmed that SARS-CoV-2 RNA was observed in inflow wastewater and not found in outflow one. Even if the occurrence of SARS-CoV-2 in water influents has been affirmed, a fundamental interrogation is whether it could remain alive or contaminate following the disinfection method of potable water. Until now, only one study asserted that the infectivity of SARS-CoV-2 in water for persons was null founded on the absence of cytopathic effect in infectivity tests. Thus, more researches must be dedicated to the survival of SARS-CoV-2 in water and wastewater below various working circumstances (temperature and water matrix) and whether the diffusion from COVID-19-infected water to human is an emerging anxiety.

## Subject Areas

Chemical Engineering & Technology

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## Keywords

Coronaviruses (CoVs), Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), SARS-CoV-2 Stability, Disinfection, Microorganisms (MOs), Wastewater Treatment Plants (WWTPs)

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## 1. Introduction

A sudden epidemic eruption of coronavirus disease 2019 (COVID-19), emerged from *severe acute respiratory syndrome coronavirus* (SARS-CoV), has presently provoked huge worldwide anxieties [1] [2] [3]. The causative agent of such pandemic was forever called SARS-CoV-2 (temporarily baptized 2019-nCoV) to differentiate it from the SARS-CoV-1 virus that was initially perceived in 2002 [4] [5] [6]. Researchers [7] discovered lately that the SARS-CoV-2 was associated with Malayan pangolins (*Manis javanica*) in China. Therefore, the pangolins were holding responsible as a likely halfway host in the arrival of COVID-19 eruption in humans. Other scientists [8] reached an identical deduction affirming that the pangolin species is an innate recipient of SARS-CoV-2-like coronavirus.

Comparable to the Middle East respiratory syndrome coronavirus (MERS-CoV; recognized in 2012), the SARS-CoV-1 and SARS-CoV-2 viruses mostly spread out of the small respiratory droplets of disease carriers produced from sneezing and coughing by humans [1]. This way is known as human-to-human propagation [9] or respiratory propagation [10]. Therefore super spreaders (SARS-CoV-2) are able to quickly transfer the contagion to numerous others, mainly out of usual international travel or mass meetings in public spaces. Even if the faecal-oral diffusion of SARS-CoV-2 is conceivable [10] [11] [12], there are not any observational information or solid confirmations to set the faecal-oral supposition. In fact, three types of coronavirus (MERS-CoV, SARS-CoV-1, and SARS-CoV-2) are identical in terms of their biochemical and physical characteristics [4] [5] [13] and categorized as enveloped viruses that hold the bits of protein and genetic material surrounded by a lipid host cell membrane [9]. As a result, in a measure, foregoing investigations on SARS-CoV-1 and MERS-CoV coronavirus and different enveloped viruses are able to present an approaching information for SARS-CoV-2 [14].

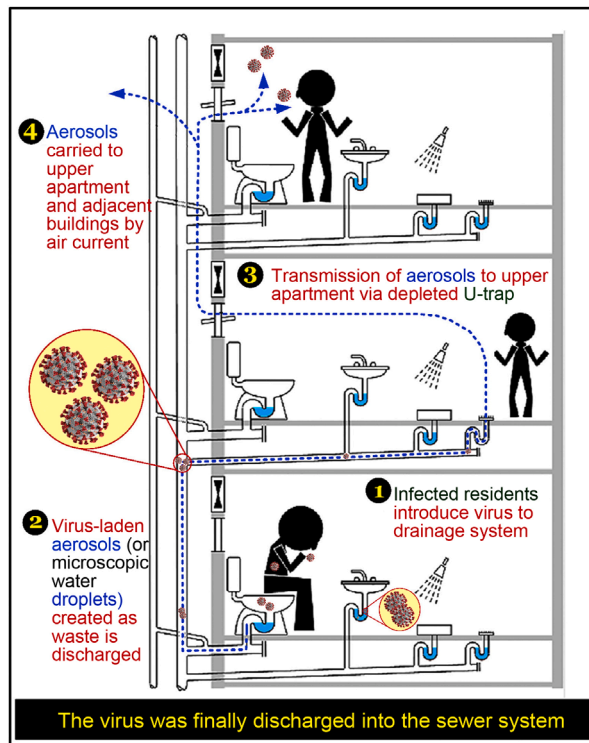
Lately, nucleic acid pieces of SARS-CoV-2 coronavirus have been observed in extracted sludge from wastewater treatment plants (WWTPs) [1] [15] [16], municipal sewage [17] [18] [19] or wastewater [20] [21] [22], medical wastewater [2] [8] [23], wastewater from commercial cruise ship and commercial passenger aircraft [1], non-potable water [1], secondary-treated wastewater [20] [24] [25], and river water [20] [26]. Therefore, additional studies remain requested in such direction [4] [27] [28]. So as to evaluate the efficiency of wastewater treatment

methods for the actual pandemic catastrophe, this review is dedicated to the next fundamental interrogations: 1) what the transmission routes of the SARS-CoV-2 coronavirus into sewage or wastewater are, and 2) whether CoV can survive after drinking water disinfection process.

## 2. Diffusion Way of SARS-CoV-2 into Water and Wastewater

Since 2013, for the CoV-contaminated communities living in apartment buildings, wastewater plumbing systems (WPSs) have been viewed as a likely passage for transporting the SARS-CoV-1 coronavirus into the sewer system [1] [29] [30]. Identical to SARS-CoV-1, the SARS-CoV-2 virus may be disseminated by means of aerosols or microscopic water droplets [31] [32] [33]. Indeed, scientists [14] mentioned that the SARS-CoV-2 and SARS-CoV-1 viruses are identical in their persistence in aerosols and on surfaces. Following the inoculum shed, the viruses are able to stay viable and contagious on surfaces (until a few days) and in aerosols (for hours). Likewise, researchers [34] examined the survival of SARS-CoV-2 in air, surface, and personal protective equipment of disease carriers and healthcare workers. They noticed that the samples collected from air outlet fans, door handles, sinks, and toilet bowls were positive. Such findings prove that SARS-CoV-2 could be transferred via the stools of contaminated people. Moreover, scientists [35] gathered the high-touch surface samples of a quarantine room and discovered that the percentage of gathered samples was positive for SARS-CoV-2 as follows: 70% (in the bedroom) > 50% (bathroom) > 33% (corridor). The most infected sites with the highest viral loads were identified at the inner walls of the toilet bowl and the sewer inlet of the room [35]. Such a diffusion passage, through the WPS, might be likely in charge of environmental pollution and propagation of COVID-19 in the communities (Figure 1). Consequently, researchers [29] lately furnished many advices to guarantee that propagation via the WPS is reduced. Figure 2 outlines some worthy propositions to avert the danger of diffusing the microorganisms (MOs) via WPS in the buildings.

Investigations proved that the stool specimens gathered from contracted patients (comprising asymptomatic children) had the SARS-CoV-2 virus [36] [37] [38]. This is due to the presence of COVID-19 contagion in the gastrointestinal tract of patients and could be excreted from the gastrointestinal tract via their faeces [1] [39]. Such fact proposed that the SARS-CoV-2 virus is mostly excreted in the stools of a contaminated human. Lately, scientists established that the median lifespan of SARS-CoV-2 in the stool specimens of the patients was up to 22 days [40], which was longer than that of SARS-CoV-1 (only 4 days) [41]. These scientists as well depicted that SARS-CoV-2 is able to survive longer in the stool specimens (22 days, 17 - 31 days) than that in respiratory (18 days, 13 - 29 days) and serum (16 days, 11 - 21 days) ones [40]. Broadly, the faeces and urine from some COVID-19-infected patients are discharged into sewer systems and subsequently enter WWTPs [17] [42]. This could be viewed as the key way of



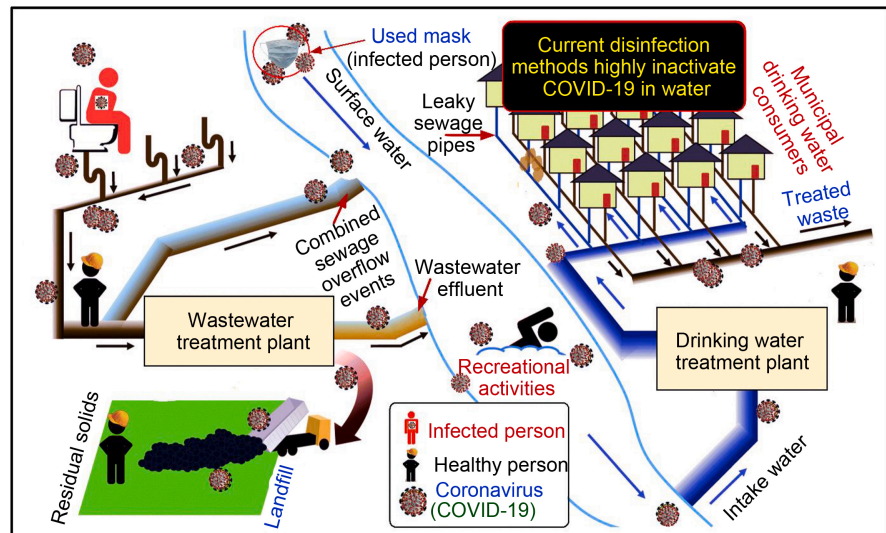
**Figure 1.** A diffusion pathway of SARS-CoV-1 virus (likely for SARS-CoV-2 virus) at the buildings via the wastewater plumbing system (WPS) [1].

<p>To minimise transmission through the wastewater plumbing system, the following steps need to be taken:</p> <ul style="list-style-type: none"> <li>• Do not overpass some unexplained foul smells in bathrooms, kitchens, wash areas (i.e., countertop washbasin);</li> <li>• Ensure that all water appliances in bathrooms and kitchens are well fitted with a functioning U-bend;</li> <li>• Open a tap on whole water appliances frequently (duration &gt; 5 s) in morning and evening along with taking notice of floor drains in wet rooms (i.e., bathrooms). Those actions will help to prohibit the loss of the water trap seal within a U-bend;</li> <li>• Enclose wastewater pipeworks from an appliance immediately (using elastic rubber glove to cover the end; plastic bag and some tape will suffice, ensuring the bag has no holes) when they appear a disconnected or tightly-uncosed situation.</li> <li>• Seal the crack or leak in pipeworks with tape or glue in case of their appearance.</li> <li>• Monitor consecutively all system performances (for large or tall buildings).</li> </ul>	
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**Figure 2.** Propositions to reduce the pathogens diffusion via the wastewater plumbing system (WPS) in the building [1].

SARS-CoV-2 diffusion to water and wastewater [4] [42] since SARS-CoV is able to keep its contagious potential in the stool specimens for >7 days at 20°C [41]. Schematic way of propagation for the SARS-CoV-2 virus is illustrated in **Figure 3** [1].

Since the fresh COVID-19 pandemic provokes severe respiratory illness and related casualties, persons are constantly persuaded or demanded to follow a



**Figure 3.** A route of transmission for SARS-CoV-2 [1].

compulsory policy to wear face masks in public areas as a precaution against the diffusion and contagion of SARS-CoV-2 [43] [44] [45]. Ho *et al.* [46] observed that there was no big distinction between the commercial surgical mask and self-designed triple-layer cotton mask for blocking droplets during coughing. Thus, cotton masks could serve as an encouraging substitute for medical surgical in stopping the diffusion of respiratory droplets in micro-environments [46]. Leung *et al.* [31] proved that surgical face masks could ban the direct propagation of influenza viruses and human CoVs from the virus-borne airborne particles, droplets, and body fluids of infected persons. On the other hand, researchers [47] deduced that “*surgical and cotton masks seem to be ineffective in preventing the dissemination of SARS-CoV-2 from the coughs of patients with COVID-19 to the environment and external mask surface*” [1]. Nonetheless, this investigation has been withdrawn as demanded by the editor [48] since their explication of exploratory findings was confusing. Surprisingly, scientists [49] mentioned that the SARS-CoV-2 virus could yet remain at an identifiable degree of contagion on the outer film of a surgical face mask for up to a week. Consequently, handling thrown face masks that may constitute a very possible propagation way of SARS-CoV-2 into water should be accorded primacy for examination. This is particularly significant since none of the masks utilized are gathered and treated as poisonous wastes [1]. Scholars [50] noticed that some of them may have been thrown away or disposed carelessly into the surface water. The occurrence of CoV-carrying masks discarded into water could form an additional diffusion route (Figure 3), even if more investigations have to work on this hypothesis [1].

As aforesaid, one of the propagation courses of COVID-19 into water and wastewater is via the huge quantity of face masks employed throughout the globe by general public, patients and health workers [1]. After their usage, those face masks have been disposed without treatment or disinfection, therefore rais-

ing worries concerning the possible health hazards and threatening to the nature. Numerous techniques have been suggested to disinfect the utilized masks for reusing or before disposing to diminish the poisonous wastes [45] [51] [52] [53]. As an illustration, researcher [51] proposed to employ the microwave technology for sanitizing the disposable medical and utilized cloth masks. Such process implies an antiseptic solution (*i.e.*, 0.9% physiological saline) being sprayed on the mask to keep the moisture. The moist mask was thereafter transferred into a microwave oven with a default capacity of 800 W and then heated during 1 min. Such disinfection procedure has been observed to efficiently eliminate 99.9% of viruses [51].

For disinfecting the surgical face masks and N95 respirators employed, an additional physical process (dry heat pasteurization) has been newly noted by scientists [53]. Six species of respiratory bacteria (*Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Acinetobacter baumannii*, and *Corynebacterium pseudodiphtheria*), one fungi species (*Candida albicans*), and one H1N1 indicator virus (an RNA-enveloped virus identical to SARS-CoV-2) were chosen as target pathogens. Xiang *et al.* [53] deduced that the dry heat of utilized surgical face masks and N95 respirators at 70°C for 1 h in an electric oven could warrant the efficient disinfection of them. The sterile masks and respirators could be consecutively employed at least three rounds of the heating without considerably modifying their filtering performances and physical properties [53].

Li *et al.* [52] observed that a shorter steam treatment is an efficacious technique for the quick decontamination of methicillin-resistant *S. aureus* and bacteriophage MS2 on the surface of the N95 respirators and medical face masks. The inoculated N95 respirators and medical masks were placed into a steamer (100°C) for various steam periods of 2, 10, or 30 s. They noted that the steam periods of 10 and 30 s were enough for decontaminating *S. aureus* and bacteriophage MS2 on both respirators and medical masks, while the opposite was true for the 2-s steam treatment. Nevertheless, the technique of steam treatment did not efficiently decontaminate *Geobacillus stearothermophilus* spores in the surface of respirators and medical face masks [1].

### 3. Search If SARS-CoV-2 Lives Following the Disinfection Process of Potable Water

Scholars affirmed that there are no at hand proofs affirming the endurance of SARS-CoV-2 virus following the disinfection method for both wastewater and potable water [1] [54]. Lately, scientists [55] gathered wastewater samples from the County Wastewater Treatment Plant and examined whether SARS-CoV-2 virus is tracked in the samples. They depicted that the RNA gene fragments of the SARS-CoV-2 virus were not observed in the treated wastewater.

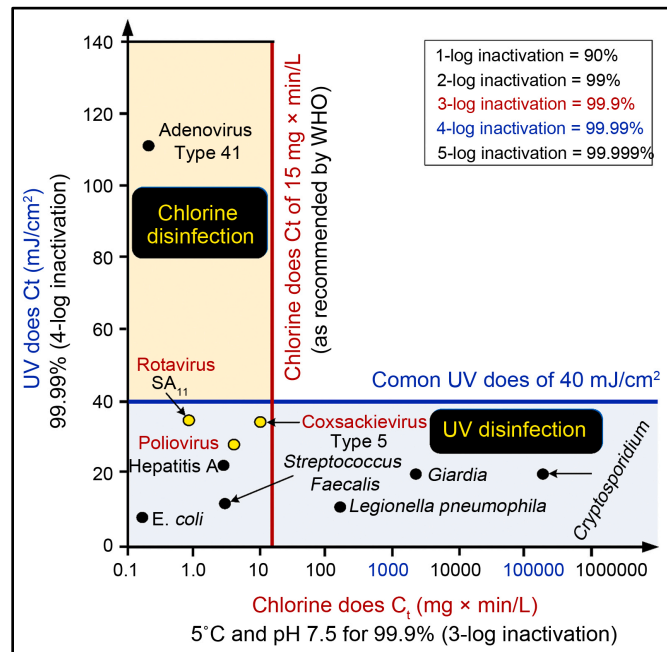
As a rule, there are two groups of virus: enveloped virus and non-enveloped virus (large and small non-enveloped viruses) [1] [56]. SARS-CoV-2 is a typical

enveloped virus (surrounded by a fragile outer lipid membrane) that has been acknowledged as the easiest virus to be neutralized when comparing with large or small non-enveloped virus [1] [57]. Due to the fact that the MERS-CoV and SARS-CoV-1 viruses are derived from the same family of the SARS-CoV-2 coronaviruses, they present identical biochemical and physical characteristics. Thus, to a certain degree, they could be viewed as a typical example.

Among the present techniques (*i.e.*, adsorption, ozonation [58], chlorination [59] [60] [61], membrane, ultraviolet (UV) light [62] [63], and advanced oxidation processes [64] [65] [66]) that are utilized for demobilizing CoVs [67] or enveloped viruses [1], the UV radiation and chlorination remain the most frequent processes employed for disinfecting water supplies [1] [68] [69]. Investigators [70] used chlorine dioxide ( $\text{ClO}_2$ ) and sodium hypochlorite ( $\text{NaClO}$ ) as the target disinfectants to examine the demobilization of SARS-CoV-1 in wastewater. They discovered that SARS-CoV-1 was so vulnerable to the selective disinfectants; even if both of them could neutralize SARS-CoV-1 virus in water,  $\text{NaClO}$  was better than  $\text{ClO}_2$  in terms of killing [70]. For instance, in the identical low-concentration disinfectants (10 mg/L), the rates of SARS-CoV-1 neutralization utilizing  $\text{ClO}_2$  and  $\text{NaClO}$  were observed to be 99.99% and 68.38%, respectively after 10 min of contact period. Nonetheless, below the identical empirical circumstances, both disinfectants were less efficient in eliminating *E. coli* with the small demobilization rates of 17.4% for  $\text{ClO}_2$  and 14.3% for  $\text{NaClO}$ . Such finding proved that SARS-CoV-1 coronavirus was more sensible to disinfectants than *E. coli* [70] [71] [72]. As a consequence, the treated water was found to be safe for humans [1] [73].

Lately, researchers [8] examined the demobilization of SARS-CoV-2 in medical wastewater from the septic tanks of the Fangcang hospital by  $\text{NaOCl}$ . They noticed that injecting free chlorine  $>0.5$  mg/L (residence period of 90 min) could not guarantee a total disinfection of the SARS-CoV-2 virus in medical wastewaters, while the opposite was correct for employing 6700 g/m<sup>3</sup> dosage of  $\text{NaOCl}$ . Even if the SARS-CoV-2 viral RNA was not observed inside the over-dosage of  $\text{NaOCl}$  employed, an elevated degree of disinfection by-product residuals could provoke many hazards to natural system and menaces to human health [1] [8] [74].

**Figure 4** depicts the disinfection performance of different MOs in water using chemical disinfectant (chlorination) and non-chemical disinfectant (UV light) [1]. Obviously, non-enveloped viruses (poliovirus, Coxsackievirus, and Rotavirus) could be demobilized by two techniques. Minutely, non-enveloped viruses are able to be killed at a chlorine dose ( $C \times t$ ) of less than 15 mg  $\times$  min/L. Consequently, it is anticipated that the enveloped SARS-CoV-2 virus will be efficiently demobilized by chlorination even at a lower chlorine  $C \times t$  dose of 15 mg  $\times$  min/L [1]. In like manner, Ye *et al.* [75] proved that enveloped viruses (*Pseudomonas virus*  $\phi 6$ ) were more vulnerable than non-enveloped viruses (*i.e.*, bacteriophage MS2) under free chlorine disinfection (prepared from  $\text{NaClO}$ ) and



**Figure 4.** Synergistic utilization of the common disinfection systems: UV (ultra-violet) light and chlorination [1].

UV radiation at 254 nm ( $UV_{254}$ ). In a similar fashion, scientists [1] observed that H5N1 (an enveloped virus) was very sensible to UV radiation ( $>5.5$ -log inactivation reached within a low UV fluence of  $25 \text{ mJ/cm}^2$ ); however, the opposite was correct for bacteriophage MS2 (1.87-log inactivation). Despite the fact that each disinfection process is efficacious for killing the enveloped virus (as well for SARS-CoV-2), the integration of these techniques is constantly advised [1]. This is due to the fact that chlorination-based disinfection is not efficacious in neutralizing protozoan parasites (*i.e.*, *Cryptosporidium*), while the opposite is correct for UV light-based disinfection (Figure 4).

In particular, scientists newly affirmed that the RNA of SARS-CoV-2 virus was observed in untreated wastewaters in WWTP such as influents [76] [77] and secondary-treated water samples [1] [76]. Nevertheless, its RNA was not found in tertiary effluent samples of WWTPs following the present disinfection method with alone  $\text{NaClO}$  [76], the inetegration of  $\text{NaClO}$  and UV [76], peracetic acid [76], or high intensity UV lamps [77]. Even if the present disinfection method from WWTPs in Spain [76] and Italy [77] neutralized completely SARS-CoV-2 virus, the scientists did not mention the explained circumstances of the disinfection method (*i.e.*, the employed disinfectant injection and residence period) and the impacts of such circumstances on the survival of such CoV [76] [77].

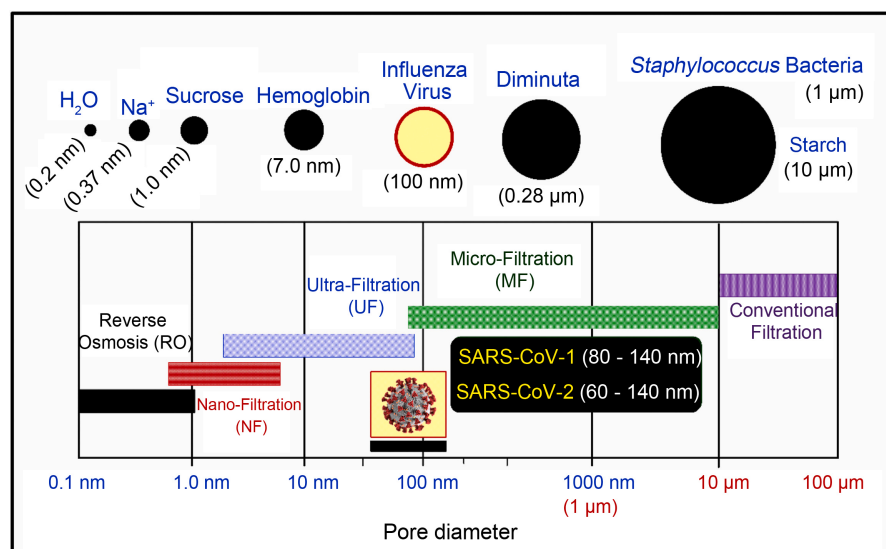
Membrane technology has been largely utilized as a traditional disinfection technique for potable water [78] [79] [80]. In such technology, the size of the viruses has a crucial contribution in choosing the suitable types of membranes [81] [82] [83]. Each virion (particle) of CoVs (*i.e.*, SARS-CoV-1 and MERS-CoV



related to the Coronaviridae family in the Nidovirales order) ranged from 80 nm to 220 nm in diameter [1]. Newly, scientists [5] noted that the diameter of SARS-CoV-2 virion varied from 60 nm to 140 nm [13], which is identical to that of SARS-CoV-1 (from 80 to 140 nm) [84]. **Figure 5** presents a juxtaposition of MOs' sizes with the pore sizes of the membranes. Following the diameter of each SARS-CoV-2 virion and membranes, it is decidedly advised that the ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) membranes are convenient for demobilizing (or throwing away) the CoVs in SARS-CoV-2-infected water [5].

Relating to adsorption process, investigators [85] proposed the biopolymeric material (*i.e.*, the cations-modified chitosan-based nano/microspheres) and used it for the selective and reversible adsorption of different CoVs from aqueous suspensions. The target CoVs comprised two human CoVs (HCoV-NL63 and HCoV-OC43) and mouse hepatitis coronavirus (MHV). They proved that the biopolymeric material is able to adsorb the HCoV-NL63 (strongly) and MHV (moderately) CoV from water, but cannot adsorb HCoV-OC43 coronavirus. The desorption investigation employing 2.0 M NaCl depicted that the desorbed HCoV-NL63 coronavirus could be desorbed from the laden biopolymeric material. The number of viral RNA copies that was desorbed from the laden biopolymeric material was  $2.4 \pm 0.9 \times 10^6$  (copies/mL). Impressively, the HCoV-NL63 particles desorbed were still contagious (*i.e.*, the retention of virus virulence) [85] [86]. Nonetheless, whether the biopolymeric material could efficiently adsorb SARS-CoV-2 coronavirus in water is an actual dare that must be confirmed by more examinations [1] [87] [88].

To recap, even if until this moment, there is no proof on the survival of SARS-CoV-2 virus in treated water, more investigations stay to be performed to minutely accept such hypothesis [1] [89] [90]. As mentioned above, the treatment



**Figure 5.** Juxtaposition of microorganisms (MOs) sizes comprising SARS-CoV-1 [84] and SARS-CoV-2 [5] coronaviruses with the pore size diameters of membranes [1].

technologies of running disinfection might be enough to neutralize SARS-CoV-2 in water [91] [92] [93]. Nevertheless, the protocols for disinfecting the SARS-CoV-2 virus in potable water treatment are missing [94] [95].

#### 4. Conclusions

This review disclosed that until now, even if the presence of SARS-CoV-2 coronavirus in river water and untreated wastewater is proved, a firm proof of its survival time in water ecosystems remains absent. Additional investigations have to be dedicated to robustly assert the survival time of SARS-CoV-2 coronavirus in different water circumstances (temperature, pH, organic matter, etc.) as well as its infectivity. The running disinfection technologies might be sufficient to effectively kill SARS-CoV-2 in water. The procedures for disinfecting SARSCoV-2 virus must be defined by the pertinent scientific communities. The manifestation of fresh SARS-CoV-2 coronavirus in water and wastewater is very potential as mentioned throughout the globe. Nearly all CoVs are vulnerable to temperature and are fast demobilized in water. The most prevalent diffusion way of SARS-CoV-2 into water, sewage, and wastewater is via stools of symptomatic persons. Actual disinfection techniques applied in the potable water treatment efficiently demobilize and effectively demolish SARS-CoV-2 in water. Periodic observation of wastewater could furnish an early warning medium for the apparition of the SARS-CoV-2 coronavirus in a population, which leads to reducing the pathogen propagation [1].

Researches have proved that SARS-CoV-2 coronavirus has been observed in river water, sewage, and wastewater samples; however, the danger produced to humans and the nature is low. The stability of the virus is as well insignificant and mainly gets demolished in the ambient temperature and climatic circumstances. Nonetheless, the presence and distribution of the virus in WWTPs help us to determine the source and location that people are being touched [1].

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#### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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