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Review

A review on Saudi Arabian wastewater treatment facilities and available disinfection methods: Implications to SARS-CoV-2 control

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ABSTRACT

COVID-19 pandemic has severe impacts on human health and economy worldwide. Aerosols and droplets are the major routes of transmission of SARS-CoV-2 coronavirus causing COVID-19 disease. However, wastewater is a possible transmission pathway. Therefore, many studies have been published about the relation of wastewater and COVID-19 disease. Many studies have shown the presence of viral RNA in wastewater throughout the world recently. Therefore, research on wastewater treatments and disinfection methods are needed. Communities must make sure that the virus is not transmitted via treated wastewater. This review focuses on the Saudi Arabian wastewater treatment and disinfection techniques to assess the possibility of SARS-CoV-2 transmission through wastewaters. In view of the current pandemic situation, the wide analysis of wastewater treatments in Saudi Arabia is needed. The review gives guidelines to develop the wastewater treatment in Saudi Arabia.

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1. Introduction

Water reserves contamination with feces has been identified as a risk for human health for a long time. Waters are polluted with chemicals such as drugs as well as with biological contaminants such as pathogenic bacteria and viruses. The contamination of waters with viruses is becoming more important along with Corona pandemic and the pandemics that most probably are coming in the future.

The major group of viruses known to be transmitted through water is the enteric viruses including non-enveloped viruses. These viruses multiply in the gastrointestinal tract of humans and are responsible for many diseases such as infections in the central nervous system, viral hepatitis, and other respiratory infections. Viral families such as Adenoviridae (*Adenovirus*), Picornaviridae, and Caliciviridae include water-borne enteric viruses. The viruses were found to be present in urine and feces of the diseased patients. Viruses have been found not only in sewage but also in various types of waters such as freshwater, drinking water, and seawater (Bonadonna and La Rosa, 2019).

Non-enveloped viruses are chemically different from enveloped viruses. In water environments, the behavior of enveloped viruses is less known than that of non-enveloped viruses (Wigginton et al., 2015). Viruses with envelope include the families of Orthomyxoviridae (influenza viruses), Coronaviridae, Herpesviridae, and Paramyxoviridae (mumps virus, measles virus). SARS-CoV-2 virus causing COVID-19 disease belongs to Coronaviridae family. The spherical structure of the virus is covered by an envelope, which has a diameter of about 120 nm. In the life cycle of a virus, the enveloped proteins play a vital role in the disease progress inside the host cell. Viral envelope consists of a helical-shaped capsid that covers the RNA and nucleoproteins. The size of the viral genome is 25–35 kb. The two important open reading frames namely ORF1a and ORF1b were assembled at 5' end, which involves in polyprotein enzyme replicase coding and spike and capsid structural proteins.

Coronaviruses spread in direct human-to-human contact through droplets from talking, sneezing, and coughing, or by touching a contaminated surface. The disease can spread via wastewater in certain circumstances. The virus has been found from the COVID-19 infected person's stool and the transmission can therefore occur through the fecal-oral way (Jevšnik et al., 2013). The prevalence of COVID-19 disease and the mortality rate are highly positively correlated (Alshehri and Abdelrahman, 2021). The disease incidence has been high in Saudi Arabia, and therefore, all actions are needed to prevent the disease spreading (Ameen et al., 2020). Until June 2021, a total of 486,106 coronavirus cases with 7,804 deaths has been reported in Saudi Arabia. Epidemiology of the disease in Saudi Arabia has been described recently

(Alyami et al., 2020)

In Saudi Arabia, a limited amount of water and groundwater as well as the vulnerability of the few groundwater sources to pollution calls for action in sewage treatment, (Alshehri and Abdelrahman, 2021; Kahal et al., 2021). Groundwater might get contaminated through sewage spills, which must be prevented (Huo et al., 2021). Therefore, our aim is to collect information on the wastewater treatment facilities in Saudi Arabia and give guidelines to develop wastewater treatment.

2. Saudi Arabia clean water sources and demand

High population growth and urbanization of Saudi Arabia has increased the demand for water rapidly (Ouda, 2015; Ouda, 2014). Between supply and demand of water, a gap of 11.5 m³ was detected (Table 1). The gap can be narrowed down by following certain practices like maximizing the treated water utilization,

Table 1

Clean water sources and demand in Saudi Arabia.

Source	Quantity (million m ³ per year)
Groundwater	3,850
Surface water	1,300
Traditional sources	5,150
Treated wastewater	240
Desalinated water	1,050
Non-conventional source	90
Total clean water	6,440
Demand	
Population	2,063
Business	800
Farming	15,000
Aggregate	17,863
Gap between demand and source	11,423

Source: Ministry of Water & electricity (2012).

water desalination and by advising people to save water. Various sectors like commercial, industrial, and agricultural have been utilizing the treated water (MWE: Ministry of Water & Electricity, 2012).

2.1. Wastewater services in Saudi Arabia

Wastewater treatment coverage varies within Saudi Arabia a lot. In Damman city, 78 % of wastewater is treated, in the capital city Riyadh 60 % whereas in Jeddah only 50 % of wastewater is treated. In some cities such as in Najran and Al Baha no centralized wastewater treatment is taking place. Proper sewage system take place only in half of the urban areas and the remaining areas use either unlined or completely lined septic tanks for clearing wastewater. The government of Saudi Arabia aims to treat all wastewaters by 2025 and set the target by 2035, to treat 6.8 million m³ of wastewater per day (Drewes et al., 2012). The Ministry of Water and Electricity derives a strategy to fulfill all the service needs, and proper research to be carried out to discharge the wastewater in all 13 areas of the country. The medium and large size towns of Saudi Arabia have been equipped with suitable plants for treating wastewater. National Water Company works in Makkah, Al Taif, Riyadh, Jeddah, and Medina sustain sewage treatment plants with secondary and tertiary water treatments. The traditional active sludge system is the frequent secondary treatment methodology while decontamination by chlorination and filtration serve as the normal process for tertiary treatment. Reverse osmosis is used in the industrial sector in addition to the above treatment techniques (NWC, 2021).

In general, the major cities employed one fourth of the treated wastewater, meaning 240 million m³, to plantations and public parks in 2010 (Ouda, 2014). In Riyadh city, water was used for the irrigation of date palm and fodder crops plantations. Treated water was used also in rural areas such as in Hanifa valley to offer green municipal parks to population. In Al Kharj, treated wastewater is lead through a 40 km long canal to a pond where it is stored and filtered through the soil via groundwater recharging process. The sewage water storage and treatment processing are estimated to grow and generate 2.5 km³ per year treated wastewater by 2035. For economic reasons, the treatment is financed more by the industrial sector than agriculture. Currently, the six major cities of Saudi Arabia such as Riyadh, Dammam, Medinah, Makkah, Jeddah and Al Taif and the regions of eastern province have the highest potential to treat and use the treated wastewater. Due to higher cost involved in desalination process, usage of treated water in Saudi Arabia is expanded in different sectors (DeNicola et al., 2015)

Table 2
Wastewater treatment capacity and generation in different parts of Saudi Arabia.

Region	Major waste water treatment plants	Proportion of population covered	Treatment level	Total existing treatment capacity (1000 m ³ /day)	Calculated waste water flow (By the year 2035)
Al Baha	8	NI	NI	–	107
Al Jouf	NI	NI	NI	38	119
Assir	NI	NI	NI	82.5	529
Eastem province	NI	NI	NI	527.3	1128
Hail	NI	NI	NI	19.2	162
Jizan	NI	NI	NI	20	381
Madinah	1	68%	Tertiary	351	496
Makkah	3	45%	Primary and Secondary	888	1911
Najran	NI	NI	NI	0	133
Northem Borders	NI	NI	NI	24	88
Qaseem	NI	NI	NI	131.5	328
Riyadh	6	55%	Tertiary	832	1890
Tabouk	NI	NI	NI	60	214
Total	NI	NI	NI		

*Source: Kaust: King Abdullah University of science and technology (2011), NI – Information not available.

In Saudi Arabia, the major problem in treating the sewage is the scanty supply of modern wastewater treatment plants and the lack of proper connectivity in the existing sewage system. Wastewater treatment in Saudi Arabia is substandard when compared with other surrounding Gulf countries (Rabah and Darwish, 2012). Wastewater management systems in Saudi Arabia are insufficient (Table. 2). The people of Saudi Arabia are not well informed about the production and distribution of water either about the scarcity of water. Wastewater database after treatment processes and its organizational reforms and regulations are necessary elements required to accomplish wastewater and treated sewage water goals.

Wastewater collection and treatment services are provided free of charge in Saudi Arabia. The current water tariff system is subsidized by the government; consumers pay less than 5% of the water production cost (Ouda et al., 2013). An improvement in water supply will result in enhanced flow of wastewater. For instance, Riyadh experienced an increase of 317,000 m³/day of wastewater flow from 2008 to 2014 (NWC, 2021).

The Saudi Arabia government and MWE propose to utilize the treated water for industrial purpose and increase groundwater. Wastewater treatment should remove not only nutrients but various contaminants such as heavy metals, organic compounds, and biological pollutants (Shomar and Dare, 2015). Micropollutants such as antibiotics and other synthetic chemicals as well as microplastic are of great concern in treated wastewater (Chollom et al., 2020). Moreover, disinfectants used in the treatments should not hamper human health.

3. SARS-CoV-2 detection from treated wastewater

SARS viruses are enveloped respiratory viruses that are found to occur in the droppings of infected people. Several reports have showed the presence of fragments of viral RNA in feces and anal swabs of the COVID-19 infected people (Holshue et al., 2020). but the transmission of SARS-CoV-2 through any aquatic environment has not been evidenced till date (Elsamadony et al., 2021). However, several recent reports point out the possibility of the spread of COVID-19 disease through feces entering a sewage system and especially the workers in treatment plants can transmit the virus further (Rooney et al., 2021). Early studies on SARS-CoV-2 stipulated that only those people who suffered from diarrhea shed the coronavirus in their feces but extensive studies in this area reveal

that corona positive patients shed the virus in stools no matter whether they suffered from diarrhea or not. A huge amount of research about wastewater surveillance has been published recently which suggests the monitoring of wastewater to get an indication of the spreading of COVID-19 disease is highly important (Alahdal et al., 2021; Medema et al., 2020).

Coronavirus RNA has been identified and detected in wastewater from various parts of the world (Table. 3). Many questions about the persistence of coronavirus in wastewater are still open. The virus seems to be alive in wastewater without disinfection from few hours to days (Tran et al., 2020). It also seems that disinfection such as chlorination and septic tank sanitation might be adequate to treat municipal wastewaters and the sterilization strategies and guidelines with respect to SARS-CoV-2 was published by U.S. Occupational Safety and Health Administration (OSHA) (OSHA, 2021).

During the pandemic, monitoring the viral RNA in water is essential to stop the spread of the disease. Several different virus detection methods from waters are available (Fig. 1.) and they should be considered and practiced in Saudi Arabia.

Usual treatment of wastewater should be sufficient to destroy enteric viruses (Kumar et al., 2021).

The RNA of SARS-CoV-2 was inactivated in traditional wastewater treatment in Italy (Rimoldi et al., 2020). Conventional treatments followed by disinfection with peracetic acid or UV radiation were also found to be efficient (Randazzo et al., 2020). Thermal hydrolysis, anaerobic digestion, membrane bioreactors, and up-flow anaerobic sludge blanket technology, and activated sludge process has been reported to remove SARS-CoV-2 RNA from sewage (Balboa et al., 2021; Bhatt et al., 2020; Kumar et al., 2021; Lesimple et al., 2020; Naddeo and Liu, 2020).

Although general sewage treatments seem to destroy viral RNA, it has to be studied extensively because of the presence of lower quantity of RNA even after the treatment of wastewaters (Alahdal et al., 2021; Bibby and Peccia, 2013; Wurtzer et al., 2020). The survival time of the virus in wastewater is not clear and need further research (Kampf et al., 2020). Various factors like wastewater composition, temperature, and pH affect the survival of viruses in wastewater (Medema et al., 2020).

Proper disinfection of sewage is necessary to avoid people being infected with pathogenic microbes. Different viruses are also known to be present in sewage while SARS-CoV-2 raised the problem of possible contamination of treated wastewater to the next level (Fig. 2.)

Table 3
Viruses detected from different types of waters.

Virus	Water type	Country	Analysis	Reference
SARS-CoV-2	Municipal wastewater	US	RT-qPCR	Wu et al. (2020)
SARS-CoV	Feces of diarrhoea patients	Hong Kong	RT-qPCR	Zhang et al. (2020)
SARS-CoV-2	Wastewater	Barcelona	RT-qPCR	Randazzo et al. (2020)
SARS-CoV-2	Sewage	Italy	RT-qPCR	Rimoldi et al. (2020)
SARS-CoV-2	Sewage	Brazil	RT-qPCR	Fongaro et al. (2020)
Human coronavirus	Tap water and wastewater	US	Cell culture	Patricia et al. (2009)
Feline infectious	Tap water and wastewater	US	Cell culture	Patricia et al. (2009)
Peritonitis virus	Tap water and wastewater	US	Cell culture	Patricia et al. (2009)
Poliovirus	Tap water and wastewater	US	Cell culture	Patricia et al. (2009)
SARS-CoV-2	Untreated wastewater	India	RT-qPCR	Kumar et al. (2020)
SARS-CoV-2	Untreated wastewater	Australia	RT-qPCR	Ahmed et al. (2020)
SARS-CoV-2	Wastewater treatment plant influent	Chile	Taqman 2019-nCoV assay	Ampuero et al. (2020)
SARS-CoV-2	Hospital wastewater	China	RT-qRT-PCR	Wang et al. (2020b)
SARS-CoV-2	Untreated wastewater	Czech Republic	Flocculation	Mlejnková et al. (2020)
SARS-CoV-2	Wastewater	France	RT-qPCR	Wurtzer et al. (2020)
SARS-CoV-2	Wastewater treatment plant influent	Japan	QIAamp viral RNA mini kit	Haramoto et al. (2020)
SARS-CoV-2	Sewage	Israel	RT-qPCR	Bar Or et al. (2020)
SARS-CoV-2	Sewage	Netherlands	RT-qPCR	Medema et al. (2020)
SARS-CoV-2	Sewage	Pakistan	RT-qPCR	Sharif et al. (2020)
SARS-CoV-2	Wastewater	Turkey	RT-qPCR	Kocameci et al. (2020)
SARS-CoV-2	Sewage	Saudi Arabia	RT-qPCR	Alahdal et al. (2021)

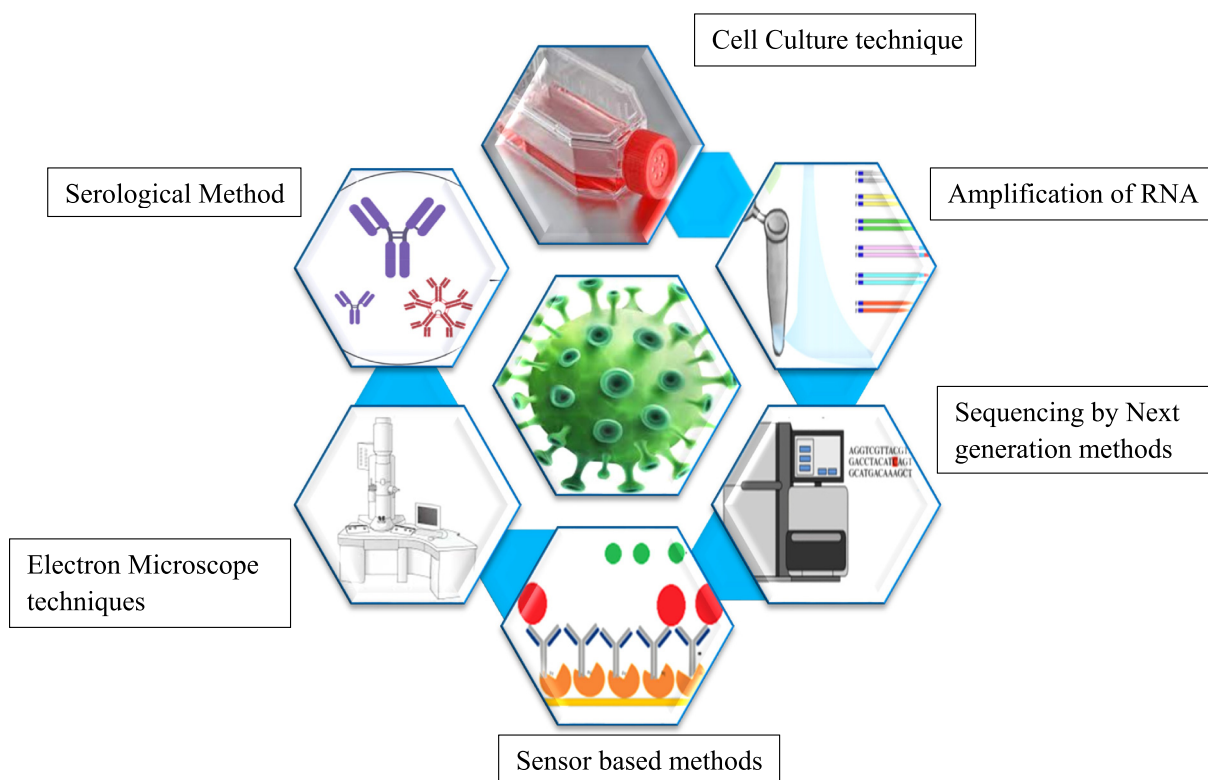


Fig 1. Virus detection methods from water.

4. Disinfection methods

4.1. Ultraviolet radiation

Ultraviolet radiation has been widely utilized to disinfect water since 1910 (Leifels et al., 2019),

and the radiation is divided into four wavelength bands: UV-A (315–400 nm), UV-B (280–315 nm) and UV C (200–280 nm). Vacuum UV (200–280 nm) is absorbed by wastewaters, and therefore, cannot be used for wastewater disinfection. UV-B and UV-C are used to disinfect wastewaters because they have strong bactericidal property.

The wavelength of 253.7 nm is commonly thought to be the most effective in UV disinfection. Although UV disinfection is relatively cheap because of its insufficient penetration and emerging pollutants, more efficient methods are needed.

4.2. Hydrogen peroxide

Hydrogen peroxide can be used where a biological treatment is not feasible and for wastewaters with poisonous compounds. H₂O₂ treatment is based on its dissolution product oxygen, which is a non-polluting substance and thus a safe method.

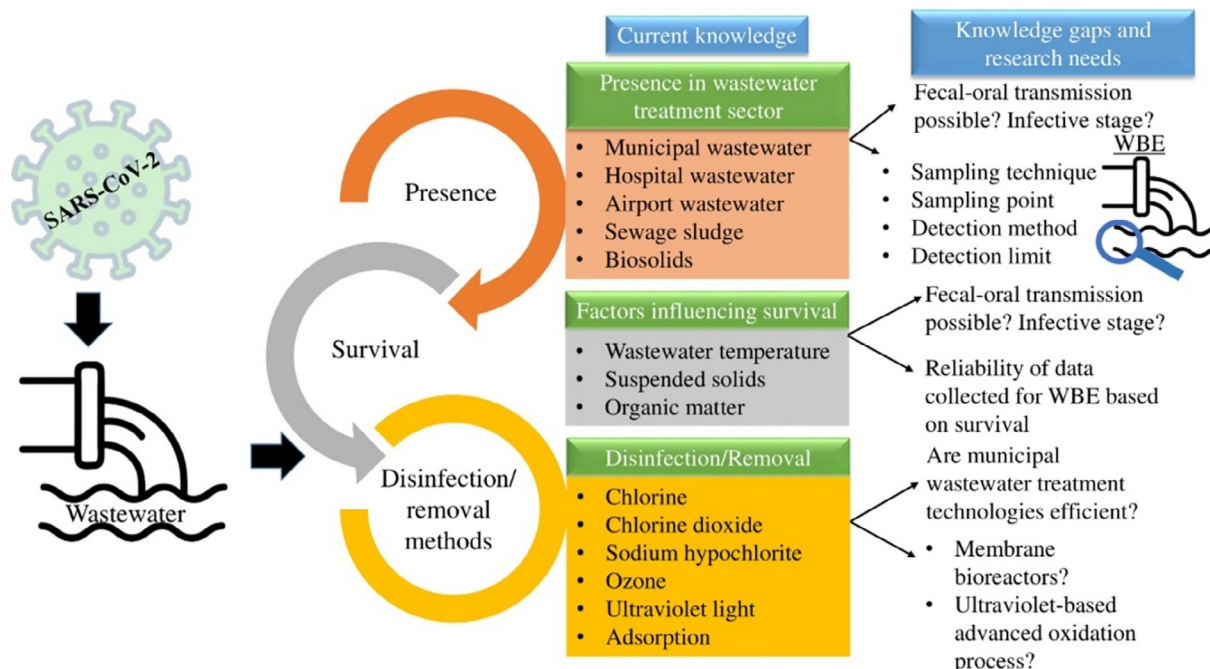


Fig 2. Aspects of SARS-CoV-2 in wastewater (Giacobbo et al., 2021).

Dilute H₂O₂ (3 %) as an oxidizing substitute is effective against bacteria, fungi, yeast, spores/ moulds and viruses. H₂O₂ injures the cell organelles, lipids, and the genetic material of microbes. It destroys viruses because viruses lack repair mechanisms, and hence, cannot avoid the damages caused by hydrogen peroxide's OH radicals. The viral load has been shown to be reduced remarkably in H₂O₂ vapor at a very less a concentration of 20 µl in three hours (Goyal et al., 2014). However, the use of H₂O₂ in a large-scale treatment of wastewater is insufficient (McDonnell, 2014) and its efficacy against SARS-CoV is not known.

4.3. Chlorine-based disinfectants

Chloramines is a group of mixed chlorinated substances whose usage have been increased recently. Despite its weaker oxidising and disinfection properties than hypochlorous acid and hypochlorite ion (Bowman and Mealy, 2007), it has benefits such as greater stability, and thus, it releases chlorine for a longer time. Chloramine is commonly used in emergency. For public water supplies, the US EPA proposed the concentration of 4.0 mg l⁻¹ of chloramines (WQA, 2013).

Free chlorine, O₃ or ClO₂ has been used as a major antiseptic substance (WQA, 2013). When ammonia is added, monochloramine is formed as a residual chemical that has a long shelf life and it a lower risk for trihalomethanes (THM) formation. Chloramines in combination with Cl have a long-lasting disinfection effect with few by-products.

Viral RNA is destroyed by free accessible chlorine from HClO and ClO⁻ and free chlorine (0.2 to 0.5 mg/l) in urban waste water was sufficient to kill viruses quickly (Lee et al., 2018). The dissociation of HClO to the lesser germicidal type hypochlorite ion is regulated by pH and the inactivation of viruses is influenced by pH; the deactivation was found to be rapid at low pH (Zhang et al., 2020). Hypochlorite is thought to be a more efficient virus disinfectant against SARS-CoV than chlorine dioxide (Zhang et al., 2020). After contacting for 30 min, the SARS-CoV was fully inactivated by a chlorine solution formed from hypochlorite at a concentration of >10 mg L⁻¹. SARS-CoV was found to be fully inactivated in less

than one minute in a 0.05 % hypochlorite solution. However, hypochlorite ion was acting slower at high pH. It may be utilized as a small-scale virus disinfectant due to its relatively low residual toxicity, robust movement, easy handling, cost-effectivity, and consistency.

Chlorine dioxide is more suitable disinfectant than chlorine. Chlorine dioxide is an excellent viral inactivator (Lee et al., 2018). ClO₂ is attached to viral proteins (capsomeres) and interacts with RNA. Chlorine dioxides efficacy against human rotavirus, coxsackievirus B5, simian rotavirus, bacteriophage f2, poliovirus1 and echovirus 1 has been reported (Ge et al., 2021). Chlorine dioxide at 1.0 mg/L is efficient over a wide pH spectrum and found to be more efficient than Cl. However, ClO₂ is less efficient than chlorine against SARS-CoV (Zhang et al., 2020). After 30 min of exposure at 40 mg/L, ClO₂ deactivated SARS-CoV (Kim et al., 2016).

NaDCC is listed as one of the active ingredients in the EPA's list of chemicals against SARS CoV-2. Chloramines pierce biofilms and inactivate embedded viruses (Symons et al. 1977). Regular chlorination of wastewater units is adequate to deactivate viruses. FAC must be present during and after the treatment (WEF, 2020). The removing of unprocessed substances with pre-filtration decreases the risk of THM formation.

4.4. Quaternary ammonium compounds

The hydrophilic cationic region of Benzalkonium chloride (BKC) forms electrostatic connections through harmfully exciting pathogen exterior elements, destabilising it (McDonnell and Russell, 1999). BKC is effective against fungi, a few protozoa, bacteria, yeasts and viruses by destroying membranes (Fazlara and Ekhtelat, 2012).

Enveloped viruses such as human immunodeficiency virus, influenza and hepatitis B are susceptible to BKC (McDonnell and Russell, 1999). Adenovirus Ad3, Ad5, Ad19, Ad7a, and Ad37 were destroyed by BKC (Romanowski et al., 2019).

Quaternary composite is efficient against influenza viruses in general (Schrack et al., 2020). SARS-CoV-2 has similar external membrane structure, which has been suggested as a reason to

the efficiency of quaternary composites against both SARS-CoV-2 and influenza viruses (Schränk et al., 2020). Previous research has suggested that, due to the restricted antiviral action of quaternary ammonium composites, it may be useful to combine different antiseptic compounds (Bruins and Dyer, 1995).

4.5. Organic peroxides

Due to environmental factors with chlorine-based disinfectants, peracids or peroxyacids are becoming more popular wastewater treatment methods which has a wide spectrum of microbicidal properties, lack of harmful disinfection by-products, and high oxidising capacity (Luukkonen et al., 2015).

Advantages of peracetic acid include effortless usage, reliability, low freezing point, little development of chlorinated decontamination by-products (THM), fast response time, reasonable sterilization concert in the occurrence of untreated, less concentration, less contact time and efficiency (Rossi et al., 2007). However, since the bio-chemical oxygen demand is incompletely compensated by the dissolved oxygen provided by the disintegration of the peracetic acid and hydrogen peroxide mechanism of the peracetic acid solution, such addition is unlikely to be important (www.peroxychem.com, retrieved on 10.5.2021). One more disadvantage is the high compound rate of PAA payable to inadequate global manufacture; nevertheless, according to a current report (Bettenhausen, 2020), this rate is usually to fall as extra plants implement peracetic acid –depend on decontamination.

Performic acid (CH_2O_3) (PFA) is a disinfectant and oxidising mediator used in combination (1:1) with H_2O_2 (35 %) and 12 to 20% of formic acid (Lasik et al., 2013). It is considered to be a new compound with simple set up and operating conditions (Chhetri et al., 2014), and can be worked even at low temperatures (Heinonen-Tanski and Miettinen, 2010). Hydrogen peroxide and formic acid are the by-products of PFA dissolution, neither of them has ecotoxicological effects (Gehr et al., 2009). Ragazzo et al., (2013) reported absence of harmful by-product development in real world applications.

Peracetic acid (PAA) is a safe, effective antiseptic that has a broad assortment of germicidal properties (Antonelli et al., 2013). PAA's decontamination effectiveness against various microorganisms is capable of series as follows: protozoan cysts < bacterial spores < viruses < bacteria (Kitis, 2004). PAA, which is commercially available in concentrations of 6% and 15%, is a well-built oxidising representative than hypochlorite or chlorine dioxide, except not as physically powerful as ozone, according to EPA (U.S. EPA Office of Wastewater Management, 2012). PAA has too been added to the list of SARS-CoV-2 viricide recommendations by the WHO. The peracetic acid amount range for viruses is wide (12–2250 ppm), and moderately increased concentrations are needed in sewage waste matter (20–140 ppm) to achieve significant virus inactivation (CDC, 2008; Lazarova et al., 1998; Rutala and Weber, 2008a; Rutala and Weber, 2008b). A study by Ansaldi et al., (2004) found to a 35 ppm PAA solution might interrupt the reproduction of SARS-CoV-1 in culturing of a cell for about two minutes contact, but same concentration had no effect after 30 min of exposure, indicates the need for further research. Harakeh (1984) found that comparatively increased absorption of acid was needed to attain substantial deactivation of bacteriophages, enteroviruses and rotaviruses by peracetic acid in sewage waste matter. Based on this analysis, Human rotavirus found to attain 99.98 deactivation with 140 ppm, whereas the least resistant simian rotavirus deactivated with only 20 ppm. Earlier laboratory research finds it effective against viruses found in sewage such as Echovirus, Coxsackie virus, and poliovirus (Baldry et al., 1991). The operation of PAA was found to be retained in wastewater even when the organic load was high.

PFA was more efficient disinfectant than UV and PPA according to Gehr et al. (2009) findings. It is also found to be more efficient than peracetic acid and perpropionic acid (Luukkonen et al., 2015). PFA had greater antiviral activity against Coxsackievirus B1 than PAA (Měrka and Horáček, 1979). It is also found to be effective in deactivating viruses even at low dosage (Karpova et al., 2013), with conflict reality of MS2-coliphages > DNA-coliphages > enterococci. A small dosage (0.5 mg l^{-1}) with 10 min reaction time is required for the sterilization of wastewater and to prevent regrowth for next 24 h. No information on SARS was found.

4.6. Ozone

Ozone is considered to be an effective antiseptic to enhance organic water quality. Since of its short half-life, it might be possible to release treated water without causing environmental damage. The influential ozone is antiseptic suitable in water with organic pollutants and can be used at high concentrations to improve the efficiency. The problem with ozonation is the increasing acidity of water (Zaied et al., 2020). Ozone is poisonous and considered to be a general pollutant according to USEPA. Due to the short half-life of ozone, it is usually recommended as the main sanitizer because it's not capable to retain residuals. It is recommended to be used together with chlorine, chloramines, or chlorine dioxide to achieve sufficient disinfection (Earth Tech, 2005).

Ozonation has appeared efficient in destroying SARS-CoV-1, and thus, it was suggested to be used to disinfect SARS-CoV-2 containing wastewater (Schwartz and Sánchez, 2020). Standard primary ozone dosage of 3 to 10 mg/l and the reaction time of 10 min is effective (Paraskeva and Graham, 2002) against most viruses.

5. Conclusion

SARS-CoV-2 pandemic has now become a challenge worldwide. Research alerting that COVID-19 disease can spread not only through air but also through wastewater requires attention in wastewater treatment processes. Major actions are needed especially in Saudi Arabia where only a part of wastewater is being treated. First of all, the wastewaters should be studied for the presence of viral RNA. Thermal hydrolysis, anaerobic digestion, membrane bioreactors, up-flow anaerobic sludge blanket technology, and activated sludge process has been reported to remove SARS-CoV-2 RNA from sewage. If they are not in use, the wastewater treatment processes should incorporate proper disinfection. Various disinfection treatments efficient against viruses are easily available. The literature review shows that regular chlorination of wastewater units is adequate to deactivate viruses in general and also SARS CoV-2. However, due to the side effects, other safer chemicals against SARS CoV-2 such as sodium dichloroisocyanurate, quaternary compounds, ozone and peracetic acid are listed by the United States Environmental Protection Agency, and the timely information should be checked from their websites (U.S. EPA Office of Wastewater Management, 2012). Since the virus is stable at high humidity and warm temperature existing in Saudi Arabia, wastewaters should be treated in such a way that SARS CoV-2 is completely inactivated. Public must be given confidence that COVID-19 is not spreading through treated wastewater.

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Declaration of Competing Interest

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.

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