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Review Article

Disinfectant impacts on water quality and fishes during the fight against COVID-19 spread

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Abstract

The World Health Organization recommended disinfectant use as a way of tackling the global spread of corona virus pandemic (COVID-19). A total of 246,245,186 infection cases, 246,134,984 recoveries and 4,995,890 deaths have been reported across the world with 3,767,744 confirmed cases in over 160 countries. The spread of the virus was addressed by restricting human and vehicular movements, compelled use of sanitizers, social distancing, and wearing of masks. Chlorine, alcohol and bleach disinfectants, which contain different active compounds, were also used to combat the spread of the virus by applying them on surfaces. The indiscriminate use of disinfectants was reported to have disastrous effects on water quality, and on skin and organs of fish in the long run. The virus affected generally almost all spheres of life. To this end, disinfectants must be used at recommended rate of application, and the proper disposal of wastewater is also important, so as to limit transmission of diseases. Strict adherence to human activities based on the approved guidelines by the government and stakeholders in the health sector is essential for a healthy life. This paper therefore reviews the types of disinfectants, and their effects on water quality, fish species and sustainability of the environment.

Keywords: COVID-19 spread, disinfection, fish species, human response, waste water disposal

1. Introduction

Coronavirus is an enveloped virus which belongs to the family Coronaviriodae. It is characterized by spikes on its exterior surface, minute in size (65 – 125nm in diameter) (Shereen, Kahn, Kazmi, Bashir, & Siddique, 2020). It was named officially as COVID-19 (abbreviated from coronavirus disease 2019) on the 12th of February 2020 and declared a pandemic on the 11th of March 2020 by the World Health Organization (WHO) (Bhowmick *et al*., 2020). It has continued to be a global pandemic in our time with confirmed cases in over 160 countries. The virus was first reported as pneumonia by the World Health Organization on the 31st of December, 2019 (Khadka *et al*., 2020a; World Health Organization [WHO], 2020) and it was announced as a Public Health Emergency of International Concern (PHEIC) on 11th of March 2020 by the World Health Organization (Khadka *et al*., 2020a). As at 9th of May, 2020, the total confirmed case had increased to 3,767,744 and deaths to about 259,593 (Coronavirus, 2020). Across the globe as of 29th October 2021, the infection case count was 246,245,186; with 223,134,984 recoveries and 4,995,890 deaths recorded (Worldmeters, 2021).

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The coronavirus (CoV) has four genera, namely Alpha-, Beta-, Gamma-, and Delta- coronaviruses, with the Alpha and Beta genera affecting humans (human Coronavirus; HCov-229E and HCoV-NL63) and Middle East Respiratory Syndrome (MERS-COV), and betacoronaviruses (severe acute respiratory syndrome coronavirus SARS-CoV) (Cui *et al*., 2019). The virus is seriously impacting all spheres of the world economy, especially in the developing and poor economies. COVID-19 will have a huge impact on the sustainable development of the world. A preventive measure has been the use of disinfectants because it can effectively deactivate the virus and its mode of action. Currently, the use of disinfectants is global and it can facilitate a more rapid die-off of the COVID-19 virus (WHO, 2020a). The process of disinfection has been done *en masse* by the by governments, local authorities, and public health institutes in public places and some community spaces. An example is illustrated in Figure 1, which shows a major disinfectant exercise in a Ghanaian market to manage the spread of coronavirus. At the household level, individuals continue to use disinfectants (that are home-made) to tackle the virus.

The governments across the world have posed measures to combat the spread of the disease. The major one was the restriction of movement at various levels and degrees locally, regionally and internationally (Calina *et al*., 2021). Another was the mandatory use of face masks/shields and sanitizing public places, and the disinfection of surfaces and objects (Barcelo, 2020; Kwok *et al*., 2020). The contamination that is a risk for human health can induce a disease outbreak through the sporadic spread of the pathogen. The viruses that are transmitted via water belong to the enteric virus group and have the ability to multiply rapidly in the gastrointestinal tract of human beings (WHO, 2017a). They are mostly released in faeces in large quantities and occasionally in urine of infected humans (Rusinol & Girones, 2017). These bacteria have been reported to be detected in wastewater and water sources.

Currently, there is no evidence that human coronaviruses are transmitted through contaminated drinking-water (WHO, 2020b). On the other hand, it has been found that the COVID-19 virus can survive on surfaces from 2 hours up to 9 days (Kampf, Todt, Pfaender, & Steinmann, 2020). Thus, improper usage of disinfectants (chlorine, bleach, or alcohol) and discharge of water used in disinfection can affect the aquatic system and fish. This review will elaborate on the usage of disinfectants and how it affects the aquatic system, especially water and fish. It will also elaborate the mode of transmission and its usage in aquaculture. The information will be aimed at knowledge improvement on the use of disinfectants thereby reducing the effects on water quality, fish species and the environment.

1.1 Mode of transmission and disease symptoms

SARS –Cov 2 is a positive RNA virus which has a genome sequence 96.2% similar to the bat coronavirus sequence RaTG13. The virus is transmitted to humans by an intermediate host cell and fuses to the receptor cell of the host with the epithelial cells and lung membrane as principal target points (Rothan & Byrareddy, 2020). The disease symptoms are mostly observed after two weeks of exposure to the virus and signs can range from cough, headache, mild fever, short breath, pneumonia, and shock, to an acute respiratory distress syndrome (ARDS). There are two basic routes of transmission, which are the respiratory droplets (direct transmission) and contact transmission (indirect transmission) where the virus might land on surfaces whereby healthy people may get infected. These have led to increased use of disinfectants on surfaces to inactivate the virus. As a result, increased wastewater with a high concentration of disinfectants is discharged from areas, with its presence reported in community wastewater systems in the USA, Netherlands, and Sweden (Igomu, 2020). The virus may also be spread through fomite contacts such as door handles, utensils, taps, light switches, etc. (Qu, Li, Hu, & Jiang, 2020).

Human-to-human transmission of the virus can occur by the fusion of the receptor-binging virus spikes with the angiotensin-converting enzyme 2 (ACE2) receptor (Rothan & Byrareddy, 2020). After a latency of 3 – 7 days, the virus is fully developed and extremely contagious, most especially between humans with health challenges and low immune system activity (Cao & Hong, 2020; Guo *et al*., 2020). This is a form of direct transmission, and a high transmission capacity has been reported when there is close contact within 1 metre to an infected person (Pastorino, Touret, Gilles, de Lamballerie, & Charrel, 2020). There have been attempts to observe and isolate samples from air droplets where patients of covid-19 are isolated (WHO, 2020b). It is reported that the use of PCR test in COVID-RNA detection in the environment does not present viable and transmissible viruses. Some studies reported the virus lasting for 3 hours in the air and that it can be neutralized by aerosols (Khadka, Hashmi, & Usman, 2020a).

There has been no evidence of virus transfer from mother to fetus when Caesarian operation or vaginal birth occurs (Rothan & Byrareddy, 2020). Evidence has been published on the spread of the virus through fomite contacts such as door knobs, taps, utensils, etc. (Hindson, 2020; Ong *et al*., 2020). The virus can live for hours on surfaces of aluminum, gloves, sponges, etc. and can easily be transmitted by touch. Samples were taken from fomite objects and a positive significance was reported, which implied mode of transmission (Ong *et al*., 2020). Based on these facts, the WHO and the Centre for Disease Control (CDC) advised medical practitioners to keep a distance of 3 – 6 feet from patients, because the rate of breath can increase to 100 from 33 feet per second (Bourouiba, 2020). Some modes of disease transmission and measures to address them are presented in Table 1.

Figure 1. Major disinfection exercise in a Ghanaian market to manage the spread of coronavirus

Table 1. Transmission modes of COVID-19, and associated safety measures

Mode of transmission	Characteristics	Measures of safety	References
By droplets	They are of different sizes; the respiratory droplets are between 5 – 10µm and the droplet nuclei < 5nµm	Maintain social distancing and use sanitizers, gloves, mask or goggles, frequent hand washing, cleaning of surfaces with disinfectants	WHO (2020b); Amgain, Rana, Shrestha, & Shrestha (2019)
By air	Microbes of the virus may be dispersed in air and transmitted over distances more than 1metre.	Maintain social distancing and use sanitizers, gloves, mask or goggles, frequent hand washing, cleaning of surfaces with disinfectants	Khadka *et al.,* (2020a); WHO (2020b); Amgain *et al.,* (2019)
By contact	It occurs when there is contact with infected person and virus may enter through the nose, mouth, or eyes	Maintain social distancing and use sanitizers, gloves, mask or goggles, frequent hand washing, cleaning of surfaces with disinfectants	WHO (2020b)
By fomites	When items around the infected person or area are touched, virus can be transmitted and enters through the nose, eyes or mouth when dirty.	The use of soap or hand sanitizers, wearing gloves	Cai *et al.,* (2020); Ong *et al.,* (2020).
By feco-oral routes	The virus has been found in fecal swab	The use of soap or hand sanitizers, wearing gloves, movement should be limited	Hindson, (2020)
By mother to foetus	There is no reported evidence of virus transmission	Hygiene is very important	Rothan, & Byrareddy, (2020)

Source: Adapted from Khadka *et al.,* (2020b).

2. Disinfection as a Measure to Reduce COVID-19

The practice of disinfection is important to reduce the occurrence of coronaviruses on surfaces and public places. This resulted from the rapid spread of the pathogen, since there is no existing therapy to curb the pandemic. Frequent washing of hands is recommended with soap and sanitizers and this excessively practiced with the aim of eradicating the virus. Despite their benefits these disinfectants and sanitizers have side effects: hand sanitizers can lead to infections, dry skin, and alcohol poisoning to which children are more susceptible (Ghafoor, Khan, Khan, Ualiyeva, & Zaman, 2021). According to the CDC (2021), disinfection is employed in places where:

- There is a large number of people or it is a high-traffic area
- There is poor ventilation
- People do not have access to hand sanitizer or hand washing
- The area contains people who are particularly susceptible to COVID-19.

2.1 Chlorine disinfectants

The use of chlorine disinfectants particularly for the disinfection of drinking water and the subsequent washing of hands with water has played a central role in reducing the incidence of COVID-19. This measure can be considered one of the most important success stories of our time in preventing the spread of COVID-19. The use of chlorine to combat COVID-19 has been reported in countries like China where the virus was first detected. Globally, about 884 million people do not have access to fresh water, with around 1.8 billion people using the fecal matter contaminated sources of their drinking water (Heller, Mota, & Greco, 2020; Naidoo & Olaniran, 2013). During the outbreak, water treatment plants are susceptible to contamination and chlorination can inactivate the virus so that it does not infect consumers. SARS-CoVs can survive up to several days in untreated water; and even for a much longer period in low-temperature regions. Thus, proper precautions are necessary. According to Bhowmick *et al*. (2020), SARS-CoV-2 has not yet been found in any drinking water facilities. Still, proper precautions must be taken to prevent contamination.

The use of chlorine disinfectants to combat COVID-19 can be harmful to water and fish if not properly disposed. Chlorine-releasing agents are harmful to aquatic organisms and water bodies. Chlorine disinfectants are acutely toxic to aquatic animals, causing respiratory and digestive lesions or even death (Heller, Mota, & Greco, 2020). Chlorine release into water bodies as a result of controlling COVID-19 can kill living cells, most often damaging the fishes' sensitive gills as well as the skin that covers their entire bodies. Fish species can uptake chlorine from wastewaters originating from the use of disinfectants. It is thus recommended to adhere with the 10mg/L acceptable levels for waters that fish species may come in contact with (Food and Agricultural Organization [FAO]/WHO, 2000). In aquaculture, chlorine compounds can be toxic to fish survival, can kill plankton and benthos, leaving little natural food available when post larvae are stocked. Thus, it is necessary to be cautious when using chlorine as disinfectant.

2.2 Bleach disinfectants

These contain sodium hypochlorite as the active ingredient (3 - 6% concentration range) and are very strong and effective in eliminating bacteria, viruses and fungi (Al-Sayah, 2020; Iyiola, Asiedu, & Fawole, 2020). Bleach is a form of chemical disinfectant that can be used to reduce the spread of COVID-19 by application on surfaces. It is the most common domestic disinfectant due to its availability, low cost, low toxicity, and a wide spectrum of activity. Its activation period is between 10-60 minutes of contact with surfaces. WHO (2014) guidelines recommend its use for surface disinfection in hospitals, dispensaries, and homes. However, its use must be done with the utmost caution because it can irritate the mucous membranes, the skin, and choke airways. It can be easily decomposed by heat and light; and is reactive with other chemicals. Strict precautions include proper ventilation and compliance with relevant occupational health and safety guidance.

Bleach should also be used at recommended dilutions so as to maintain its effectiveness. Before disinfecting a surface, the area should be cleaned of any superficial dirt. There has not been any report of fatality or food safety issue of fish that have come in contact with surfaces cleaned with bleach. It should be noted that consuming fish that contain bio-accumulated sodium hypochlorite may result in complications such as vomiting, diarrhea, nausea, and in some cases death. It should be noted that the safety of food is a fundamental and legal requirement.

Due to COVID-19, the industrial production of bleach has increased. Often, manufacturers release bleach-containing waste into water bodies. Once in the water, bleach reacts with other chemicals to form, among other products, dioxins. Dioxins are known to be highly dangerous toxins that can have serious impacts on health. Environmental toxins created by bleach have lowered the populations of several species of fish (Al-Sayah, 2020). Bleach is especially damaging to the environment because it lingers on for many years. Even small amounts of the toxic chemical can accumulate in air and water over time, and can eventually result in adverse health effects (Compact Appliance, 2020). In aquaculture facilities, excessive disinfection and improper disposal of bleach and wastewaters can affect the cultured fish. It is thus critical to put in place biosecurity measures. However, these measures may be a challenge to small-scale fish farmers, thereby posing a threat to food security (Al-Sayah, 2020).

2.3 Alcohol disinfectants

In combating COVID-19, alcohol-based hand sanitizer with at least 60% alcohol or 70% ethyl alcohol can be used to disinfect small areas between uses. These chemicals break down the virus by breaking down the lipid cover of the virus (WHO, 2020). The COVID-19 virus on surfaces can be detached and broken down with alcohol (Kampf *et al*., 2020). Common disinfectants, such as 70% ethanol if properly applied, can inactivate the COVID-19 virus within 1 minute (WHO, 2020). Isopropanol (isopropyl alcohol) can destroy the virus within 30 seconds at concentrations of 70–90%. In many poorer countries, alcohol is not available for everyone due to its high cost and scarcity so they tend to use low-cost and readily available disinfectants (Kampf *et al*., 2020). There is no evidence of any risk associated with using alcohol as a disinfectant to fish. However, fish skin exposed to alcohol may lower the value of the fish, affecting the income of fishermen. Long-term exposure of humans to alcohol in aquaculture facilities can cause asthma and cancer (Yu *et al*., 2020).

2.4 Effects of disinfectants on water quality

The increase in human population has increased the demand for clean and fresh water and, in turn, increased waste discharges to the environment. Therefore, treatment and management of wastewater must be addressed. This can be achieved by inactivating the pathogens, and disease outbreaks are reduced. The use of chlorine is very common for treating effluents from wastewater plants before discharge to receiving waters. If residual chlorine is high in such waters, it can harm aquatic life by forming various genotoxic, mutagenic, and/or carcinogenic by-products (DBP) from interactions with the residual chlorine. Chlorine disinfectants can destroy the cell walls or damage proteins in aquatic flora and fauna, and bind with other materials to form toxic compounds. In surface water with high content of dissolved organic matter, synthesis of disinfection by-products such as trihalomethanes (THM) or haloacetic acids (HAA) can occur. These by-products have been shown to be very toxic to aquatic organisms (Liu & Zhang, 2014). In addition, disinfectants could combine with nitrogen, forming chloramine or N-nitrosodimethylamine, both of which have been identified as carcinogens.

2.5 Effects of disinfectants on fish species organs and skin

2.5.1 Gills

The gills are essential organs of fish and act as the center of gaseous exchange. They are protected under the operculum on both sides of the pharynx. Gills have short protein structures called filaments which absorb oxygen from the water that contacts them. When exposed to excess disinfectants, the epithelial appears to become swollen and gill edematoses are observed in the proximal area of the secondary lamellae. Occurrence of epithelial lifting and severe erosions can occur, which can increase with the concentration of disinfectants (Mahjoor & Loh, 2008). Derksen *et al*. (1999) reported severe damage to the gill surfaces of fish exposed to excess disinfectants. The gill surfaces were rapidly covered with bacteria and the bronchial tissues were smeared. The gills can be congested and hemorrhage can result. Chronic exposure can result in the death of fish (Yu *et al*., 2020).

2.5.2 Liver

The liver is a very vital organ in fish and it is the point of detoxification (Iyiola, Ipinmoroti, Akanmu, & Oladejo, 2018; Yu, Li, Chen, Li, Jiang, & Wang, 2020). It performs other functions such as the buildup of blood plasma, and storage and release of glycogen. Various forms of pollution from disinfectants relate to changes in morphology, histology and histopathology of the liver (Ipinmoroti, Iyiola, & Fayiga, 2017; Kolawole & Iyiola, 2020; Kulshrestha & Jauhar, 1984). Evidently the effects of disinfectants can be very prominent and severe erosion and damage was observed on the liver cells. Matthiessen and Roberts (1982) investigated the effects on histopathology, and observed focal and toxic necrosis, oedema in the sub-capsule, melano-macrophage center reduction, and accumulation of toxic fluids in the liver.

2.5.3 Tissues/Skin in fish

When the skin is affected by disinfectants, signs such as restlessness, lying on the side of fish, frequent leaping out of the water, and spasm movements in the fins, tail and mouth, are observed in the fish. In some cases, the skin is covered with mucus and body can become pale. There is also dystrophy and desquamation of the skin epidermis in fish exposed to excessive disinfectant levels (Yu *et al*., 2020).

2.6 Impacts of coronavirus on fisheries and aquaculture

Water is a principal component in the fisheries and aquaculture sector and must be present in the right quality and quantity. In this context, the fisheries sector refers to the capture fisheries (wild fisheries in rivers, high seas and other large water bodies) while the aquaculture sector refers to culture fisheries (fish farming in ponds, tanks and facilities you have control over, in production). During the restrictions, there was decreased fishing activities, closure of fish markets and jetties, and local and international trade were affected. The fish processing sector and supply chains were also affected (Yu *et al*., 2020). This affects the female gender fish, the prominent actors in the fish processing sector. Reductions in availability of fish feed, seeds, and items related to aquaculture were also seen due to restrictions on movements and personnel. The demand for fish was reduced as well as the price of fish stocks (WHO, 2020).

2.6.1 Is consumption of fisheries and aquaculture products safe?

The benefits from consumption of fish cannot be overemphasized. It is a product rich in essential amino acids and minerals, and low in cholesterol. The safety of human consumption of this product relies mostly on the nature, type, or activities around the environment in which it has been caught or raised. Some fish species may be present in a safe environment but might have migrated from polluted areas in which bioaccumulation of toxicants may have occurred; such cases cannot be ignored. Fish are not hosts for coronavirus, but they may become contaminated when infected patients do not practice good personal hygiene. The virus can be spread via contamination of fishing crafts (boats, canoes, paddles, vessels, etc.) and gears (fishing nets and implements), which are the primary contact points for fish when captured. Based on this, there is need for proper hygiene to protect fisheries and aquaculture products from contamination (WHO, 2020).

2.6.2 Can COVID-19 affect global fish-food chain?

Fish are traded with a lot of other produce going for exports. They also serve as a source of livelihoods for riverine communities and underdeveloped countries. During restrictions, the global supply was affected due to logistical challenges.

2.7 Effects of coronavirus on target and non-target organisms

The use of disinfectants in combating coronavirus is key although the effects on non-target organisms are unknown. It has been reported from various studies that the chemicals used as disinfectants can induce hormesis in plant cells, animal cells, and microbes (Liu *et al*., 2020; Neagu *et al*., 2021). When these disinfectants are applied at sub-lethal, it is considered safe and pose no ecological risk. The sub-lethal doses may cause pathogenicity and proliferation of pathogenic microbes and enhance the resistance of the drug. These effects are used to establish the threshold doses because the Linear-No-Threshold (LNT) and threshold dose-response models may not be able to predict or identify the effects of these doses.

2.8 Disinfectant concentration in Aquaculture

The use of chemicals is the most common disinfection method applied in aquaculture systems to kill all disease pathogens that may colonize the aquaculture water. The choice of disinfection is a function of the type, size, nature of disinfectant material, type of culture facility, and the chemical product availability in the country. The aim of disinfection must be followed and diseased animals must be isolated away from culture facilities and equipment, so as not to infect the healthy stocks. The process of disinfection and washing may include the following procedures:

- The removal of solid wastes in the facility
- Deep cleaning and washing of facility
- Disinfection of facility
- Rinsing of surfaces and facilities

Disinfection may be done on culture facilities and the culture water in an aquaculture system. Disinfectants used in aquaculture systems are discussed in Table 2.

3. Conclusions

The use of disinfectants in combating the spread of coronavirus has been recommended by countries and health agencies. Despite this, their excessive use can have tremendous negative effects on the environment. The virus can be spread from infected to non-infected persons through respiratory droplets and by contact transmission. Measures such as lockdowns, reduced physical contact, frequent disinfection of health centers, and mandatory use of masks and sanitizers, were advocated by countries to reduce the spread. Health practitioners were advised to keep a distance of at least 1 meter and always wear Personal Protective Equipment (PPE) to reduce the spread. The chlorine, bleach and alcohol types of disinfectants are the major types applied to surfaces to combat the virus spread. These items have different application rates and timing, which must be adhered to in order to reduce environmental and water pollution from wastewater discharges. The fish liver, gills, and tissues can be altered by the presence of elevated levels of toxic chemicals in water, as well as by the inhibition of oxygen which is principal for survival of aquatic organisms. The virus also affects fish consumption, marketing, supply, food chain, and both target and non-target organisms. With this, the increased use of disinfectants is posing serious effects on the environment; thereby such usage should be properly managed for each required application.

4. Recommendations

Disinfectants pose a serious threat to water bodies, especially by inhibiting oxygen, and affect the organs and tissues of fish species. The following measures may be recommended.

- The disinfectants used to control COVID-19 must be selected and applied according to safety guidelines to avoid pollution of the water resources and aquatic organisms.

Table 2. Effects of poor water quality on fish

Facility	Disinfectant used	Rate of inclusion	Method of application
Culture pond	Chlorine solution	1600ppm	Spraying surfaces with the chemicals
Culture pond	Iodophor solution (free Iodine)	220ppm	Sponged on surfaces
Floor of culture facility	Chlorine	200ppm	Surface to a depth of 5cm for 48 hours
Culture building	Formaldehyde gas	-	30 – 60 hours minimum
Buildings for fish processing	Formaldehyde gas	-	Spraying
Aquaculture clothing and equipment	Iodophors	200 – 250 mg Iodine/liter	Footbath
Aquaculture clothing and equipment	Chlorine (bleach solution)	50mg chloride/liter	Effective bathing or washing of equipment
Aquaculture clothing and equipment	Sodium hydroxide	1% NaOH + 0.1% Teepol or other detergents	Effective footbath
Surface of tank	1% NaOH + 0.1% Teepol or other detergents	2.5 liters per square meter of tank surface	Spraying
Grow out ponds	Calcium hypochloride	10 ppm	Minimum of 24 – 48 hours
Liming of ponds	Quick lime (Calcium oxide)	4000 – 5000 kg/ha	Spread on the bottom of the ponds for at least one week

Source: Adapted from Chen (2009)

- Other measures of addressing the spread, such as use of protective materials, should be adhered to in order to reduce the use of disinfectants.
- Proper hygiene and maintenance are required for both humans and culture facilities.

Wastewater from disinfection procedures should be treated before discharge into the environment. The wastewater may be exposed to sunlight where the volatile compounds can be sublimed, and then the water discharged will be less harmful to the environment.

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