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Research Article

Ecological Consequences of COVID-19 Outbreak

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1. Summary

The COVID-19 outbreak has urged the countries around the globe to adopt restrictive measures to control the outbreak. This includes using large quantities of chlorine that are several times higher than the recommended dose to control the outbreak. In this article, we reviewed the articles that have direct relation with chlorine and ecological consequences and discuss them with the using chlorine in covid-19 outbreak. Using chlorine includes spraying external and internal surfaces. This may have resulted in photochemical reactions of chlorine creating potential ecological consequence that may become the second international problem after Covid-19 in the world. Here below, we highlight the possible ecological consequences that may be associated with using chlorine as a disinfectant material during covid-19 outbreak. These consequences are atmospheric, aquatic and terrestrial ones that may arise from using chlorine as a disinfectant. We also extend an appeal to the governments over the world countries to stop using chlorine as a disinfectant and to adopt restrictive physical measures to control the outbreak and to protect the environment.

3. Introduction

The ongoing COVID-19 outbreak, which emerged in China during December 2019 becomes a global pandemic by March 2020 [1], urged the governments in most countries to use a chlorine as an efficient disinfectant to control the virus.

These are several methods of disinfection [2] in this article, the use of chlorine as a disinfectant is the focal point.

It is well known in the literature that chlorine has strong effect to destroy the living cells in different ways. Chlorine is an efficient disinfectant, cheap and available everywhere but it has long residual effects. It has been used for disinfection of indoor swimming pools [3, 4]. These authors revealed the formation of trihalomethanes (THM_4) in indoor swimming pools filled with seawater that adopt these disinfection methods.

On the other hand, Manasfi et al.[5], evaluated the toxicity of chlorination byproducts in swimming pools and revealed that exposure to disinfectant byproducts increases the risk of respiratory adverse effects and bladder cancer.

Chlorine has also been used to inactivate water born viruses, for instance Gall et al. [6] observed that PR772 inactivated by free chlorine still attached to host cells, and viral DNA synthesis and early and late gene transcription were inhibited.

Furthermore, a photochemical reaction of chlorine is well established. Moreover, it has been shown that photoactivation of aqueous chlorine could promote degradation of chlorine-resistant and photochemically stable chemicals accumulated in swimming pools. For instance Sun et al. [7], investigated the degradation of N, N-diethyl-3-methylbenzamide in different water bodies using simulated sunlight activated free chlorine. They revealed that Cl and OH free radicals were responsible on the degradation of the tested compound.

Asobvious,the above-mentionedstudies revealed the activity of chlorine as a disinfectant on the other hand revealed the formation of hazardous byproducts. The objective of this study is to highlight the ecological consequences that may emerge in different countries due to the excessive use chlorine as a disinfectant.

4. Materials and Methods

4.1. Data collection

A deep search of scholarly databases such as Scopus, Web of Science, ScienceDirect PubMed, BMC, Research Gate, and Google Scholar was conducted using the following keywords: 'chlorine as disinfectant' , 'chlorine and photochemical reactions', 'chlorination and byproduct synthesis', 'chlorine and air components', 'chlorine and water reactions'and 'chlorine and human health effects/impacts/risks'.

4.2. Inclusion and exclusion criteria

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Full text of articles were down loaded and carefully reviewed. The articles that have direct relation to chlorine reactions in air, water and soil components were considered relevant to this article and included in the study whereas articles that did not have a direct reactions of chlorine were considered irrelevant to this article and excluded.

About 25 relevant articles that evaluated chlorine as a disinfectant were included in this review regardless.

5. Results and Discussion

The ecological consequences associated with the COVID-19 outbreak emerges from the fact that large quantity of chlorine is being used in many countries for possible controlling of COVID-19. So far, the effectiveness of chlorine as a disinfectant was revealed by several authors [8-10].On the other hand, the same authors indicated the formation of disinfectant byproducts that may be harmful to several organisms.

This disinfectant (chlorine) may stay in the external surfaces of building exposed to sunlight and undergo continuous photochemical reactions producing free radicals of chlorine atom that can react with organic and inorganic molecules in the atmosphere, aquatic and terrestrial ecosystems producing chlorinated hydrocarbon that poses cancer risk to the population.

Here below we discussed the potential ecological consequences of discharged disinfectant "chlorine" with the components of ecosystems.

6. Atmospheric Consequencesof Chlorine Disinfectant

Chlorine may undergo photochemical reactions with atmospheric components that results in increasing atmospheric pollutants and create depletion to ozone layer. So far, under sunlight chlorine may undergo the following reactions with air components.

Photodegradation of Cl_2 under sunlight to produce free radicals of as shown in equation reaction

$$\text{(1)}\ \ Cl\text{-}Cl2 \rightarrow Cl^{\bullet} \qquad (1)$$

The free radicals produced in Eq. 1 may react with oxygen molecules to produce chlorine oxides that may be classified in monochlor- and dichloroxi- derivatives asshown in the reaction in equation.

$$2Cl^{\bullet} + O2 \rightarrow ClO + Cl2O \qquad (2)$$

All these compounds are thermally unstable and may decompose readily in the atmosphere. Nevertheless, these reactions are continuous and may lead to the formation of $C1_2O_4$ which may undergo a reformation reaction to reproduce Cl-Cl or undergo continuous reaction as shown in equation reactions (3-4). The proposed equation reaction in (2) is in accordance with a previous report [11] that revealed the formation of chlorine oxides.

$$2Cl2O4 \rightarrow Cl2O7 + 0.5\ O2 + Cl2 \qquad (3)$$

$$Cl2O4 \rightarrow 2\ O_2 + Cl2 \qquad (4)$$

These proposed reactions are in accordance withLopez et al.[11] who indicated the formation of these photochemical reaction under exposure to light at wave length of 366 nm. Nevertheless, the excessive use of chlorine as a disinfectant to control the outbreak resulted in a continuous reaction.

On the other hand, the free radicals produced in Eq. 1 may react with methane gas emitted from biodegradation of animal manure to produce various species of chloromethane according to equation reaction (5)

$$2Cl^{\bullet} + CH4 \rightarrow CH_3Cl\ + HCl \qquad (5)$$

This chloromethane is a volatile organic molecule and can be inhaled by human beings or animals creating variety of harmful effects. It is well known in the literature that volatile organic compounds such as chloromethane is a criterial pollutant of USEPA.

Moreover, ClOproduced in Eq. (2) may react with NO forming chloride free radical as in equation reaction (6) that may react with ozone layer (O_3) causing ozone depletion as shown in equation reaction (7)

$$ClO + NO \rightarrow NO2\ + Cl \qquad (6)$$

$$2Cl^{\bullet} + 2O3 \rightarrow 2ClO\ + 2O2 \qquad (7)$$

As obvious from reaction 7, a depletion of ozone layer may occur due to the massive use of chlorine as a disinfectant. Consequently, the harmful solar radiation may reach the earth in many countries and create a lot of health hazards and or global warming. This statement is in accordance with a previous report [12] that revealed the implications for human health, ozone depletion, and global warming due to formations chloromethanes.

7. Aquatic Consequences of Chlorine Disinfectant

Aquatic consequences from extensive use of chlorine as a disinfectant may emerge from reaction of chlorine with the components of aquatic system. So far, accumulated disinfectant on the external surfaces and/or internal surfaces may be discharged to sewage systems and finally reach the aquatic ecosystem and undergo the following reactions.

8. Reaction of Chlorine Disinfectant with Water Molecules

Discharged chlorine may react with water molecules according to reaction equation (8) to produce hypochlorous and hydrochloric acids.

$$Cl_2 + H_2O \rightarrow HOCl + HCl \quad (8)$$

It appears from eq. (8) that aquatic system becomes acidic due to the production of hypochlorous and hydrochloric acids in which hydrochloric acid dissociates to H^+ and Cl^-. Accordingly, hypochlorous acid may be the major reactive form during the discharge of chlorine disinfectant to the aquatic system. The formation of these two acids is in accordance with Morris [13], who revealedthat the formation of hypochlorous acid was the major active form during water treatment using chlorine as a disinfectant.

9. Oxidation of Dissolved Organic and Inorganic Molecules by Chlorine Disinfectant in Water

So far, hypochlorous acid produced in Eq. (8) may oxidize organic and inorganic compounds that are dissolved in water according to eq. (9) to produce chlorinated compounds

$$HOCl + A \rightarrow \text{Chlorinated compounds} \quad (9).$$

Where A is an organic or inorganic compound.

On the other hand, chlorinated compounds produced in eq (9). can also be acid-catalyzed reaction of hypochlorous acid or Cl_2 reactions with A as in eq. (10) and (11). The acidity emerged from the dissociation of hydrochloric acid (HCl) in eq (8).

$$H+ HOCl + A \rightarrow \text{Chlorinated compounds} \quad (10)$$

$$Cl_2 + A \rightarrow \text{Chlorinated compounds} \quad (11)$$

Accordingly, large quantity of chlorinated organic and inorganic compounds may be produced due to discharge of large quantity of disinfectant to aquatic systems. These proposed reactions are in accord with previous reports [14, 15] that found similar approach in water chlorination.

The chlorinated hydrocarbons have long-termpersistence effects and can accumulate in adipose tissues and create health hazards (3).

Moreover, it can be suggested that dissolved organic matter in aquatic ecosystems may undergo continuous chlorination reactions under sunlight leading to formation of many types of chlorinated hydrocarbon that may have genotoxic, cytotoxic, mutagenic and carcinogenic effects. These chlorinated hydrocarbons may also be toxic to the aquatic life and human beings. Since chlorinated hydrocarbons have long-term residual, effect due to its long persistence. It has also the ability to accumulate in human body. This statement is in accordance with previous reports [16-19] that revealed the formation of toxic byproducts due to discharging of disinfectants to aquatic systems. Those byproducts caused health risks to humans [20].

10. Influence of Chlorine Disinfectant on Aquatic Photosynthetic Activity

It has been shown that discharging disinfectant to the aquatic system produced high acidity as shown in equation reaction (8). This high acidity may partially/totally inhibit the activity of carbonic acid anhydrase, the enzyme responsible for converting HCO_3^- to CO_2 in the photosynthesis in aquatic plants [21], consequently a severe inhibition of phytoplankton growth and photosynthetic activity may occur, hence reducing energy and oxygen production. This threats food security and human lives.

11. Effects of Chlorine Disinfectant on Cyanobacteria

It has been shown that chlorine may have a direct effect on cyanobacteria throughout destroying their cell wall and releasing their toxins (cytotoxic, hepatotoxic, and neurotoxic compounds) in aquatic system. These toxins have been shown to cause severe acute and chronic effects on vertebrates [22, 23]. On the other hand, discharging of disinfectant in aquatic ecosystem may significantly inhibit the photosynthetic activity of phytoplankton resulting in severe reduction in oxygen production which threats aquatic and terrestrial living organisms including humans.

12. Influence of Chlorine Disinfectant on Fish

It has been shown that chlorinated phenols (2, 4, 6-trichlorophenol and 2, 4-dichlorophenol) are the most prevalent

chlorinated phenolic pollutants in aquatic environments. These compounds can be formed according the reaction

equations, 5, 9-11 shown above. These compounds have been shown to create a variety of fish toxicities such as,

decrease hatching rate and malformations. Similar observations have recently been reported [24].

Furthermore, polychlorinated biphenyls may be produced according to the reaction equations 5, 9-11 under excess

of chlorine concentration in aquatic systems. Then, they move to fish body due to partitioning coefficient and create

health hazards to fish. Similar observations were recently observed [25, 26].

13. Terrestrial Consequences of Chlorine Disinfectant

13.1. Effects of Chlorine Disinfectant on Plants

It can be noticed that dumping disinfectants to the atmosphere can produce chlorinated hydrocarbons according to equations (5; 9-11). Some of these chlorinated hydrocarbons are volatile organic compounds and can reach the plants elsewhere and create phytotoxic effects. So far, chlorinated hydrocarbon has been shown to cause phytotoxicity to Hybrid poplar trees [27].

Moreover, Ma, and Havelka (28) investigated the phytotoxicity of hexachlorobenzene and its metabolites (1, 3, 5-trichlorobenzene and 1, 4-dichlorobenzene) to common wetland plants (Typha and Phragmites). They found severe phytotoxicity on the tested plants.

Moreover, Miguel et al. (29), evaluated the biological responses of maize (Zea mays) to chlorobenzene derivatives. They found that significant growth inhibition (based on biomass gain) was observed from exposure to monochlorobenzene (MCB), dichlorobenzene (DCB) and trichlorobenzene (TCB) concentrations higher than 10 mg/ l.

13.2. Effects of Chlorine Disinfectant on Birds

Effects of discharged chlorine disinfectant on birds occur via indirect ways such as accumulation of persistent chlorinated hydrocarbons on birds or throughout its effects on birds generations. So far, effects of chlorinated hydrocarbons in birds have been tested on 10 bird species [30]. They found greater concentration of chlorinated hydrocarbons in predatory birds than non-predatory birds, indicating the importance of diet and trophic position in the food chain for bioaccumulation of these contaminants to occur. On the other hand, Omer [31] evaluated the acute and prolonged toxicity of organochlorine derivatives on birds. He revealed that chlorinated hydrocarbon are toxic to both mammals and birds without histologic alterations in the central nervous system which are relatively slight or nonexistent. Additionally, Nambirajan et al. [32)], investigated the incidences of mortality of Indian peafowl Pavo cristatus due to accumulation pattern of chlorinated pesticides in tissues of the same species collected from Ahmedabad and Coimbatore in India. They found Peafowl from Ahmedabad had significantly ($p < 0.05$) higher level of total chlorinated pesticide (149.0 ng/g) than birds from Coimbatore (47.8 ng/g).

13.3. Effects of Chlorine Disinfectant on Soil Insects

Excessive use of disinfectants may result in soil contamination with chlorine molecule. This may result in formation of chlorinated hydrocarbon in soil. The sechlorinated hydrocarbons may be adsorbed in soil particles and clay minerals and form a slow release of chlorinated hydrocarbons in soil resulting in a continuous killing of bifacial soil insects and earth worms. Similar observation was recently noticed with 1, 3-Dichloropropene [33].

Furthermore, chlorinated hydrocarbons have been shown to alter the behavior of honeybees. Similar observation was previously reported [34].

In conclusion, using chlorine as a disinfectant may result serious ecological consequences such as air pollution, ozone layer depletion, water contamination and human health risk. We extend a call to all governments in countries to conduct an environmental impact assessment to all components of the ecosystem to exactly estimate the ecological consequences resulting from the excessive use of disinfectants during Covid-19 outbreak This may save the quality of the ecosystem and protect the human live.

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