Letter to the Editor

Use of Hypochlorite Solution as Disinfectant during COVID-19 Outbreak in India: From the Perspective of Human Health and Atmospheric Chemistry

Abhijit Chatterjee*

Environmental Sciences Section, Bose Institute, P 1/12 CIT Scheme, Kolkata-700054, India

ABSTRACT

The current situation in India regarding the COVID-19 pandemic is the worst since its first detection, in terms of the number of new cases per day, and it is now more than 10000 (as of June 16, 2020). In addition to several precautionary steps being taken (social distancing, use of masks, sanitizing hands etc.), spraying disinfectants (NaOCl solution) over several residential, official and commercial buildings, open areas, markets, public road transports, railways etc. has been occurring on a regular basis. It has also come to the world’s attention that spraying of disinfectants has been especially used on people who are migrating from one part of the country to another. In this letter, I have made an attempt to discuss some major impacts of NaOCl on human health as well as atmospheric chemistry. NaOCl once emitted into the air reacts easily with the water vapor to form HOCl that further gets photo-dissociated into various reactive species. These reactive species have significant potentials to participate in various tropospheric chemistry of chlorine radical, ozone, S (IV) oxidation, hydrocarbon oxidation, modification of chloride salts etc. I have also recommended some important steps to be taken if spraying of NaOCl is deemed essential.

Keywords: COVID-19; NaOCl solution; Disinfectants.

INTRODUCTION

The first Corona virus disease 2019 (COVID-19) case was detected in India on 30th January 2020. Subsequently, COVID-19 was declared a pandemic by the World Health Organization (WHO) on 11th March 2020 At present (as of 16th June 2020) the total number of active cases and deaths due to COVID-19 is 3,448,186 and 439,577 worldwide. In Indian context, the active cases and deaths are 153,178 and 9,900 respectively as of 16th June 2020 (Ministry of Health and Family Welfare, Government of India). Government of India called a complete lockdown on 25th March 2020 and its fourth phase completed on 31st May 2020. The Government of India has now called the fifth-phase lockdown from 1st June 2020 with the relaxations in several sectors and has named it Unlock-1. While the entire official and commercial activities were completely shutdown (other than the emergency services) in the first phase (till 15th April 2020), the services started resuming slowly sector-wise during the later phases. It was observed that the local administration in different states of India started spraying disinfectants over various commercial and residential buildings on either side of the roads especially in the urban/sub-urban regions including the metro cities. The chemical used as the disinfectant is the alkaline solution of sodium hypochlorite or NaOCl. Surprisingly it was used to spray over people too. Several disinfectant tunnels were installed in many places whereby people were asked to walk through. National and regional newspapers also published news which told us that such spraying was done over the people including children when they migrated from one part of the country to another. However, later on, Directorate General of Health Services, Ministry of Health & Family Welfare, Government of India issued an advisory against spraying the disinfectant on people. But such spraying of NaOCl is being continued on a large scale over several official, residential and commercial buildings, streets, open areas, markets, shops, road transport, railways etc. The major concern is the concentration of such hypochlorite solution being used. The concentration has not been fixed and regulated by any administrative/regulatory boards and therefore it varies over a wide range. Based on a personal survey, NaOCl solutions of 5–10% are being used over most of the parts of the country, however highly concentrated solutions (> 10%) are also in use over some of the cities.

*Corresponding author.
Tel.: (+91) 9051585800
E-mail address: abhijit.boseinst@gmail.com; abhijit@jcbose.ac.in

© Copyright The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are cited.
Through the present letter, I have made an attempt to highlight the possible impacts of such excessive use of highly concentrated NaOCl solution/spray on human health. Although the spraying of NaOCl on people stopped by order of the Indian Government, we are still exposed to its vapor and are inhaling as the spraying over buildings, markets, transports etc. are still on (as of June 16, 2020). This could have adverse effect too. In addition, such high emissions of NaOCl into the air could also have various changes in terms of tropospheric chemistry. In this note, I discuss the probable effects of NaOCl spraying on human health and the atmospheric chemistry in urban areas.

**MAIN TEXT**

**Health Effect of NaOCl**

NaOCl and its by-products HOCl and Cl₂ gas are well known as the respiratory irritants. The severe damage of the respiratory tract by NaOCl vapors could cause acute respiratory distress syndrome (ARDS) (Kuiper et al., 2005). Severe dermal injury caused by the high concentration of NaOCl solution (> 5%) has been reported by the studies performed on animals (Pashley et al., 1985). Concentrated NaOCl could severely damage the body tissues causing Necrosis (death of tissues). High concentration of NaOCl also causes the breakdown of muscle tissue, known as Rhabdomyolysis. Rhabdomyolysis releases a protein called myoglobin into the blood affecting kidneys leading to acute kidney injury (AKI) (Bosch et al., 2009). HOCl and Cl₂ vapors cause the burning sensation in the esophagus (the tube connecting the throat and the stomach) and the swelling of mucous membrane medically known as edema of mucosa (Zwischenberger et al., 2002). The direct inhalation of HOCl or the breaking down of NaOCl into HOCl when mixed with plasma destroys the red blood cell causing Hemolysis (Visser et al., 1998). HOCl reacts with the proteins and the lipids of our body and generates reactive oxygen species like superoxide and OH radicals. These species severely damage the renal epithelial cells causing AKI and other renal diseases (Nath and Norby, 2009).

**Role of NaOCl on Atmospheric Chemistry**

**Reaction with H₂O Vapor and Formation of Chlorine Radical**

NaOCl once emitted as aqueous droplets reacts with the atmospheric H₂O vapor to form HOCl or hypochlorous acid.

\[
\text{NaOCl} + \text{H}_2\text{O} = \text{HOCl} + \text{NaOH}
\]

HOCl is a weak acid and very unstable. It readily dissociates in the presence of sunlight. The high daytime maximum temperature (> 35°C) and intense solar insolation (> 500 watt m⁻²) in the country (India Meteorological Department) during the month of April and May 2020 could facilitate the photo-dissociation of HOCl. However, the dissociation in water depends on its pH too (Luke et al., 1992). The photo-dissociation of HOCl is one of the major routes to global tropospheric Cl radical production (Faxon and Allen, 2013). HOCl is photolyzed to form Cl radicals through the following reaction:

\[
\text{HOCl} + \text{hv} = \text{Cl} + \text{OH}
\]

Thus with the high concentrations of HOCl, photolysis reactions are the major sources of Cl radicals in the urban atmosphere. Chang and Allen (2006) have reported an HOCl emission flux of 10⁴ kg day⁻¹ from the use of hypochlorite solutions in the swimming pools, cooling towers and industrial point sources over the Houston area. The photolysis rates of HOCl under 30°, 50° and 70° solar zenith angles are 18600, 14100 and 5200 min⁻¹ (Carter, 2010). Wong et al. (2017) studied the impact of use of commercial NaOCl solution on indoor air quality. They reported significant emissions of gaseous Cl₂, HOCl, ClNO₂, Cl₂O, Chloramines (NHCl₂, NCl₃) along with particulate chlorine. They also observed that the indoor illumination governed the formation and the concentrations of OH, Cl and ClO radicals from HOCl.

**Reactions of Cl Radical with Hydrocarbons**

The Cl radicals produced from the photolysis of HOCl can easily oxidize the hydrocarbons (mainly the volatile organic compounds (VOCs)) forming alkyl radical (Finlayson-Pitts, 1993; Atkinson et al., 2007).

\[
\text{Cl} + \text{RH (hydrocarbon)} = \text{R} + \text{HCl}
\]

The behavior of Cl radicals towards VOC oxidation is different from that of OH radicals. It was experimentally established that Cl radicals with the concentration of more than one order of magnitude than OH radicals bear equivalent potential to oxidize VOCs (Wingenter et al., 1999). They have studied several n-alkanes, alkynes, chloro and bromo alkanes, alkenes etc and shown that the ratios of OH and Cl rate constants (k₀₉/k₀ₑ) ranged from < 1.0 (for methyl chloroform; 100% loss by OH) to > 300 (for ethane, tetrachloroethene; 70–75% loss by OH and 25–30% loss by Cl). Such oxidation of VOCs could in turn form secondary organic aerosols (SOA) enhancing the loading of total carbonaceous aerosols. The anthropogenic VOCs could be expected to be very low in the atmosphere under the COVID-19 lockdown period. However, biogenic VOCs should not experience any impact of lockdown and hence could produce SOA significantly.
Reaction of Cl Radical with Tropospheric Ozone

Cl radicals produced in the atmosphere can readily react with O$_3$ to form ClO radicals. The following reaction is considered to be the major removal pathway of tropospheric O$_3$ in absence of NO$_x$.

\[ \text{Cl}^- + \text{O}_3 = \text{ClO} + \text{O}_2 \]

The above reaction between Cl radicals and ozone is of immense importance for the regions where NO$_x$ level is low. Under low NO$_x$ conditions, O$_3$ is destroyed by Cl radicals (Simpson et al., 2015). Under the lockdown period due to COVID-19 outbreak, the anthropogenic emissions have been limited. Especially the major sources of NO$_x$, e.g., vehicular emissions. Therefore, we expect that under the low NO$_x$ conditions, O$_3$ will be reduced by Cl radicals. The Central Pollution Control Board of India as well as several other ongoing studies (unpublished) is reporting very low NO$_x$ concentrations as well as high O$_3$ over several places across the country. However, the regions with high use of hypochlorites (hence high Cl radicals) could have higher surface O$_3$ depletion.

The ClO radicals formed through the reaction shown above could combine with each other either to form Cl$_2$ or regenerate Cl radicals (Simpson et al., 2015).

\[ \text{ClO} + \text{ClO} = (\text{Cl}_2 + \text{O}_2) \text{ or } (\text{Cl} + \text{Cl} + \text{O}_2) \]

Oxidation of S (IV) Compounds to form Sulphate Aerosols

The oxidation of S (IV) compounds (SO$_2$, H$_2$O or HS$_2$O$_3$ or SO$_4^{2-}$) by H$_2$O or O$_3$ to form SO$_4^{2-}$ aerosols is well known (Finlayson-Pitts and Pitts, 2000). Recent studies (though started by Vogt et al., 1996) have also established the crucial role of HOCl in S (IV) oxidation. von Glasow et al. (2002) have shown that HOCl could contribute 30 % to the total SO$_4^{2-}$ aerosol production over the marine ecosystem. The HOCl oxidation of S (IV) compounds takes place through the following reactions:

\[ \text{HSO}_3^- + \text{HOCl} = 2\text{H}^+ + \text{SO}_4^{2-} + \text{Cl}^- \]
\[ \text{SO}_4^{2-} + \text{HOCl} = \text{H}^+ + \text{SO}_3^{2-} + \text{Cl}^- \]

The very low SO$_2$ concentrations during the lockdown period (as reported by Central Pollution Control Board of India) could not only be due to the low emissions but also for high SO$_2$ (gas)-to-SO$_4^{2-}$ (particle) conversion favored by HOCl.

RECOMMENDATIONS

- Spraying hypochlorite solution over people should be strictly prohibited.
- Proper cautions should be taken during spraying of hypochlorite solution e.g., use of masks for the people who would spray as well as the residents where the spraying would be done. Masking of eye, nose and mouth could help protect from immediate irritations, however, it is difficult to mask the effect of Cl$_2$ and HOCl.
- A public announcement needs to be made well before spraying the hypochlorite solution so that the residents of the concerned regions could stay at safe place (at home) and mingling of the people on the streets could be stopped.
- A regulatory board should be established to restrict the use of hypochlorite solution and adhere to the safety regulations set by WHO.
- If at all needed, spraying during evening or after the sunset could be a better option so that the photolysis of HOCl could be inhibited to further generate the toxic and reactive species that affects human health as well as changes atmospheric chemistry. However, the emission of Cl$_2$ by the surface reactions of NaOCl solution does not depend on the time of the day but depends on the material the spraying is done on.

REFERENCES

Atkinson, R., Baulch, D.L., Cox, R.A., Crowley, J.N., Hampson, R.F., Hynes, R.G., Jenkin, M.E., Rossi, M.J., and Troe, J. (2007). Evaluated kinetic and photochemical data for atmospheric chemistry: Volume III – gas phase reactions of inorganic halogens. Atmos. Chem. Phys. 7: 981–1191. https://doi.org/10.5194/acp-7-981-2007

Bosch, X., Poch, E., and Grau, J.M. (2009). Rhabdomyolysis and acute kidney injury. N. Engl. J. Med. 361: 62–72. https://doi.org/10.1056/NEJMra0801327

Carter, W.P.L. (2010). Development of the SAPRC-07 chemical mechanism and updated ozone reactivity scales. Report to the California Air Resources Board, Contracts 03-318, 06-408 and 07-730. California Air Resources Board, Sacramento, CA.

Chang, S. and Allen, D.T. (2006). Atmospheric chlorine chemistry in southeast Texas: Impacts on ozone formation and control. Environ. Sci. Technol. 40: 251–262. https://doi.org/10.1021/ES050787Z
Faxon, C.B. and Allen, D.T. (2013). Chlorine chemistry in urban atmospheres: A review. Environ. Chem. 10: 221–233. https://doi.org/10.1071/EN13026

Finlayson-Pitts, B.J. (1993). Chlorine atoms as a potential tropospheric oxidant in the marine boundary layer. Res. Chem. Intermed. 19: 235–249. https://doi.org/10.1163/156856793X00091

Finlayson-Pitts, B.J. and Pitts, Jr., J.N. (2000). Chemistry of the upper and lower atmosphere. Elsevier. https://doi.org/10.1016/B978-0-12-257060-5.X5000-X

Kuiper, J.W., Groeneveld, A.B., Slutsky, A.S. and Plötz, F.B. (2005). Mechanical ventilation and acute renal failure. Crit. Care Med. 33: 1408–1415. https://doi.org/10.1097/01.ccm.0000165808.30416.ef

Luke, C.A., Istvan, F., Kazunori, S. and Gilbert, G. (1992). Hypochlorous acid decomposition in the pH 5-8 region. Inorg. Chem. 31: 3534–3541. https://doi.org/10.1021/ic00043a011

Nath, K.A. and Norby, S.M. (2000). Reactive oxygen species and acute renal failure. Am. J. Med. 109: 665–678. https://doi.org/10.1016/S0002-9343(00)00612-4

Simpson, W.R., Brown, S.S., Saiz-Lopez, A., Thornton, J.A. and von Glasow, R. (2015). Tropospheric halogen chemistry: Sources, cycling, and impacts. Chem. Rev. 115: 4035–4062. https://doi.org/10.1021/cr5006638

Vogt, R., Crutzen, P.J. and Sander, R. (1996). A mechanism for halogen release from sea-salt aerosol in the remote marine boundary layer. Nature 383: 327–330. https://doi.org/10.1038/383327a0

Wingenter, O.W., Blake, D.R., Blake, N.J., Sive, B.C., Rowland, F.S., Atlas, E. and Flocke, F. (1999). Tropospheric hydroxyl and atomic chlorine concentrations, and mixing timescales determined from hydrocarbon and halocarbon measurements made over the Southern Ocean. J. Geophys. Res. 104: 819. https://doi.org/10.1029/1999JD900203

Zwischenberger, J., Savage, C. and Bidani, A. (2002). Surgical aspects of esophageal disease: Perforation and caustic injury. Am. J. Respir. Crit. Care Med. 165: 1037–1040. https://doi.org/10.1164/ajrccm.165.8.2104105

Received for review, May 23, 2020
Revised, June 7, 2020
Accepted, June 13, 2020