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EDITORIAL

Environmental chemistry is most relevant to study coronavirus pandemics

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On May 18, 2020, the COVID-19 pandemic has globally killed 315,248 people since the virus outbreak in Wuhan, China, in early December 2019 (https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6). As a matter of urgency, research has promptly focused on designing cures and vaccines, which is understandable, but is the classical 'painkiller' approach that will be less and less efficient in our globalized society because such an approach is treating the effect and not the original cause (Lichtfouse 2009, 2010). In particular, this is somehow underestimating environmental factors such as climate change and pollution that have more or less directly favored the pandemic. For instance, climate modeling has predicted increased risks of food- and waterborne diseases with very high confidence (Woodward et al. 2014). Similarly, air pollution has been shown to alter the immune system (Glencross et al. 2020; Bauer et al. 2012). Environmental chemistry, as the science of contaminants in the environment, thus deserves more attention to prevent future pandemics (Qu et al. 2020).

The emergence of viral epidemics in the past 20 years has caused great threats to public health (Wang et al. 2020). Lassa and Ebola are examples of infectious viruses associated with hemorrhagic fever. The novel coronavirus is a class of enveloped, positive-sense single-stranded RNA viruses that are responsible for the Middle East respiratory syndrome, MERS-CoV, and the severe acute respiratory syndrome, SARS-CoV, in humans. The current pandemic caused by the novel coronavirus SARS-CoV-2 causes severe acute respiratory symptoms and is often referred to as coronavirus infectious diseases 2019: COVID-19. No effective vaccine or drugs are available, which makes it very challenging to treat or prevent the deadly COVID-19. Below are some of our thoughts on how environmental chemists can play pivotal role in understanding the occurrence and evolution of COVID-19 in protection of the global community.

In the environment, SARS-CoV-2 may survive in the air, on the surfaces, in water and wastewater (Qu et al. 2020). In the air, the SARS-CoV-2 virus may be present as droplets, or as dust, or particulate matter (PM). The decay of the virus under various environmental conditions would determine the survival of the virus. These conditions may include the size of particulate matter and aerosols, humidity and temperature. These suggest the potential role of climate change on occurrence and the fate of the virus. Environmental chemistry research on the fate of pollutants in air (Kfoury et al. 2016; Yu 2019; Gopinath and Kadirvelu 2018), water (Gopinath and Kadirvelu 2018; Mahmood et al. 2012; Rodgers et al. 2019; Wen et al. 2019) and wastewater (Padervand et al. 2020; Simas et al. 2019; Villaseñor and Ríos 2018; Crini and Lichtfouse 2019) is therefore highly relevant to the study of pathogenic microbes. Future detailed investigations about the physiochemical role of environmental parameters of air might therefore address the control of future outbreaks or pandemics with greater efficiency.

The survival of SARS-CoV-2 on solid surfaces might be of high importance. For example, the novel coronavirus may survive for prolonged periods on surfaces such as latex gloves, sterile sponges, aluminum, wood, laminate, steel and plastics. Viruses usually have longer survival in a host and thus may have increased likelihood of transmission. Similarly, complete information is essential on how the novel

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coronavirus interacts with surfaces on a mask that vary in composition, material and pore size to understand survival and protection. Systematically designed experiments will help us gain insight into the virus survival on various surfaces, thus minimizing the exposure of the novel coronavirus to the humans. Here, recent research in environmental chemistry has shown the role of surface materials on antimicrobial resistance (Khan et al. 2019) and bacterial communities (Dong et al. 2019).

Surprisingly, researchers are paying little attention on the interaction of the virus with food products such as vegetable and fruits, whereas food-borne outbreaks such as diarrheal outbreaks due to the contamination of food by *Escherichia coli* in spinach are well described (Sharapov et al. 2016). Fundamental understanding of the survival and possible replication of SARS-CoV-2 on different food will improve food security and safety of the global community. Additional insights might be gained from recent reports on smart packaging (Rai et al. 2019; Gaikwad et al. 2019; Pandit et al. 2017), biosensors (Brinda et al. 2018; Jyoti and Tomar 2017) and nanotechnology (Manickam et al. 2017; Dasgupta et al. 2019) (Fig. 1).

Generally, viruses in water come from excretion in feces. Viruses can survive in fecal matter and in sewage water for up to 10 days. Very little information is currently available on the transmission of enveloped viruses via feco-oral transmission or through our sewer system. In case of the 2003 SARS outbreak, the human coronavirus was found in stool samples (Peiris et al. 2003). The urine samples have also shown human enveloped viruses such as the cytomegalovirus (CMV).

The first detection of SARS-CoV-2 in sewage occurred on March 5, 2020 in the sewage systems of the Schiphol airoport and major cities in the Netherlands, only one week into the epidemic (Medema et al. 2020). Coronavirus-type viruses may inactivate in wastewater, with temperature highly influencing the inactivation rate (Wigginton and Boehm 2020). During wastewater treatment, oxidants and disinfectants can inactivate enveloped viruses (Manoli et al. 2020). However, many poor communities lack the infrastructure to provide clean water, and therefore would face exposure of infectious viruses. Additionally, faulty plumbing in buildings may increase exposure to the viruses. Very limited data sets are available on human viruses in the literature. Research on enveloped-virus transmission and on the treatment of wastewater must include a wide range of enveloped viruses. Here, environmental chemists have developed a wide array of wastewater treatment techniques (Crini and Lichtfouse 2019; Bello and Raman 2019; Crini et al. 2019; Lichtfouse et al. 2019; Bouabidi et al. 2019; Bourgeois et al. 2015), which deserve further testing for virus inactivation.

In determining the fate of novel coronavirus, measurements should be conducted with great care regarding conditions and characterizing the media composition. The purity of the stock of virus must be checked fully. Many efforts should be made to explain the novel coronavirus concentrations in gene copies and infected units. The recommendation of using oxidants and disinfectants to inactivate

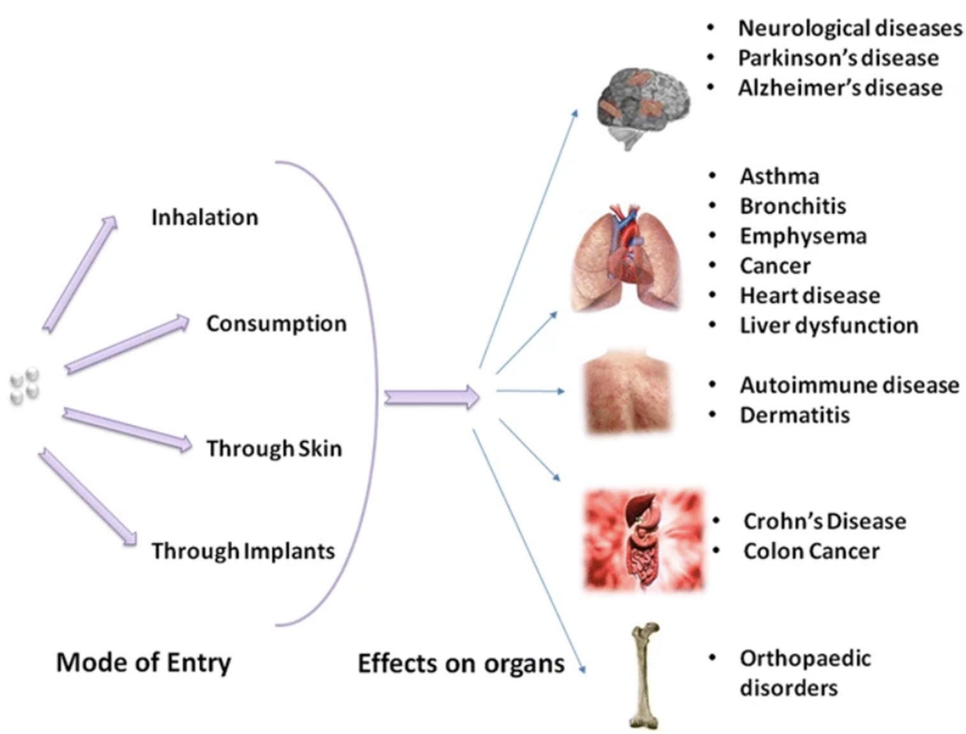

Fig. 1 Environmental research findings on nanoparticles could be useful to study the behavior of viruses. Modified after Manickam et al. (2017)

SARS-CoV-2 must be experimentally based, which includes testing dose demand and contact time under the environmental conditions at which the virus would be presented. In applying light-based processes to inactivate the SARS-CoV-2, attenuation through the treated water must be fully reported. Researchers should also study the surrogate virus, similarly as the well-investigated nonenveloped bacteriophage MS2, thus enabling different laboratories in world to compare their findings among different global communities.

Overall, research in environmental chemistry is disclosing unique knowledge that may help to understand the behavior of viruses and other microbial pathogens in the environment. Therefore, we advise that environmental chemists and biomedical scientists collaborate to decipher mechanisms and design adapted treatments to fight pandemics.

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