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COVID-19 PANDEMIC: A REVIEW ON THE RESPONSES OF CHEMICAL ENGINEERS TOWARDS PRODUCTION OF MEDICAL SUPPLIES AND PREVENTIVE MEASURES

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ABSTRACT

Coronavirus Disease 2019(COVID-19) is a pandemic caused by a virgin virus, SARS-CoV-2, which has infected millions of people worldwide, via aerosol containing virus or by contact with an inanimate surfaces infected with the said droplets nuclei. Up till now, there are still no matching and novel antiviral drugs or viable vaccines to cure the disease. According to World Health Organization, physical distancing, and frequent and correct hand hygiene are important measures to prevent infection of the coronavirus. Chemical engineers have joined the rest of scientific community to respond to the COVID-19 challenges, by inventing critically needed medical supplies and the techniques to manage the inherent medical wastes. In this review paper, chemical engineering expertise on supplies for preventive measures and hospital service requirements are highlighted. Notable

Introduction:

A novel and threatening respiratory disease surfaced in Wuhan, Hubei Province, China in December 2019 and World Health Organization (WHO) designated it as Coronavirus Disease 2019 (COVID-19). The disease is caused by a new class of coronavirus named as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by International Committee on Taxonomy of Viruses (ICTV) and it was declared by WHO as the sixth international disease of high threat on 30th January, 2020 and as global pandemic in early March, 2019 (Chakraborty and Marty, 2020; Nakada and Urban, 2020; Muhammad *et al.*, 2020; Nghiem *et al.*, 2020). Coronaviruses emerge from

among the supplies that can be used to flatten the cure of the epidemiological spread of COVID-19 are soap, for washing of hands with water to destroy the viral genome; hand sanitizers for disinfection; improved personal protective equipment and vaccine delivery systems. Waste management, as another response of chemical engineers to minimize possible secondary impacts of the disease is also explained.

***Keywords**: Coronavirus, Chemical engineers, Response, Hand hygiene, Personal protective equipment, Waste management.*

Corona viridae, that consist of α, β, γ and δ, including other species. They incite breathing threat in humans, in addition to usual cold and more intimidating diseases like Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS). SARS-CoV-2 is a β –coronavirus that leaves cells it has infected, and envelope itself with cells' lipid based walls and protein. The hydrophobic interaction and hydrogen bonds are responsible for the strength of lipid bilayers that envelope SARS-CoV-2 (Goel et *al*., 2020). The disease has cut across all the continents of the world, with global human infection of over 19 million and more than 718,530 people were confirmed dead, as of August 7, 2020. In these casualties, significant numbers of health care workers were victims of the pandemic, due to their direct involvement in diagnosis, treatment and medical waste management (Ibeh *et al*., 2020). By extension, it has dwindled the economy of virtually all nations in the world, due to lockdown of both government and private facilities, as social distancing is not practicable because of worker-dense nature of most on-site jobs.

The most affected sectors by the lockdowns include tourism, transport (both automotive and aerospace), production and sales. COVID-19 could be contacted between individuals at home, in schools and workplaces, on transport, and at community gathering. That is the more reason, lockdown and social distancing (especially when there is dare need to be in the midst of people) are proffered as ways to step down the waves of the contagious and infectious disease (Islam, 2020). At the moment, there is no available and reliable clinical treatment or a potent vaccine for SARS-CoV-2, except

management by trial and error, and other adoptable means to reduce the dissemination of the virus. Apart from social distancing, other preventing mechanisms to straighten the curve of the epidemiological propagation of COVID-19 are keeping of hands clean at all times, uses of hand sanitizer, using personal protective equipment (PPE), disinfection of inanimate surfaces and proper management of wastes, especially infectious health-care wastes. The present challenge in the manufacture of drugs for COVID-19 is their veracity and clinical safety, while the potential challenge after the breakthrough of the antiviral vaccine is the production platforms with capacity of large scale production of the vaccine (Calina *et al*., 2020).
Physicians and other health experts use their experiences of SARS epidemic to source for drugs which may be capable to treat the coronavirus (Rabi *et al*., 2020). In addition to identifying these life-saving drugs, their availability in the required quantities has to be ensured. In this regard, chemical engineers partner with pharmaceutical companies to produce the require dosages (Jasi, 2020). The field of chemical engineering provides the expertise on the production of hand sanitizers, soaps, PPE, vaccine delivery systems and waste management. Chemical engineers apply the knowledge of unit operations for chemical synthesis (with proper product design) followed by downstream purifications, based on phenomena like thermodynamics, reactions (be it chemical, biochemical, or thermal conversions) and transport (which could be mass, heat and /or momentum) (Gani *et al*., 2020; Gani and Zhang, 2019). In this review paper, the health care products, management facilities and prevention mechanisms as responses provided by chemical engineers for COVID-19 are highlighted. Emphasises are made on how hand sanitizers and soaps can disintegrate the virus, improved PPE, uses of antibodies, and proper health-care waste management can stop the spread of the virus. The essence is that, for now, preventive measures and personal hygiene are defensive barriers to block and to deactivate the released virions, altering its transfer pathways, in order to protect susceptible hosts.

Morphology, structure, possible mode of transmission and test for SARS-CoV-2

SARS-CoV-2 has single-stranded RNA genome of approximately 30kb, spike-shaped proteins that cover the outer capsule of the virus, in form of crown-like or corona-like appearance, which culminate into the name "coronavirus". It is with the aid of spike proteins that the virus attack and gain onward entrance into host cells' protein (Goel *et al*., 2020).The virus has genetic similarity with SARS-CoV 1 ,which is assumed to be disease transmitted from animal to human. SARS-CoV-2 is a minute spherical particle (approximately 100nm in diameter), which has double-layered lipid membranes with two bands of hydrophobic tails sand-witched between two rings of hydrophilic heads. In view of its small size and structure, it binds to host cells (containing ACE2 protein) via airway, especially the human lungs, and in turn make the lung inflame and breathing become more difficult. SARS-CoV-2 mainly targets host cells containing ACE2 proteins. AEC2 is an enzyme usually attach to cell membranes of lungs, arteries, heart, kidney, and intestines.

According to WHO, it is majorly transmitted via respiratory droplets of viral particles from breathing, talking, sneezing and coughing, that could gain entrance into the body via the eyes, mouth, or nose, and by close unprotected contact of infectious objects with persons (Muhammad *et al*., 2020; Nghiem *et al*., 2020). Transmission mainly relies on factors like number of droplets, their size, and velocity during expiratory events. The critical factor in respiratory exhalation is air velocity: aerosols carry beyond 6m away by exhaled air at a velocity of 50m/s (sneezing), beyond 2m away at a velocity of 10m/s (coughing), and below 1m distance at a velocity of 1m/s (breathing) (Bizzoca *et al*., 2020; Graham, 2020). The infection of SARS-CoV-2 is characterized by fever, dry cough and difficulties in breathing. The prevalent method of detecting SARS-CoV-2 is nucleic acid testing using real-time polymerase chain reactions technology. In view of the fact that, vaccine for COVID-19 is still at trial stage, uses of soap and hand sanitizer for personal hygiene, physical distancing, proper medical waste management, and other preventive measures are the best ways to break the spread pathway of the released virions.

The efficacy of soap in disintegration of SARS-CoV-2 virus

Novel coronavirus, the flu, and the common cold are examples of respiratory viruses that can be transmitted through hands, if the hands are stick with mucus and viral particles. Proper hand washing with soap is critical in the fight against COVID-19. The lipid membranes of the coronavirus aid it in infecting cells. During washing of hands with soap and water, virus on the hands is surrounded with soap molecules. The hydrophobic tails of the free floating soap molecules squeeze themselves into the lipid envelopes of the virus and breaking it apart, and the destroyed virus are then washed away, as shown in Figure 1(Stiepan, 2020; Jabr, 2020). The WHO and United Nations Children's Fund (UNICEF) respectively prescribed steps for proper washing of hands against coronavirus are: (1) moisten of hands with flowing water, (2) adequate soap application to cover wet hands, (3) scrubbing of hands surfaces (back and front), between fingers and under nails, for at least 20 seconds, (4) thorough rinsing with running water, (5) drying of hands with clean cloth or single use towel (Kampf *et al*., 2020; UNICEF, 2020).

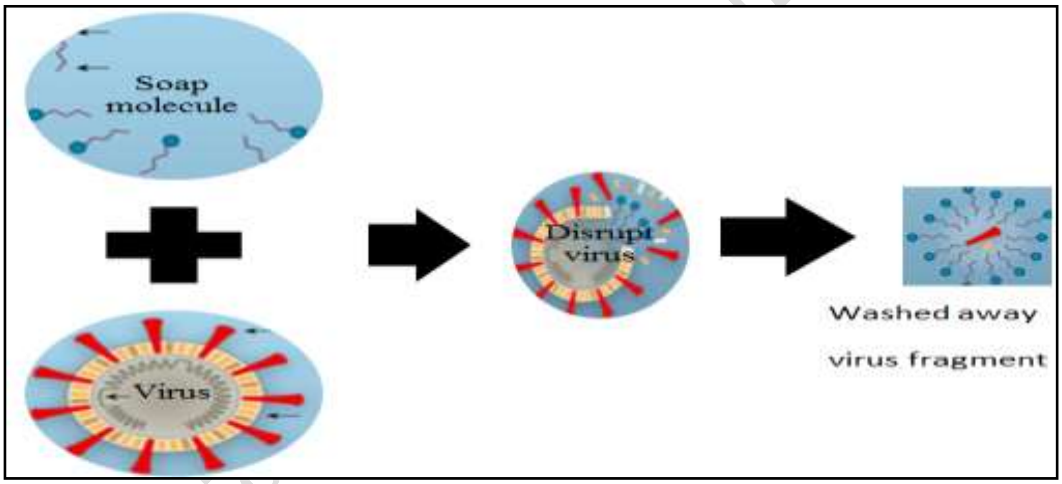

Figure 1: Disintegration of SARS-CoV-2 virus using soap

2.2 Disbandment of lipids membranes of SARS-CoV-2 virus using hand sanitizers

SARS-CoV-2 is surrounded by the lipid bilayers fastened tight with a combination of hydrogen bonds and hydrophobic interactions. When hand sanitizer is applied, the alcohol in it disrupt the hydrogen bonds in between amino acids that make up viral proteins, resulting to destruction of structure and malfunction of the protein, thereby inactivating the virus (as shown in Figure 2). Ethyl alcohol or isopropyl alcohol is typically used in the production of hand sanitizers, in addition to antimicrobial compounds that provide protection against bacteria. For effective utilization of hand sanitizer to fight COVID-19, the Centers for Disease Control and Protection (CDC) prescribes that people should use hand sanitizer that contains at least 60% of alcohol to rub all surfaces of their hands together until dry. The WHO prescribes alcohol-based hand sanitizers due to their microbicidal activity against bacteria and viruses (Jing *et al.*, 2020; Kampf *et al.*, 2020). However, care should be taken in the selection of hand sanitizers, because some are susceptible to fire hazard and skin damage due to high alcohol content. They are also not strong enough if your hands are especially dirty or greasy.

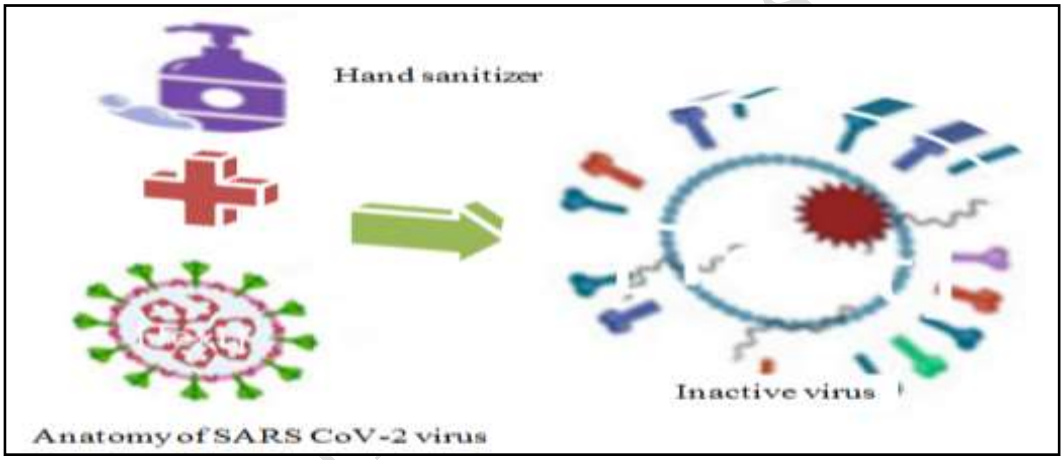

Figure 2: Inactivation of SARS-CoV-2 virus using hand sanitizer

The usefulness of personal protective equipment in fight against COVID-19

Medical masks and other protective equipment are indeed crucial to protect the people who are directly involved in treating patients infected with coronavirus, and persons suspected to be having COVID-19, in order to step down the transmission of the virus to healthy people via contact with blood, body fluid, secretions and excretions. Among the personal protective equipment that could be used by persons exposed to COVID-19 include respirator, facial masks, protective suits, gloves, boot covers, and googles or face shields for eye protection (Rowan and Laffey, 2020). WHO is specific in limited supply of PPE for frontline workers, which pose them to threat during the diagnosis and treatment of COVID-19 patients. Accelerating and scaling up the production of ventilators, health care products, antiviral synthesis and food supplies are all cardinal aspects of the responses provided by chemical engineers. Chemical engineers use their expertise to produce N95 masks with nanofibrous filter or facemask with plasma-deposited antiviral agents like copper, in order to provide full protection against the COVID-19 and resolve the shortage of conventional N95 masks. Chemical engineers are working with developers of barrier technology that would shield health care workers, and a process for decontaminating PPE so it does not have to be discarded after a single use. They are equally involved in the development of biodegradable personal protective equipment, as an alternative way to process waste safely, in addition to existing waste management techniques (Huang *et al*., 2020).

Production of therapeutic proteins, antiviral synthesis and medical devices to combat COVID-19

Novel vaccines in form of virus-like particles and based on the recombinant proteins are innovative methods to combat coronavirus (Calina *et al*., 2020). Protein drugs are often capable of focussed stimulation of desired cell functions for treatment of disease. During an infection, antibodies or an enzyme like ACE2-FC go after these spike proteins to stop them from binding to other cells. Behzadinasab *et al*. (2020) reported that, a chemical engineering Professor (William Ducker) developed an antiviral surface coating that when painted on inanimate objects, it inactivates SARS-CoV-2, the virus responsible for COVID-19. The antiviral surface coat was made of Cu_2O particles mixed with polyurethane. After an hour of application on glass, the longevity of viral tiler was reduced by 99.9%, compared to the control sample. Candanosa (2020) reported that Thomas Webster, a Professor of chemical engineering, whose major research area is on nanoscale drugs and technology to treat diseases, is a contributor of ideas and technology to the Centers for Disease Control and Preventive to fight the COVID-19. He has proposed iron-based nanoparticles (being natural to our bodies and diet) that can be administered via magnetic fields to the targeted organs like lungs and other respiratory tracks susceptible to complications of the viral infections.

McAlpine (2020) reported that, an Associate Professor of chemical engineering (Fei Wen), is working on COVID-19 vaccine, and also forming alliance with Physicians to get the knowledge of immune responses at the cellular level. Web's team uses metal particles (with resemblance of spikes of the virus SARS-CoV-2) to sort out how much of each protein is present in shredded cell using machine. This method reveals not only which immune cells are present but also their numbers and their functional state. West (2020) reported that a team of chemical engineers and chemists at Imperial College London have produced a novel set of multi-functional sequence-defined polymers using liquid-phase synthesis coupled to molecular sieving, for application in drug delivery, nanotechnology, and information storage. Salehi *et al*. (2015) reported that set of chemical engineers have developed a novel and fast system to produce vaccines for the strange viruses, using biological machinery(incorporated with freezer for storage) for large scale production. In the case of emergence of a new virus, water can just be added to a kit to rapidly produce vaccines. Oxygen therapy via ventilator is a prominent medical care to resuscitate COVID-19 patients, in order to maintain the required oxygen level (greater than 88%) in arterial blood (Pearce, 2020). Chemical engineers work on the production of oxygen in large scale, with minimal energy and environmental impact, and in the design and manufacture of ventilators for treating patients.

The impact of medical waste treatment and disposal in the spread of COVID-19

With the emergence of COVID-19, heap of medical and hazardous related wastes are generated around countries of the world, and proper handling of the wastes to reduce the tendency of secondary impacts on humans and natural environment is sacrosanct. Generally, wastes are piled up from health and related facilities during the diagnosis, treatment or immunization, research activities and quarantine centers. Medical wastes include sharps, pathological wastes, infectious wastes, radioactive waste, pharmaceutical waste, genotoxic waste, and polyvinyl chloride plastics (WHO, 2018). Based on WHO classification of medical wastes, 85% are not hazardous, about 10% are infectious, while the remaining 5% are non-infectious but hazardous (Biswal, 2013). To curtail the spread of COVID-19, essential services like collection and proper disposal of wastes from medical and quarantine centers hosting persons suspected or with positive COVID-19 patients are tedious and crucial, being part of the key roles in mitigating infectious disease transmission. In 1998, government of India rolled out Biomedical Waste (Management and Handling) Rules, for better management of medical wastes. The revised edition in 2016 contains several changes in order to strengthen waste management mechanisms (ranging from collection to disposal) in an environmental benign way. In the revised guidelines, medical wastes are categorized into four based on source of generation and coded with colours (yellow, red, white and blue). Yellow is for medical wastes comprises of human/animal anatomical waste, soiled waste, expired drugs, chemical waste, and microbiology and other related medical laboratory wastes; red is for contaminated waste that are recyclable i.e. tubing, bottles, etc.; white is for sharp waste including metals i.e. needles, syringes with fixed needles, blades etc., while blue is for glassware and metallic body impacts (Singhal et al., 2017; Kharat, 2016; Singh et al., 2017).

SARS-CoV-2 virus could survive on inanimate platforms like metal, glass, plastics, for some days, which implies that waste materials from health care facilities managing COVID-19 patients or suspected persons could be a source of infection. Survival time of the virus lies on many factors like the nature of the platform, temperature, relative humidity and strain type of the virus (Nghiem *et al*., 2020; Huang *et al*., 2020; Scavarda *et al*., 2015). Among the responses of chemical engineers to the management of COVID-19 is the treatment of infectious health care and medical related wastes in the environment, to become inactive before disposal. Improper management of bio-waste could cause secondary source of transmission of COVID-19 (Devirajeswari *et al*., 2016; Khan *et al*., 2019). The key medical waste treatment and disposal techniques are chemical disinfection, incineration, autoclaving, microwave, and inertization.

(a) Chemical disinfection: This method is very suitable in treating liquid waste like blood, urine, stools or hospital sewage, including non-liquid infectious wastes, which must be shredded for proper exposure and disinfection (Zhang *et al*., 2019). The essence of using chemicals is to inactivate the pathogens inherent in the wastes. The commonly used compounds in chemical treatment of medical wastes are hydrogen peroxide, sodium hypochlorite, aldehydes, ammonium salts, phenolic compounds and Fenton reagent. The chemical-based disinfected wastes become non-risk, but should be disposed in a well-fenced burial pit insulated with highly permeable material, in order to avoid groundwater contamination (ICRC, 2011). This technique is to be carried out by experienced and knowledgeable persons, as the chemicals involved are liable to produce undesirable by-products like volatile organic compounds (VOCs).

(b) Incineration: This treatment process involves oxidation of wastes at high-temperature, to turn it into ashes and gases (Khan *et al*., 2019). Without proper design and operation, the liberation of dioxins, furans, heavy metals and other pollutants from disposal process are liable to cause advanced pollution problem to the ecosystem. In addition, incineration is also peculiar with dilution of air quality, due to its use of atmospheric oxygen as reagent in the process. It also consumes so much energy, especially if the waste contains high water content, because most of the energy is used to vaporize the water, prior to carbonization of organic portion of the waste (Jiang *et al*., 2012). Pollutants formation can be reduced by optimization of process parameters of incineration approach. Incinerators are modified with electro-filter or industrial air scrubber to separate the particulate matter and gases from emission. Optimization of operating parameters of an incinerator (whether on-site or off-site) is worthwhile; especially to scale down the impact of the emission, step down maintenance costs and to elongate the life expectancy of the incinerator. This method is most suitable for the treatment of pathological waste like body parts and recognizable tissues (Wajs *et al*., 2019; Olanrewaju and Fasinmirin, 2019).

(c) Inertization: It is a waste treatment process which requires mixing of cement, lime and water, in addition to waste, before disposal, so as to reduce the risk of toxic from transferring into water body. Inertization method is most applicable in treatment of pharmaceutical wastes and incineration ashes. A typical example is the small scale inertization of heavy metal residues, using iron phosphate glass, due to its physicochemical properties. (Gobbo *et al*., 2014).

(d) Autoclaving: It is a thermal treatment method of sterilizing medical waste, using adequate pressurized steam at designated time. Autoclave sterilization could continue for 30-90 minutes at 130-190 °C and under 100-500 kPa. Autoclaves are capable of treating 100-4000 litres of bulk waste materials. Autoclaving is highly used for infectious waste prior to disposal and sterilization of medical instruments in hospitals. As compared to incineration, autoclaving is more suitable for treatment of medical wastes. After sterilization, medical wastes are considered safe and can be disposed of on solid waste landfills (Ferdowsi *et al*., 2013; Okten *et al*., 2015). However, medical materials like pharmaceuticals, chemotherapy and chemical wastes cannot be handled by an autoclave and must be treated using other methods of disposal and decontamination.

(e) Microwave treatment: It is a waste treatment system where high frequency radio wave is used for sterilization of medical wastes. This treatment method can be best used when the waste is moistened with water and shredded for easy penetration of heat and efficient sterilization. Microwave is typically operated at 250Hz. A radioactive isotope of cobalt is employed in this technique. Microwave technique is preferable to autoclave, in terms of energy cost and environmental impact. A microwave treated waste could be considered safe for disposal (Zhang *et al*., 2019; Zimmermann, 2018). However, it is a high capital intensive technique.

Irrespective of treatment technique, treated infectious solid waste can be disposed of along with other solid wastes, according to state or federal regulatory laws. The comparative advantages and downturn of the stated waste treatment and disposal techniques have been highlighted, since there is no particular technique which is optimal for every handling. However, incineration is the most effective means of treatment of medical wastes, especially rotary kiln incinerator because pollution abatement systems can be built with it and other methods are not applicable for the efficient treatment of medical wastes like pathological and pharmaceutical wastes.

Conclusion

The emergence of COVID-19 in China, which escalates to other parts of the world, has threatened the wellbeing of people and every sector of the economy of the affected countries. In view of the fact that, there is no vaccine for its cure for now, most science-based and engineering disciplines are inventing ways to produce critically needed medical and related supplies and techniques to mitigate the spread of the virus. Among the engineering profession, chemical engineering expertise has come to the glare of the public, in terms of provision of chemical disinfectants, soap and hand sanitizers, improved personal protective equipment and efficient waste management mechanism to curtail the dissemination of COVID-19. A significant contribution is also made by chemical engineers in the scalability of production of trial antiviral drugs or vaccines to generate sufficient doses for the teaming infected persons, all over the world. With the practise of good hygiene, exhibition of physical distancing and adherence to safety rules while using public facilities, COVID-19 infection would be curtailed.

Recommendations

The authors recommend the following directions as a way forward towards minimizing the spread of COVID-19:

1. As a preventive measure, all medical wastes should be managed with the adoption of Biomedical Waste Management Rules, 2016.
2. It is recommended that public surfaces like door handlers, hand rails, desks, etc should be coated with antiviral agents like cooper.
3. Government (at all levels) should create an enabling environment to the chemical process industries, to encourage them produce PPE and needed medical supplies in large quantities.
4. For quick neutralization of the virus, nanomedicine should be developed in virus-like particles that is biocompatible to the body and based on the recombinant proteins.

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