Journal of Bioterrorism and Biodefense

Saxena A, J Bioterr Biodef 2022 , 13:5

Research Article

Open Acces

Biohazard: Prevention, Personal Protection and Waste Management

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ABSTRACT

Biological hazard poses a great threat to living organisms and can even prove fatal. It is extremely necessary to dispose of it by following the necessary protocols depending upon its biohazard level. There are various categories of biohazardous waste which should be identified, segregated, decontaminated and disposed of in a proper manner so that it can help reduce occupational exposure and prevent the risk of releasing into the environment. The perfect example of this would be the SARS-CoV-2 outbreak that the world is currently facing. The World Health Organization (WHO) has declared the outbreak as a Public Health Emergency of International Concern on 30 January 2020 and recognized COVID-19 as a pandemic on March 11, 2020. Social distancing, quarantining and self-isolation are crucial steps that the public is adopting to prevent themselves from getting infected and spreading it to others. Apart from this, the pandemic is also generating tons of biomedical waste that has to be safely discarded to prevent further spreading. This article gives a detailed overview on the definition of a biohazard, general preventive measures that can be adopted, waste management techniques and also throws light on how the world is coping up with the ongoing pandemic.

Keywords: Biological hazard; Biohazard level; SARS-CoV-2 outbreak; WHO; COVID-19; Pandemic; Biomedical waste; Waste management

Introduction

Postprandial Biological hazard or biohazard is any biological sample of a microbe, toxin or virus that primarily affects health of humans but can be extended to animals. It is used as a warning so that people who are potentially exposed to it can take necessary precautions. It is extremely important to contain it if there are any risks of it getting exposed to the environment. The biohazard symbol was developed by Charles Baldwin in 1966 (Figure 1) [1]. It is extensively used as a label on biological materials that have potential health risk, such as used hypodermic needles and virus samples. The biohazard symbol in Unicode is (U+2623). There are various categories of biohazardous substances for transportation purposes. Infectious substances that are life-threatening or can cause diseases that may be fatal in humans belong to Category A (UN 2814); substances that are harmful to animals only but may not be fatal belong to Category B (UN 2900); biological substances that are transported for investigative reasons or diagnostic purposes belong to Category B (UN 3373) and biomedical waste belongs to UN 3291 [2].

Figure 1: Symbol for biohazard [3]

Levels of Biohazard

- Five Biohazard level 1: includes viruses and bacteria like Bacillus subtilis, Escherichia coli, varicella and protection gear includes gloves and facial masks.
- Biohazard level 2: includes viruses and bacteria that may cause very mild diseases and are difficult to contract through aerosols in a lab and include Hepatitis A, B, C, mumps, measles, dengue fever and HIV.
- Biohazard level 3: includes viruses and bacteria that cause fatal diseases in humans but vaccines or treatment exists; examples include West Nile virus, tuberculosis, typhus, SARS virus, MERS coronavirus and the COVID-19 coronavirus.
- Biohazard level 4: includes viruses that cause fatal diseases in humans and for which no vaccine or treatment is available; examples include the Ebola virus, Marburg virus and Lassa fever virus. Currently, no bacterium is identified under this level.

Other examples of biohazard include mold, fungi, blood, body fluids, stinging insects, harmful plants, animal and bird droppings, airborne pathogens, sewage, etc.

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Citation: Saxena A (2022) Biohazard: Prevention, Personal Protection and Waste Management. JBTBD.13:300.

Received: 30-July-2022, Manuscript No. jbtbd-22-001; **Editor assigned:** 01-August-2022, PreQC No. jbtbd -22-001(PQ); **Reviewed:** 15-August-2022, QC No. jbtbd -22-001; **Revised:** 20-August-2022, Manuscript No. jbtbd -22-001(R); **Published:** 27-August-2022, **DOI:** 10.4172/2157-2526.1000300

Biocontainment

Biocontainment is in direct relation to the laboratory biosafety and is concerned with mainly microbiology labs that require physical containment of pathogenic organisms or bioagents (bacteria, viruses and certain toxins) [4]. There are two terms which are extensively used in relation to biocontainment- primary containment and secondary containment. When the person is in direct contact with the container containing biohazardous material, it is termed as primary containment [5]. It requires use of proper storage vessels, good microbiology skills and proper safety equipment. Secondary containment is used for protecting the external environment outside of laboratory from infectious agents and requires a cumulation of facility design and operational procedures.

Bioterrorism

It is a kind of terrorism involving deliberate dissemination of biological agents. These agents may be naturally occurring or genetically modified. Agricultural business is most vulnerable to such attacks and can disrupt the economy as well as consumer confidence [6]. However, it is difficult to use it as a bioweapon in a biological warfare that affects only enemies and not friendly forces, as in military [7]. A bioweapon is generally used by terrorists to create mass disruption and panic in a biological warfare, a germ warfare. Government agencies may respond to a bioterrorism incident by law enforcement, emergency medical units, hazardous materials and decontamination units.

Biohazardous Waste Management

Currently, the COVID-19 pandemic is generating huge amounts of biomedical waste which is hazardous in nature. The government is acknowledging the hard work of the devoted waste collection workers after the health workers in this unprecedented crisis, who are exposed to several risks and infection. The waste collection units differ in various countries but the general hierarchy remains the same. There are majorly four categories of biohazardous waste: 1. solid (non-sharps), 2. liquid, 3. sharps and 4. pathological [8]. These wastes in any form should not be left unsecured in the open like hallways or roads, which may increase risk of spreading an infectious disease.

Solid biohazardous waste (Non-sharps)

These include majorly any non-sharp items that are contaminated with human and animal diagnostic specimens like tissue debris and body fluids or any culture material that is microbiologically contaminated, for e.g. recombinant DNA. Other examples are gloves, face shields, goggles, head covers, masks, shoe covers, plasticware like pipette, pipette tips, specimen vials, towels etc.

The other category of solid biohazardous wastes, that is the non-sharps, can be collected and given a final treatment. Disposal can be done in a leak-proof container. This container is usually lined with an autoclavable bag of medium thickness to prevent damage. The collection container should be enclosed with a lid or by other means and labelled with the biohazard symbol regardless of the biosafety level of that respective lab. For Biosafety Level-2 labs, red and orange coloured bags with the biohazard symbol stamped on it can be used (Figure 2). Benchtop containers are usually used for the collection of contaminated dry goods like pipette tips and centrifuge tubes. Small plastic containers or wire bag racks that are lined with biohazard bags are suitable for such collection. These containers are not required to have a lid, unless the waste may be contaminated with a pathogen, but can be disposed in a secured bag into a larger collection container.

For serological pipettes, a cardboard box, with a biohazard label on the outside, may be lined with a bag and the pipettes can be collected with the tips facing the same direction. Later, the pipettes can be autoclaved or disposed with the help of a medical waste contractor.

Figure 2: Container vessel with a biohazard symbol containing an orange bag [8]

Liquid biohazardous waste

This mainly includes blood and its products or any other body fluid from humans and animals, culture media etc. Disposable containers carrying liquids of volume less than 10 ml should be regarded as solid biohazardous waste. These liquids can be stored by making use of closed containers that are leakproof and subsequently treated and disposed . Secondary containment can also be done by placing vessels in deep trays or buckets and should be labelled with biohazard labels if the liquid is not treated and disposed within the shaft (Figure 3). For disinfectants added to the vessel, a labelling is provided so that the chemical hazard is also identified. For example, for a collection flask containing waste cell media and bleach, a biohazard label is put on the flask as well as 'bleach-treated cell culture materials' is written to properly identify both the chemical and biological hazards. Disinfectants may be used for treatment of liquid waste to prohibit growth of microbes. Autoclave treatments can also be done and disposed through lab sink.

Figure 3: Secondary Containment [8]

Sharp biohazardous waste

Sharp biohazardous waste, also called as sharps, is any medical device that is able to puncture anything ranging from a plastic bag to human skin and that had previously been in contact with some potential infectious material. Sharps include but are not limited to needles, scalpels, microscope slides, broken glass vials and saw blades. Containers are specifically designed and allotted for collecting the sharps. They are designed to have various properties like resistance against puncture, safe to handle and leak-proof. Irrespective of the biohazard status, all kinds of sharps are collected in such vessels, but biohazardous sharps are especially labelled with a corresponding symbol. These infected sharps can be picked up and disposed by a local medical waste contractor. Plastic serological pipettes may not be sharp enough to puncture skin but can go through plastic bags. Therefore, they should either considered as sharps or separated from the rest of the solid waste.

Pathological waste

These wastes include tissues of animal origin, organs, carcass and tissue trimmings which can be collected in sealed and leak-proof bags. Red or orange coloured bags are used for collection. These are also embossed with the biohazard symbol if the pathological material contains any biological toxin, infectious agent or some recombinant/synthetic nucleic acid. Frozen and stored tissues can be disposed using the lab animal facility. Pathological waste should be double-bagged and stored similar to liquid waste in secondary containers to prevent any potential leaks. Incineration and chemical treatment are often utilised for disposal but autoclaving is never performed.

Coronavirus disease 2019

Coronavirus disease 2019 or COVID-19 is an infectious disease that is caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), a single-stranded RNA virus, that is a strain of Severe Acute Respiratory Syndrome-related Coronavirus (SARSr-CoV) (Figure 4) [9]. The disease is said to be first identified in Wuhan, China, in late December 2019. It is a highly contagious disease and the mechanism of its spreading is still being determined. The WHO and US Centers for Disease Control and Prevention have informed that it is spread through small droplets when people cough, talk or sneeze and are in close contact with each other, approximately 1-3 m away. Studies in Singapore have found that droplets can travel up to 4.5 m and other studies based on factors like protective effect and speed of warm air surrounding droplets, have advised it might travel up to 7-8 m [10].

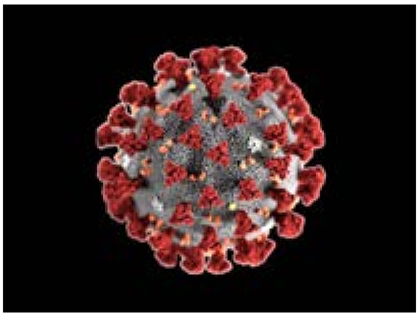

Figure 4: SARS-CoV-2 [18]

Origins of the SARS-CoV-2

Ignorance and limited knowledge about the origins of the coronavirus have provided a fertile ground for all kinds of speculations about its origin- from conspiracy theories of China releasing the virus as a bioweapon to disrupt the world's economy to blaming the US army bringing the virus to Wuhan in the first place to theories of it leaking from a scientific laboratory and so on. Scientists, researchers and doctors around the world have strongly condemned such theories. The truth of its origin remains elusive. Many virologists have varied opinions about it but they say that if anyone claims to know about the origins of the outbreak, they are guessing. There is not enough evidence to prove any one theory but many believe it may have originated from bats. Scientists discount conspiracy theories about the coronavirus being a bioweapon, their opinions are however divided on other questions. They are at loggerheads about the once widely accepted theory of it originating from the wet-market in Wuhan which is always packed with people and wild animals slated for slaughter.

Another theory states that the origin can be traced back to an accident in one of the two labs near the Wuhan market that apparently works with bats [11]. This has been denied by the Chinese government and the lab. But a chemical biology professor at Rutgers University has suggested that the possibility of the virus entering humans through a lab accident should not be dismissed.

Researchers have agreed that the virus may have jumped from animals to humans, a phenomenon called as the 'Zoonotic Spillover'. A spillover event occurs when a population with a high pathogen prevalence, called as a disease reservoir, comes in contact with a novel host population. A study published in Nature concluded that the COVID-19 coronavir ere exactly did it originate from, which bat species and how many are out there affected, remain unanswered. Another source of debate is whether there was an intermediate animal involved- many say it was the pangolin (Figure 5). Peter Daszak, president of EcoHealth Alliance, believes the bat may have infected a farm animal, that was then transported to the wet-market and potentially came in close contact with humans. An article published in Lancet, however, suggested that a third of the first 41 confirmed cases, had no direct exposure to the wet-market. The first known patient's symptom reportedly began on December 1, 2019, but an article in the South China Morning Post reports the date of the first case as early as November 17.

Figure 5: Pangolin may be suspected as an intermediate animal in spreading of the virus [22]

Transmission and Symptoms

The incubation period for COVID-19 is 5-6 days but may even range from 2-14 days. Its basic reproduction number (R0), is estimated to be between 1.4 to 3.9, which means that each infection can result in 1.4 to 3.9 new infections when no preventive measures are taken and the people are not immune [13]. The viral load is said to reach its peak in the pharynx approximately 4 days after infection. The virus is mainly spread through close contact with an infected person, with the help of droplets that are produced during coughing, sneezing, talking and breathing. It also spreads through contaminated surfaces when a person touches his/her face, called as fomite transmission. It remains viable on plastic and steel for up to 72 hours, on cardboard for about a day and on copper for about 4 hours. It gets inactivated with soap due to destabilization of its lipid bilayer. It is highly contagious when people are symptomatic. People who are infected may be asymptomatic too or develop flu-like symptoms such as shortness of breath, fatigue, cough and fever, difficulty in breathing, chest pain, bluish lips or face and confusion. The lesser common symptoms include runny nose sore throat, sneezing, vomiting, nausea and diarrhea. The disease may progress to pneumonia, multiple-organ failure and ultimately death.

COVID-19 Testing and Diagnosis

Laboratory testing for the disease includes methods that can detect the presence of virus or antibodies produced in response. The presence can be confirmed for very active cases using the method of RT-PCR (Reverse Transcription-Polymerase Chain Reaction) that detects the virus' RNA. Serology, on the other hand, can be used for diagnosis and population surveillance. Real time RT-PCR can be done on nasopharyngeal sputum or swab samples, for which results are available within a few hours to 2 days [14]. Other testing techniques include non-PCR based tests. Abbott lab uses its FDA-approved isothermal nucleic acid amplification method which is time efficient and deliver positive results in approximately 5 minutes and negative ones in 13 minutes.

Many countries have developed their own PCR tests. Berlin, for example, developed its RT-PCR test at Charité and formed the foundation for 2,50,000 kits that had been distributed by the WHO. The South Korean company, Kogenebiotech has developed a PCR-based SARS-CoV-2 detection kit. In the US, the CDC is distributing its 2019-Novel Coronavirus (2019-nCoV) Real-Time RT-PCR Diagnostic Panel to public health labs through the International Reagent Resource. In Russia, the State Research Centre of Virology and Biotechnology VECTOR has developed and produced the COVID-19 test. On March 12, 2020, Mayo Clinic developed a test to detect COVID-19. On March 13, 2020, Roche Diagnostics received FDA approval for a test which could be performed within 3.5 hours in high volume and allows one machine to conduct approximately 4,128 tests in 24 hours. Taiwan has developed a test that makes use of monoclonal antibodies which specifically bind to the nucleocapsid protein (N protein) of the virus and it may provide results in 15 to 20 minutes just like a rapid influenza test.

Preventive measures Against COVID-19

Prevention of transmission can be done through maintaining overall good hygiene, washing hands regularly, coughing or sneezing into a tissue, avoiding touching face without unwashed hands, wearing surgical masks in public, social distancing, self-isolation, quarantining and adopting standard precautions.

Washing hands for at least 20 seconds with soap which bursts the virus' protective bubble is recommended by the CDC. Alcohol-based hand sanitizer with 60% alcohol content can be used when soap and water are not readily available. Surfaces can be highly contagious because the viability of the virus is quite high. Disinfecting with various solutions like ethanol, hydrogen peroxide, sodium hypochlorite and isopropanol can be carried out. Wearing masks can help reduce the propensity of people touching their faces and is recommended for both the infected and non-infected [15]. Hong Kong recommends wearing masks in public places; Thailand urges people to make cloth masks and wear them at home; Austria has mandated for people entering grocery stores to wear masks; Taiwan, who is producing millions of masks per day, requests its people to wear masks while travelling in trains and buses; Czech Republic and Slovakia have banned people from going out in public without wearing a mask.

Social distancing, also known as physical distancing, helps to reduce and slow down the speed of spreading it through minimizing contact. Many countries, like India, have adopted methods like quarantines, shutting down of schools, malls, curfews and more stringent measures like lockdowns have been implemented in recent times. People with underlying medical conditions like diabetes, hypertension, respiratory and heart diseases have been advised by the WHO and CDC to stay at home. The term 'Physical Distancing' is more in trend due to 'Social Distancing' leading to implications that one should engage in complete social isolation. The WHO strongly recommends keeping in constant touch with friends, family and loved ones, either virtually or at a distance. Self-isolation for 14 days after exposure has been advised for people who are infected with COVID-19 or are in suspicion of being infected and detailed guidelines about the isolation are also shared by the respective health agencies [16].

Containment is done by tracing and isolating those who are infected and also introduce methods of infection control and vaccines to prevent it from spreading to the rest of the population. When containment is no longer possible, the aim is to slow it down and mitigate its effects on the society. Suppression is another strategy which aims to reverse the pandemic by bringing down the reproduction number to less than 1. Another goal of community mitigation is also to 'flatten the curve' and provide more time for development of vaccines and treatments.

Treatment and Future Research

Management is done with the help of supportive care like oxygen support, fluid therapy and supporting the vital organs. Extracorporeal Membrane Oxygenation (ECMO) is used for respiratory failure. Doctors also prescribe paracetamol over ibuprofen for the first line medication. Steroids are not recommended unless the disease is worsened by acute respiratory disease syndrome. Mechanical ventilation is an artificial support system for breathing which is mostly used to assist only the elderly (older than 60). It, however, becomes more complex for cases of acute respiratory distress syndrome and in such cases ventilators with pressure control modes are needed to maximise oxygenation and minimise risk of lung injury. CDC also recommends Personal Protective Equipment (PPE) for job-related occupational safety and health purposes. It includes face mask or respirator, medical gloves, gown and eye protection gear. Hazmat suits are impermeable whole-body garments which are currently used by paramedics (Figure 6).

Figure 6: A medical official wearing a hazmat suit [67]

No antivirals are yet approved for treating of the disease. Most people will recover staying at home, taking necessary medications, fluids and rest. Research is extensively going on and some antiviral drugs are still in clinical trials. Many are debating whether the anti-malarial drug, hydroxychloroquine, should be used a first line-medication to treat the disease as the results on patients are conflicting and the drug also causes risky side-effects. But there is no doubt about hydroxychloroquine being extremely effective in treating the symptoms, if not the disease.

A small non-randomised trial conducted in France has found it to be a promising potential treatment [17]. Convalescent plasma (plasma containing antibodies from recovered patients) has been used to treat diseases like measles and SARS. In recent situations, transfusion is done from the recovered patient to the one suffering from COVID-19. There have been success reports from China but no controlled studies are done yet. The treatment is still considered experimental. Another drug that has grabbed a lot of attention is Remdesivir, which was used for treating the SARS and MERS viruses, which are very similar to the SARS-CoV-2. It works by targeting a critical part of the virus and inactivates its ability to reproduce. It was used on a patient in the Washington state on January 20,2020 and the patient who was severely ill had survived. However, extensive research needs to be done to prove its safety and effectiveness on the larger population and randomized trials are currently underway in the US and China. A vaccine can be expected at the earliest only by 2021.

World's Coping mechanism

From travel to construction, entertainment to education, the industries have been adversely impacted by the COVID-19 pandemic. The global economy is in distress with market recessions and disruptions in supply-demand chains. World cities are trying their best to help solve and manage things efficiently by various procedures, law enforcements and lockdowns. The US is working on a third stimulus package where the government plans to give money incentives of $1200 per adult and $500 per child, to help them mitigate the crisis [18]. It has also included free testing for COVID-19, the US Central Bank has cut down its interest rates and also planned to inject $700 billion into the US economy by buying government bonds from the market. In the UK, the Bank of England has slashed the bank rate by 50 points. A scheme has been introduced that would pay grants to companies for avoiding mass layoffs [19]. Germany is planning a $1600 billion package to support its economy. The French government has announced a $50 billion package for small businesses and employees, majorly through deferral of tax payments to help tackle the economic emergency. In China, the People's bank of China (PBOC) had announced its decision in early February to inject $174 billion into the markets through open market operations in order to maintain 'reasonable and abundant liquidity' in the banking system. India is doing its part to not only help its people but people of other countries as well [20]. On April 9, 2020, India had lifted its ban on export of hydroxychloroquine for thirty nations across the world who had approached India for its release. Such actions help in strengthening international relationships and promote togetherness in fighting the pandemic.

Conclusion

Unprecedented times call for unprecedented measures. Lockdowns and quarantines are currently the way of the world. There is no certainty to anything and many even warn about a second wave of the virus. The only thing that people can do to help is to stay safe at home. Many are complaining about boredom and isolation. But not realising that the time we have right now can be used in constructive and creative ways would be a foolish thing to do. And who better to turn to advice in times of isolation than the astronauts and submariners! Peggy Whitson, the first female commander of the ISS, says to balance work and family at home, to have a feeling of higher purpose and to keep oneself busy with anything that one would like to do if they had ample time. John Rafferty, a former US Navy officer, says to do what you love, to talk and strengthen relations with your friends and family and make use of time by planning for your future. Students from IISc and IITs have developed apps from 'Go-Corona-Go' to 'Sampark-o-meter' that can help identify people that may have crossed paths with suspected COVID-19 patients and also help in detecting areas that are highly infected with the disease.

Apart from this, the only silver lining of this pandemic would be the effect on planet earth. Widespread social distancing is having some astounding effects across land, air and water. With fewer trains, buses and people pounding the pavement, seismologists are able to detect extremely lower levels of seismic activity. Earth-observing satellites have also detected a decrease in air pollution due to lower levels of carbon dioxide, nitrous oxide and other greenhouse gases being emitted. There is also a significant decrease in noise pollution. Marine researchers are also happy about the reduction in ocean noise that comes from cruise ships and cargo ships as it affects the marine life by increasing their stress-hormone levels and affect reproduction success rate. People can hear birds chirping, the sky is clearer and water canals are clean and full of fish. Thus, this pandemic can maybe help us in retrospection.

Acknowledgments

We thank all the patients who participated in the trial, the referring physicians and the local investigators who contributed to the trial, and the technicians who did the labelling and the scans.

Funding

The study was funded intramurally.

Competing Interests

All authors declare no competing interests.

Author Contributions

All authors planned the study. MH screened control patients and performed mixed meal testing. KA and PW did PET/CT readings. MH, KA, and PW did the analysis and wrote the first draft of the manuscript. All authors critically proved data, edited and approved the manuscript.

Data Availability

All data is available from the corresponding author on request.

Ethics approval

The study was approved by the local ethics committee (Ethikkommission Nordwest-und Zentralschweiz, Basel, Switzerland, EKBB 163/12).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent to publish

All authors approved the manuscript for submission.

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