Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Case Report

COVID-19 and environmental health: A systematic analysis for the global burden of biomedical waste by this epidemic

Suong-Mai Vu Ngoc a,b, Mai-Anh Nguyen a,b, Thanh-Lam Nguyen a,b, Hue Vu Thi a,b, Thi Loi Dao c, Thi Minh Phuong Bui c, Van Thuan Hoang c, Dinh-Toi Chu a,b, c,

a Center for Biomedicine and Community Health, International School, Vietnam National University, Hanoi, Viet Nam
b Faculty of Applied Sciences, International School, Vietnam National University, Hanoi, Viet Nam
c Thai Binh University of Medicine and Pharmacy, Thai Binh, Viet Nam

ARTICLE INFO

Keywords:
Biomedical waste
Pharmaceutical waste
Environmental health
COVID-19

ABSTRACT

Since the beginning of this outbreak, much evidence stated that the climb in the amount of biomedical waste harmed human health and had adverse effects on the environment. With the increase of cases of COVID-19 all around the globe, the amount of biomedical waste was also constantly rising. Also, many solutions regarding either reducing or recycling biomedical waste. However, the potential global burden of biomedical waste during this pandemic was not yet been analyzed. Herein, we perform a systematic review of literature on these modalities, including mentioning types of biomedical waste, the effect on health, the environment, and methods of handling biomedical waste during this pandemic. A total of 3551 published papers were identified by two databases. In the end, 15 references were selected for this systematic analysis. Most of the included studies focus on research on the impact of medical waste caused by the COVID-19 pandemic on the environment. The total biomedical waste during the COVID-19 pandemic was approximately 16,649.48 tons/day. Most publications agreed that the amount of waste has also increased due to the rapidly rising number of COVID-19 patients. In 15 articles, we identified 2 mentioning the COVID-19 biomedical waste on health. 9 out of 15 gave out the context related to the solution of BMW by COVID-19. More studies, including meta-analyses, are recommended to shed more light on the effects of medical waste on environmental health during the COVID-19 pandemic.

1. Introduction

Coronavirus disease 2019 (COVID-19) is a highly contagious disease caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). At the end of December 2019, in Wuhan, China, SARS-CoV-2 was first reported and then quickly spread worldwide [1]. As of November 4, 2021, the World Health Organization (WHO) has announced 5,020,204 deaths out of 247,968,227 confirmed cases of COVID-19 and environmental health: A systematic analysis for the global burden of biomedical waste by this epidemic

Suong-Mai Vu Ngoc a,b, Mai-Anh Nguyen a,b, Thanh-Lam Nguyen a,b, Hue Vu Thi a,b, Thi Loi Dao c, Thi Minh Phuong Bui c, Van Thuan Hoang c, Dinh-Toi Chu a,b, c

a Center for Biomedicine and Community Health, International School, Vietnam National University, Hanoi, Viet Nam
b Faculty of Applied Sciences, International School, Vietnam National University, Hanoi, Viet Nam
c Thai Binh University of Medicine and Pharmacy, Thai Binh, Viet Nam

ARTICLE INFO

Keywords:
Biomedical waste
Pharmaceutical waste
Environmental health
COVID-19

ABSTRACT

Since the beginning of this outbreak, much evidence stated that the climb in the amount of biomedical waste harmed human health and had adverse effects on the environment. With the increase of cases of COVID-19 all around the globe, the amount of biomedical waste was also constantly rising. Also, many solutions regarding either reducing or recycling biomedical waste. However, the potential global burden of biomedical waste during this pandemic was not yet been analyzed. Herein, we perform a systematic review of literature on these modalities, including mentioning types of biomedical waste, the effect on health, the environment, and methods of handling biomedical waste during this pandemic. A total of 3551 published papers were identified by two databases. In the end, 15 references were selected for this systematic analysis. Most of the included studies focus on research on the impact of medical waste caused by the COVID-19 pandemic on the environment. The total biomedical waste during the COVID-19 pandemic was approximately 16,649.48 tons/day. Most publications agreed that the amount of waste has also increased due to the rapidly rising number of COVID-19 patients. In 15 articles, we identified 2 mentioning the COVID-19 biomedical waste on health. 9 out of 15 gave out the context related to the solution of BMW by COVID-19. More studies, including meta-analyses, are recommended to shed more light on the effects of medical waste on environmental health during the COVID-19 pandemic.

1. Introduction

Coronavirus disease 2019 (COVID-19) is a highly contagious disease caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). At the end of December 2019, in Wuhan, China, SARS-CoV-2 was first reported and then quickly spread worldwide [1]. As of November 4, 2021, the World Health Organization (WHO) has announced 5,020,204 deaths out of 247,968,227 confirmed cases of COVID-19. At the end of December 2019, in Wuhan, China, SARS-CoV-2 was first reported and then quickly spread worldwide [1]. As of November 4, 2021, the World Health Organization (WHO) has announced 5,020,204 deaths out of 247,968,227 confirmed cases of COVID-19. Since the beginning of this outbreak, much evidence stated that the climb in the amount of biomedical waste harmed human health and had adverse effects on the environment. With the increase of cases of COVID-19 all around the globe, the amount of biomedical waste was also constantly rising. Also, many solutions regarding either reducing or recycling biomedical waste. However, the potential global burden of biomedical waste during this pandemic was not yet been analyzed. Herein, we perform a systematic review of literature on these modalities, including mentioning types of biomedical waste, the effect on health, the environment, and methods of handling biomedical waste during this pandemic. A total of 3551 published papers were identified by two databases. In the end, 15 references were selected for this systematic analysis. Most of the included studies focus on research on the impact of medical waste caused by the COVID-19 pandemic on the environment. The total biomedical waste during the COVID-19 pandemic was approximately 16,649.48 tons/day. Most publications agreed that the amount of waste has also increased due to the rapidly rising number of COVID-19 patients. In 15 articles, we identified 2 mentioning the COVID-19 biomedical waste on health. 9 out of 15 gave out the context related to the solution of BMW by COVID-19. More studies, including meta-analyses, are recommended to shed more light on the effects of medical waste on environmental health during the COVID-19 pandemic.

1. Introduction

Coronavirus disease 2019 (COVID-19) is a highly contagious disease caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). At the end of December 2019, in Wuhan, China, SARS-CoV-2 was first reported and then quickly spread worldwide [1]. As of November 4, 2021, the World Health Organization (WHO) has announced 5,020,204 deaths out of 247,968,227 confirmed cases of COVID-19. COVID-19 has had beneficial and detrimental impacts on the environment and the climate. In cities, due to restrictions on movement and a slowdown in economic and social activities, air pollution improved and water pollution decreased in the area [2].

On the other hand, the increased use of personal protective equipment (PPE) and the indiscriminate disposal will create a large amount of hospital waste that negatively impacts the environment [2]. Due to the COVID-19 pandemic, countries enacted lockdown orders, increasing demand for online shopping for home delivery, which increases the amount of household waste from shipped packaging materials transfer. However, recycling waste effectively saves energy, limits environmental pollution, and conserves natural resources. Because of the pandemic, waste recycling operations are postponed in many countries to restrict the transmission of the virus. Therefore, waste collection and recycling have been a global concern throughout the COVID-19 pandemic [2]. The COVID-19 pandemic has dramatically affected the quantity and composition of medical waste, and the amount of waste generated and infectious waste in landfills has also increased. In addition, people discarding potentially infectious masks and gloves is also a significant concern.

According to annual statistics, there were 5.2 million people in the world, of which 4 million children died from diseases caused by unmanaged medical waste [3]. Furthermore, infectious waste other than hospital waste is also increased due to the home care of sick or suspected sick people [4]. According to the United Nations Environment Program, the increase in COVID-19-related medical waste is 3.4 kg per person per
day worldwide. The COVID-19 medical waste produced in developing countries is about 2.5 kg per bed per day [5]. Due to the global spread of COVID-19, the excessive growth of biomedical waste has become a major and worrying threat to public health and the environment [6]. Because the coronavirus can adhere to the surface of tested materials, biomedical waste, if not well-managed, leads to the possibility of COVID-19 infection [7].

To date, reviews on medical waste during the COVID-19 pandemic have only focused on technologies and dealing with gaps in waste management policies in specific regions and countries [8,9]. Other reviews focus on providing waste management scenarios, strategies, or guidelines [10,11]. No study summarizes the consequences of medical waste during the pandemic on the environment, health, and solutions all over the world. Therefore, the research presented here summarized all research, publications and data about biomedical waste (BMW) during the time of the COVID-19 pandemic. The review focuses on potential problems arising from improper disposal of medical waste from COVID-19 and addresses policies and remedial measures that need to be considered to remedy this situation. Our research indicates that the volume of medical waste during the COVID-19 pandemic increased significantly. This causes a lot of adverse effects on human health as well as the environment. The future of research needs to shed light on the potential risk of biomedical waste during the COVID-19 pandemic and the right policies to deal with this situation. This review discusses the consequences of improper medical waste disposal from COVID-19, which can make the epidemic much more challenging to control and put people at higher risk of contracting various types of other dangerous diseases. In addition, policies and remedial measures to remedy this situation are also discussed.

2. Methods

2.1. Study design

A systematic review was conducted.

2.2. Literature search and selection of publications

We followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) document selection guidelines for the document selection process (http://prisma-statement.org/). The search database included are PubMed (https://pubmed.ncbi.nlm.nih.gov/) and Science Direct (https://www.sciencedirect.com/). PICOT (Population, Intervention, Comparison, Outcome, and Time) standard was used to identify the main research question and inclusion criteria. Populations were published articles in PubMed and Science Direct. There were no standards for Intervention and Comparison. Outcomes were published articles about the burden of medical or biomedical waste during the COVID-19 pandemic. Time was articles published in 2020 or 2021.

Keywords used to search: biomedical waste by COVID-19, medical waste by COVID-19, biomedical waste and COVID-19, medical waste and COVID-19, pharmaceutical waste by COVID-19, pharmaceutical waste, and COVID-19.

2.3. Data abstraction

Zotero software is used to store citation information from studies. After searching, all results are imported into Microsoft Excel, and duplicates are removed. Two researchers (SMVN and HVT) independently screened the literature. Any conflicting decisions by two investigators must be discussed in a consensus meeting or consulted by a third investigator (DTC). The screening process takes place in three steps and is presented in the PRISMA diagram (Fig. 1).

3. Results

A total of 3551 published papers were identified in this systematic analysis, collected from PubMed and Science Direct databases. After filtering the non-abstracts and duplicated articles, 1686 articles were selected. Then, articles with non-related content and not written in English were also eliminated. Sixty-six papers were being put in final screening. The majority of the publications were being filtered at this step since they were either review or systematic review articles. In the end, 15 references were selected for this systematic analysis [12–26].

3.1. Types of biomedical waste by COVID-19

In general, BMW is categorized according to numerous codings, either by letter codes, characteristics, color codes, or risks [27]. However, the publications we found each had a different coding system for
COVID-19 BMW, as shown in Table 1 and Fig. 2. Out of 15 included studies, three mentioned the types of BMW during the COVID-19 pandemic [12-14]. Two articles classified BMW as hazardous and non-hazardous waste [12,13]. Specifically, one distinguished types of BMW during the pandemic as C-type (hazardous industrial waste) and D-type (general industrial waste) [12], and the other article mentioned that BMW was being classified as non-hazardous, hazardous, and sharp waste [13]. On the other hand, one reference indicated four categories of BMW, which are being shown by colors, i.e., red, blue, white, and yellow [14]. Each color-coding of the BMW indicates a different level of hazardous. For example, blue indicated infected plastic waste; yellow indicated anatomical waste; red indicated soil waste and white indicated sharps [28].

3.2. The effects of the biomedical waste by COVID-19 on the environment

Nine publications had content about the amount of waste generated during the COVID-19 pandemic (Table 3). Five publications mentioned about the total BMW during the COVID-19 pandemic [14,17,18,23], which was approximately 16,649.48 tons/day [17]. Four publications compared the amount of BMW before and during the COVID-19 pandemic [18,19,20,17], in which, most agreed that due to the rapid rising in the number of COVID-19 patients, the amount of waste associated with COVID-19 has also increased [18,19,17]. Although, there was one exception talked about the infectious waste generated monthly in 2020 was 9% lower than in 2019 [20]. Three publications stated that there was an increase in the amount of BMW [12,15,16]. Three publications agreed that there was an increase in the amount of BMW during the time of the COVID-19 pandemic. Three articles talked about the environmental effect caused by the BMW during the COVID-19 pandemic [21,24,14] (Table 4).

3.3. The effects of the biomedical waste by COVID-19 on health

In 15 articles, we identified 2 mentioning the COVID-19 biomedical waste on health (Table 2). One said that the healthcare professionals (HCPs) had the most exposure to BMW and could be infected [13]. One stated the risk of BMW during the COVID-19 pandemic [14]. Being the most vulnerable subjects, HCPs in Al-Asha had a high risk of being infected with diseases from BMW. Therefore, the majority of HCPs must always follow the Ministry of Health’s protocol for preventing the COVID-19 pandemic. It is also mentioned that most HCPs adhered to the policies of COVID-19 prevention when treating positive patients. In addition, most HCPs were able to prevent contamination when handling items of non-COVID-19 and COVID-19 patients [13]. In India, gases, heavy metals, and poly-chlorinated biphenyls (PCBs) contributed significantly to India’s total yellow BMW (T-Y-BMW). Nevertheless, it is stated that these factors did not cause any health effects, but inhaling Cd could cause carcinogenic health concerns in adults and children [14].

3.4. Solutions for biomedical waste by COVID-19

9 out of 15 gave out the context related to the solution of BMW by COVID-19 (Table 5). All nine references talked about the waste management recommendation and precautions in handling COVID-19 BMW [12,14,16,17,20,22,24,26]. Three studies agree that BMW must be sorted and labeled when transported into the landfills [12,24,26]. Four articles mentioned that the most effective way of handling BMW was incineration, and in either above 850 °C or 1,100 °C [12,17,16,24]. Three references indicated the importance of separating and organizing when handling different types of BMW [12,14,25]. Three mentioned the alternative technology in treating various kinds of BMW [14, 24, 26]. Two studies strengthened that PPE should be taken seriously when handling COVID-19 BMW [18, 20]. Two articles stated BMW management recommendations based on government and organization [20,16].

4. Discussion

Many studies also show that the volume of medical waste increases rapidly during the COVID-19 pandemic. Research by Rahul Rajak et al., 2021 has shown that India’s MW by the COVID-19 pandemic has reached 32,996 tons in only the last 6 months of 2020 [29]. The study by Olugbemi T Olaniyi et al. pointed to the rapid increase in PPE and other biomedical wastes by the COVID-19 pandemic [30]. At the same time, this study also shows that the loopholes in the medical waste management plan can have serious consequences. Research by Abdolmajid Fadaei, 2021 has confirmed that medical waste increases from 350 to 500% in many countries [31]. The study by Gowda also shows that the amount of medical waste has reached 7.76kg/Covid-19 bed/day compared to 1.93kg/bed/day at the time before COVID-19 [32]. Perhaps it is the increase in needless practices and wastage in healthcare for COVID-19 that has led to the increase in biomedical waste and medical waste generation [33]. Furthermore, cross-contamination from exposure to biomedical wastes due to COVID-19 and effects from toxic substances (especially Cd - substances arising from medical waste incineration) make the management COVID-19 biomedical waste becomes a formidable challenge. Similar to the results of this study, in fact, methods of incineration, isolation and improvement of waste treatment methods and processes have been applied. In India, a newly developed medical waste treatment process has classified medical waste with high risk of infection according to a system of 3 red bins including red bin 1 (Goggles/face shield), red bin 2 (N-95 masks and coveralls (white) and red bin 3 (Disposable PPEs). Each medical waste in different types of red bins is received by those who specialize in handling and treated by other methods. This will help reduce cross-contamination and make the treatment process faster, more economical, and more suitable for each type of medical waste. In addition, to address the fact that all COVID-19 waste was incinerated during the initial phase detected in the study, a
new and improved process has been developed to reduce the volume of COVID-19 medical waste being burned to limit the amount of toxic substances generated from the burning process. Investing in people is a method of long-term investment and economic savings in the long run, but it has not been focused on the studies found. Creating a team of professional medical staff who are familiar with the medical waste treatment process during COVID-19 helps medical waste always be treated in a timely manner as well as resources for medical waste treatment are always available.

Our study only filtered for studies written in English and did not include research in other languages. Data for this study are limited, and the studies were collected from only two sources (PubMed and Science Direct), so data may not be complete. Furthermore, we do not have standards to evaluate the quality of articles. It may affect the reliability of this study.

In general, research on MW and MW by COVID-19 is still minimal. We suggest that future studies should gather information from studies from a variety of languages and sources. Studies should use additional meta-analysis for more substantial evidence on medical waste burdens due to COVID-19. In addition, we suggest that more research is needed on the impacts of MW on human health as well as treatment solutions for COVID-19. Moreover, the problem of medical waste in many different diseases also needs more attention.

5. Conclusion

The COVID-19 pandemic is an ongoing global health crisis. The pandemic not only has caused significant damage to health but also to...
The amount of medical waste has increased since the COVID-19 pandemic started. Moreover, there is a huge impact on the environment, and the amount of cadmium (Cd) would negatively impact the health of Indian people (Table 2). The amount of BMW has also increased since the COVID-19 pandemic started. Therefore, solutions for the BMW and MW are needed. Furthermore, it was essential to handle COVID-19 BMW and MW with care and obey PPE precautions. Our paper was a short communication that summarized all the publications that stated the impact of COVID-19 BMW on health, the environment, and the solution for the waste. We hope that this publication will be a footprint for us to continue to perform comprehensive research in the future to strengthen our results on BMW, and MW burden during this time of public health situation.

Funding

This work has no funding

Authors’ contributions

Development of the idea for this work: DTC. Conceptualization: SMVN, VTH, and DTC; Literature search and data analysis: SMVN, MAN, TLN, HVT, TLD and TMBP; Writing - original draft preparation: all authors; Writing - review and editing: DTC.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank other members at the Center for Biomedicine and Community health, International School, Vietnam National University for critically reading, and making comments to improve this manuscript.

Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| BMW          | Biomedical waste |
| C-BMW        | COVID-19 biomedical waste |
| COVID-19     | Coronavirus disease 19 |
| EU           | European Union |
| HCPs         | Healthcare professionals |
| HIV          | Human immunodeficiency virus |
| HWC          | HCW Healthcare waste Healthcare workers |
| MW           | Medical waste |
| PPE          | Personal protective equipment |
| SARS-CoV-2   | Severe acute respiratory syndrome coronavirus 2 |
| T-Y-BMW      | Total yellow biomedical waste |
| VOC          | Variants of Concern |
| VOI          | Variants of Interest |
| VUI          | Variants under investigation |
| WHO          | World Health Organization |

References

[1] M. Cascella, et al., Features, evaluation, and treatment of coronavirus (COVID-19), StatPearls (2021).
[2] T. Rume, S.M.D. Islam, Environmental effects of COVID-19 pandemic and potential strategies of sustainability, Heliyon 6 (9) (2020), e04965.
[3] F. Malekahmadi, et al., Analysis of the healthcare waste management status in Tehran hospitals, J. Environ. Health Sci. Eng. 12 (1) (2014) 116.
[4] R.R. Kalantary, et al., Effect of COVID-19 pandemic on medical waste management: a case study, J. Environ. Health Sci. Eng. 19 (1) (2021) 1–6.
[5] (USEPA), U.S.E.P.A, Recycling and sustainable management of food during the coronavirus (COVID-19) public health emergency. Available from: https://www.epa.gov/coronavirus/recycling-and-sustainable-management-food-during-corona-virus-covid19-public-health, 2020 April 19.

[6] A.K. Das, et al., COVID-19 pandemic and healthcare solid waste management strategy - a mini-review, Sci. Total Environ. 778 (2021), 146220.

[7] M.S. Haque, et al., Coronavirus disease 2019 (COVID-19) induced waste scenario: a short overview, J. Environ. Chem. Eng. 9 (1) (2021), 104660.

[8] M. Khazraji, et al., Assessment of medical and pharmaceutical waste flows during the coronavirus pandemic in the Rabat-Sale-Kenitra region, Morocco, Waste Manag. Res. (2021). 734242x211046853.

[9] R. Kothari, et al., COVID-19 and waste management in Indian scenario: challenges and possible solutions, Environ. Sci. Pollut. Control Ser. 28 (38) (2021) 52702-52723.

[10] M.R. Capoor, A. Parida, Biomedical waste and solid waste management in the time of COVID-19: a comprehensive review of the national and international scenario and guidelines, J. Lab. Phys. 13 (2) (2021) 175-182.

[11] S. Ilyas, R.R. Srivastava, H. Kim, Disinfection technology and strategies for COVID-19 hospital and bio-medical waste management, Sci. Total Environ. 749 (2020), 141652.

[12] W.-T. Tsai, Analysis of medical waste management and impact analysis of COVID-19 on its generation in Taiwan, Waste Manag. Res. (2021). 734242x211996803.

[13] S.M. Jalal, et al., Assessment of knowledge, practice and attitude about biomedical waste management among healthcare professionals during COVID-19 crises in Al-aisha, Health Care 9 (6) (2021).

[14] P.S. Thind, et al., Compromising situation of India’s bio-medical waste incineration units during pandemic outbreak of COVID-19: associated environmental-health impacts and mitigation measures, Environ. Pollut. 276 (2021), 116621.

[15] R.R. Kalantary, et al., Effect of COVID-19 pandemic on medical waste management: a case study, J. Environ. Health Sci. Eng. 19 (1) (2021) 831-836.

[16] L. Yang, et al., Emergency response to the explosive growth of health care wastes during COVID-19 pandemic in Wuhan, China, Resour. Conserv. Recycl. 164 (2021), 105704.

[17] S. Sangkham, Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia, Case Stud. Chem. Eng. Environ. Eng. 2 (2020), 100052.

[18] B. Mekonnen, N. Solomon, W. Wondimu, Healthcare waste status and handling practices during COVID-19 pandemic in tepi general hospital, Ethiopia, J. Environ. Pub. Health (2021).

[19] S. Kargar, M. Pourmehdi, M.M. Paydar, Reverse logistics network design for medical waste management in the pandemic outbreak of the novel coronavirus (COVID-19), Sci. Total Environ. 746 (2020), 141185.

[20] A. Maalouf, H. Maalouf, Impact of COVID-19 pandemic on medical waste management in Lebanon, Waste Manag. Res. 39 (1_suppl) (2021) 45-55.

[21] F. Chen, et al., Study on the relationship between crisis awareness and medical waste separation behavior shown by residents during the COVID-19 epidemic, Sci. Total Environ. 787 (2021), 147522.

[22] H.-L. Zhao, et al., Energy, environment and economy assessment of medical waste disposal technologies in China, Sci. Total Environ. 796 (2021), 149864.

[23] C. Chen, et al., What medical waste management system may cope with COVID-19 pandemic: lessons from Wuhan, Resour. Conserv. Recycl. 170 (2021), 105600.

[24] H. Zhao, et al., Comparative life cycle assessment of emergency disposal scenarios for medical waste during the COVID-19 pandemic in China, Waste Manag. 126 (2021) 388-399.

[25] N.M. Kumar, et al., Artificial intelligence-based solution for sorting COVID related medical waste streams and supporting data-driven decisions for smart circular economy practices, Process Saf. Environ. Protect. (2021).

[26] H. Yu, et al., Reverse logistics network design for effective management of medical waste in epidemic outbreaks: insights from the coronavirus disease 2019 (COVID-19) outbreak in wuhan (China), Int. J. Environ. Res. Publ. Health 17 (5) (2020).

[27] K.K. Padmanabhan, D. Barik, Health hazards of medical waste and its disposal, in: Medical waste management in the epidemic outbreak of the novel coronavirus (COVID-19) outbreak in wuhan (China), Int. J. Environ. Res. Publ. Health 17 (5) (2020).

[28] P.M. Patil, R.A. Bohara, Nanoparticles impact in biomedical waste management, Waste Manag. Res. 38 (11) (2020) 1189–1203.

[29] R. Rajak, et al., Assessment of bio-medical waste before and during the emergency of novel Coronavirus disease pandemic in India: a gap analysis, Waste Manag. Res. (2021). 734242x211021473.

[30] O.T. Olaniyan, et al., Increase in SARS-CoV-2 infected biomedical waste among low-mid income countries: environmental sustainability and impact with health implications, J. Basic Clin. Physiol. Pharmacol. (2021).

[31] A. Fadaei, Study of solid waste (municipal and medical) management during the COVID-19 pandemic, a review study, Rev. Environ. Health (2021).

[32] N.R. Gowda, et al., War on waste: challenges and experiences in COVID-19 waste management, Disaster Med. Public Health Prep. (2021) 1–13.

[33] M.A. Warner, Stop doing needless things! Saving healthcare resources during COVID-19 and beyond, J. Gen. Intern. Med. 35 (7) (2020) 2186–2188.