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International Legal Framework in Curtailing Hazardous COVID-19 Medical Waste: Issues and Challenges

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ABSTRACT

At the close of 2019, the global environment was hit by the COVID-19 pandemic. Healthcare across the global environment was overwhelmed with patients suffering from the COVID-19 virus. However, in a bid to respond by curtailing the COVID-19 pandemic through medical equipment, it resulted in unprecedented waste. However, despite there are several global laws that curtail the incidence of waste generation and disposal, most developing countries experience a high level of medical waste from equipment used in the treatment of COVID-19 patients. In this regard, the study adopts a doctrinal method of investigation to examine the global legal issues and challenges concerning waste emanating from medical equipment in the treatment of COVID-19 patients. The study found that the COVID-19 pandemic resulted in unprecedented medical waste within the global environment, low and middle-income countries suffered more as a dumping ground of medical waste emanating from the equipment used in the treatment of COVID-19 patients. The study also found that there is a legal gaps and weaknesses concerning the international laws curtailing the incidence of waste. Furthermore, the study also found that poor technology in recycling and curtailing COVID-19 medical waste is a major challenge to developing nations during the pandemic. The study concluded and recommended that to ensure a healthy and sustainable environment free from unprecedented waste. There is a need to strengthen National and international laws in curtailing the incidence and indiscriminate dumping of COVID-19 and any medical waste. Furthermore, the study recommends the need for international cooperation in knowledge sharing on sustainable waste management through sophisticated technology.

Introduction

Waste pollution is considered a major threat to man, its environment, and the entire ecosystem. Over the years the sporadic growth of the global population resulted in the developmental stride of industrial activities to meet the needs of the growing

population[1]. Concerning this, it suffices to state that the growth of population and industrial activities saw the rapid increase and indiscriminate dumping of hazardous waste that is harmful to the environment and public health[2]. Although, there are several types of waste such as organic waste, liquid waste, gaseous waste (such as carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NOx)), solid and hazardous waste (such as industrial waste, e-waste, radioactive and medical waste)[3]. This waste is considered to pose a potential harm to the environment and man if not properly managed[4]. It could result in air and water pollution, environmental degradation, flooding, and soil contamination resulting in poor agricultural produce[5]. Furthermore, a study has also revealed that waste pollution could also result in the spread of infectious diseases that could result in a significant health impact[6]. Furthermore, long-term exposure to waste pollution could result in chronic respiration illness, cancer, and other severe health impact[7].

However, it must be noted that the international community has been at the forefront of curtailing, regulating, and ensuring effective control of the incidence of waste pollution[8]. This is concerning the fact that the international community has anchored several global laws such as the Basel Convention on the transboundary Movement of hazardous waste. Also, there is the Stockholm Convention, the Bamako Convention, and several other global laws. Furthermore, there have been several international institutions to ensure the implementation and compliance of these global environmental laws on waste management[9]. Some of these institutions include the United Nations Environmental Programme also known as UNEP, the World Health Organisation known as WHO, the International Maritime Organisation, the International Solid Waste Association, and the Intergovernmental Panel on Climate Change[10]. These organisations

[1]Hela Ghali, Asma Ben Cheikh, Sana Bhiri, Lamia Bouzgarrou, Mohamed Ben Rejeb, Imed Gargouri, and Houyem Said Latiri. "Health and Environmental Impact of Hospital Wastes: Systematic Review." Dubai Medical Journal 6, no. 2 (2023): 67–80.

[2]Kennedy Degaulle Gunawardana. "An Analysis of Medical Waste Management Practices in the Health Care Sector in Colombo." Management of Environmental Quality: An International Journal 29, no. 5 (2018): 813–25.

[3]Paul Atagamen Aidonojie, Adebayo, K. Adesoji, Eregbuonye Obishie., Wakili S. Abacha, (2024), "Breaking Legal and Socio-economic Challenges to Plastic Waste Regulation in Nigeria: Lessons learned from Singapore", Yustisia, 13(1), 64-88

[4]Osikemekha A Anani, Abel Inobeme, Osayomwanbo Osarenotor, Frances Ngozi Olisaka, Paul Atagamen Aidonojie, Emmanuel Olusegun Olatunji, Aishatu Idris Habib, (2023), 'Application of Microorganisms as Biofactories to Produce Biogenic Nanoparticles for Environmental Cleanup: Currents Advances and Challenges', Current Nanoscience, 19(6), 770-782

[5]Haiying Zhou, Xiangyu Yu, Ahmad Alhaskawi, Yanzhao Dong, Zewei Wang, Qianjun Jin, Xianliang Hu, Zongyu Liu, Vishnu Goutham Kota, Mohamed Hasan Abdulla Hasan Abdulla, Sohaib Hasan Abdullah Ezzi, Binjie Qi, Juan Li, Bixian Wang, Jianyong Fang, and Hui Lu. "A Deep Learning Approach for Medical Waste Classification." Scientific Reports 12, no. 1 (2022): 2159.

[6]Osikemekha Anthony Anani, Maulin P Shah, Paul Atagamen Aidonojie, Alex Ajeh Enuneku, (2023), "Bio-Nano Filtration as an Abatement Technique Used in the Management and Treatment of Impurities in Industrial Wastewater" Bio-Nano Filtration in Industrial Effluent Treatment, 171-182

[7]Olufunsho Awodele, Aishat Abiodun Adewoye, and Azuka Cyril Oparah. "Assessment of Medical Waste Management in Seven Hospitals in Lagos, Nigeria." BMC Public Health 16 (2016): 1–11.

[8]Ukhurebor, E. Kingsley, and Paul Atagamen Aidonojie (2021). The influence of climate change on food innovation technology: review on topical developments and legal framework. Agric & Food Security 10, 50.

[9]Sarawut Sangkham. "Face Mask and Medical Waste Disposal during the Novel COVID-19 Pandemic in Asia." Case Studies in Chemical and Environmental Engineering 2 (2020): 100052.

[10]Kingsley Eghonghon Ukhurebor, Uyiosa Osagie Aigbe, Robert Birundu Onyancha, Hussain Athar, Benedict Okundaye, Paul Atagamen Aidonojie, Benita Ebindu Siloko, Ismail Hossain, Heri Septya Kusuma, Handoko

have been actively involved in championing the need for a sustainable development of industrial activities and requesting a reliable method of waste disposal and management[11]. Despite these laws in curtailing the incidence of waste pollution generation and dumping, there have been major challenges arising from medical waste as a result of the COVID-19 pandemic period[12].

The COVID-19 period was a critical moment that shook the global healthcare system and nations were overwhelmed[13]. This is concerning the fact that millions of people were infected by COVID-19 disease through transmission from carriers of the disease that may be symptomatic and asymptomatic[14]. However, the global response to the treatment of patients suffering from COVID-19 disease led to a surge of medical waste in several African, European, Asia, and American countries[15]. The majority of the medical waste emanates from medical equipment such as vaccine material, test kits, gowns, medical ventilators, face shields, dead COVID-19 patients' bed that may be infected, and other medical equipment[16]. These medical equipment after their usage are considered a major waste that is considered harmful and results in severe pollution of the global environment[17]. Furthermore, it must be noted that in several developing countries that were also major hit by the COVID-19 pandemic most of the medical equipment was not properly disposed of and handled[18]. Most of these countries were either burning medical waste and others were burying the waste[19]. This crude method of waste disposal could result in more dangerous environmental pollution and a threat to public health[20]. This is

Darmokoesoemo, "Environmental Influence of Gas Flaring: Perspective from the Niger Delta Region of Nigeria", Geofluids, vol. 2024, 17 pages, 2024. https://doi.org/10.1155/2024/1321022

[11]Rami Oweis, Mohamad Al-Widyan, and Ohood Al-Limoon. "Medical Waste Management in Jordan: A Study at the King Hussein Medical Center." Waste Management 25, no. 6 (2005): 622–25.

[12]Imoisi E. Simon and Paul Atagamen Aidonojie, (2023). Legal and Socio-economic Issues Concerning Black Marketer's Activities of Petroleum Products in Nigeria. Yuridika, 38(2), 61-84, https://doi.org/10.20473/ydk.v38i2.44999

[13]Paul Atagamen Aidonojie, Anani O. Anthony, Agbale O. Patient, Olomukoro O. John, Adetunji O. Charles. (2020). Environmental Law in Nigeria: A Review on its Antecedence, Application, Judicial Unfairness and Prospects. Archive of Science & Technology 1(2) (2020) 211-221

[14]Anani O. Anthony, Paul Atagamen Aidonojie and Olomukoro O. John, (2022), Environmental Principles and Ethics: Current Challenges in the Field of Bioscience and Law, Ethics, Media, Theology and Development in Africa: A Festchrift in Honour of Msgr. Prof. Dr. Obiora Francis Ike, Global.net Co-Publication & Others, Geneva, Switzerland, 142-158

[15]Khadija Al-Omran, Ezzat Khan, Nisar Ali, and Muhammad Bilal. "Estimation of COVID-19 Generated Medical Waste in the Kingdom of Bahrain." Science of the Total Environment 801 (2021): 149642.

[16]Paul Atagamen Aidonojie, Ukhurebor, E. Kingsley, Masajuwa, Florence, Imoisi, E. Simon, Edetalehn, O. Idemudia, Nwazi, Joseph, (2022). Legal Implications of Nanobiosensors Concerning Environmental Monitoring. In: Singh, R.P., Ukhurebor, E. Kingsley, Singh, J., Adetunji, O. Charles, Singh, K.R. (eds) Nanobiosensors for Environmental Monitoring. Springer, Cham. https://doi.org/10.1007/978-3-031-16106-3_21

[17]A. Suresh Kumar, M. Muthukannan, R. Kanniga Devi, K. Arunkumar, and A. Chithambar Ganesh. "Reduction of Hazardous Incinerated Bio-Medical Waste Ash and Its Environmental Strain by Utilizing in Green Concrete." Water Science and Technology 84, nos. 10–11 (2021): 2780–92.

[18]Paul Atagamen Aidonojie, Ukhurebor . E. Kingsley, Oaihimire E. Idemudia, Ngonso F Blessed, Egielewa Peter, and Darmokoesoemo Hussein, (2023), Bioenergy revamping and complimenting the global environmental legal framework on the reduction of waste materials: A facile review, 9(1), https://doi.org/10.1016/j.heliyon.2023.e12860

[19]Uttama Barua and Dipita Hossain. "A Review of the Medical Waste Management System at COVID-19 Situation in Bangladesh." Journal of Material Cycles and Waste Management 23, no. 6 (2021): 2087–2100.

[20]Paul Atagamen Aidonojie, Okuonghae Nosa, Moses-oke O. Rose, Majekodunmi T. Akintola, (2023), 'A Facile Review on the Legal Issues and Challenges Concerning the Conservation and Preservation of Biodiversity', Global Sustainability Research, 2(2), 34-46

concerning the fact that burning of this hazardous equipment often results in the release of carbon gas and air pollution. Also, burying the medical waste could result in soil and water contamination through decay and erosion that may transport this waste to water bodies[21]. Furthermore, there are incidences where some developing countries were used as dumping grounds for soon-to-be expired medical equipment[22]. However, it has been asserted that the global community had through legal framework combat and curtail the incidence of waste. However, the waste generated from COVID-19 medical equipment seems to have provided unique challenges to global laws on waste pollution.

Concerning the above, this study adopts a doctrinal method of study in examining how medical waste contributes to a high level of environmental pollution as a result of the use of medical equipment in the treatment of COVID-19 patients during the pandemic. Furthermore, the study will also examine various global legal frameworks as it concern curtailing and eradicating waste, therefore reflecting on the shortcomings and ineffectiveness of these laws in effectively combating medical waste emanating from COVID-19 medical equipment for treatment.

Methods

The focus of the study is on medical waste disposal during the COVID-19 pandemic which most developing countries suffered from such hazardous waste. Concerning this, to successfully execute this research, the study adopts a doctrinal method of study relying on primary and secondary sources of research material involving international legal framework on waste, scholarly written journal articles, online articles, and other relevant research material.[23] The data obtained were critically analyse relying on a conceptualised descriptive and analytical approach.[24]

Hence, the essence of adopting a doctrinal method of study is aimed at theorising and conceptualizing environmental pollution and degradation arising from the generation and dumping of waste as a result of the medical equipment used in the treatment of COVID-19 patients. Furthermore, the doctrinal method of approach is also aimed at logically analysing the existing international environmental framework as it concerns the curtailing and eradication of hazardous waste.

Discussion

Conceptual Issues on Environmental Waste Pollution Arising from COVID-19 Medical Equipment

[21]XinYing Chew, Khai Wah Khaw, Alhamzah Alnoor, Marcos Ferasso, Hussam Al Halbusi, and Yousif Raad Muhsen. "Circular Economy of Medical Waste: Novel Intelligent Medical Waste Management Framework Based on Extension Linear Diophantine Fuzzy FDOSM and Neural Network Approach." Environmental Science and Pollution Research 30, no. 21 (2023): 60473–99.

[22]Paul Atagamen Aidonojie, Majekodunmi T. Akintola, Eregbuonye Obishie and Adeyemi-Balogun O. Janet, (2024), Potential and Legal Challenges of Metaverse for Environmental Awareness and Sustainable Practice in Nigeria: A Comparative Study with Singapore, Administrative and Environmental Law Review 5 (1):37-64. https://doi.org/10.25041/aelr.v5i1.3230.

[23] Ousu Mendy and Ebrima Sarr, "The Judiciary in Governance: Understanding the Juridical Nature and Function of the Constitutional Court of Indonesia". (2025). *Journal of Indonesian Constitutional Law*, *2*(1), 1-22. https://doi.org/10.71239/jicl.v2i1.45

[24] Frei Fitri Astuti and Laila Nur Jannah, Flexibility in Accessing Legal Information Through Social Media and its Implications for Law Enforcement. (2025). *Journal of Indonesian Constitutional Law*, *2*(1), 23-36. https://doi.org/10.71239/jicl.v2i1.37

Medical waste is a broader term having a great variety of directories from infection waste and hazardous chemicals through pharmaceuticals to non-hazardous general waste produced in healthcare system[25]. It raises serious environmental problems as it is likely to emit pollution and become a hazard to public health. In this regard, medical waste can result in water, air, and soil, pollution which could pose dangers to human and ecological health[26]. However, it suffices to state that the volume of medical waste is intensifying the situation, especially in developing countries that do not possess waste management strategies[27]. It is apt to state that the very basic conceptual issue regarding environmental pollution from medical waste is waste segregation, classification, and treatment[28]. Proper classification ensures that both the hazardous waste and nonhazardous wastes are treated in different ways. As a result of misclassification, they are most often disposed off improperly, by open burning, dumping, burying, or other means, which result in the release of toxic and hazardous substances into the environment[29]. For example, dumping medical wastes incinerated without sufficient emission control systems leads to the released of hazardous dioxins and furans, which may result in a toxic and persistent environmental pollutant[30]. In this regard, ineffective segregation practices account for a large chunk of most environmental pollution and they are also associated health risks[31].

Though the occurrence of the COVID-19 pandemic came as an unsought surprise, the result of the pandemic completely shut down the global healthcare system. During the period of the COVID-19 pandemic, the reported cases and deaths fluctuated worldwide[32]. As reported by the organization, World Health Organization (WHO), at the end of December 2020, over 81 million confirmed COVID-19 cases and 1.8 million deaths were recorded in the world[33]. The statistics for each month observed a rapidly increasing number with peaks of notable infection around mid-2020[34]. In April 2020, worldwide

[25]Paul Atagamen Aidonojie, Ikubanni O. Oluwaseye, Oyedeji A. Ifeoluwa and Oyebade A. Akinsola (2022) The Legal Challenges and Effect concerning the Environmental Security in Nigeria: A Lesson from International Perspective, Journal of Commercial and Property Law, Vol. 9(1), 110-120

[26]Pensiri Akkajit, Husna Romin, and Mongkolchai Assawadithalerd. "Assessment of Knowledge, Attitude, and Practice in Respect of Medical Waste Management among Healthcare Workers in Clinics." Journal of Environmental and Public Health 2020, no. 1 (2020): 8745472.

[27]Sadia Ilyas, Rajiv Ranjan Srivastava, and Hyunjung Kim. "Disinfection Technology and Strategies for COVID-19 Hospital and Bio-Medical Waste Management." Science of the Total Environment 749 (2020): 141652.

[28]Adan Mohiuddin. "Medical Waste: A Nobody's Responsibility After Disposal." International Journal of Environmental Science & Natural Resources 15, no. 2 (2018): 555908.

[29]Sanda Narayanamoorthy, Vilk Annapoorani, Daekook Kang, Dumitru Baleanu, Jeonghwan Jeon, Joseph Varghese Kureethara, and L. Ramya. "A Novel Assessment of Bio-Medical Waste Disposal Methods Using Integrating Weighting Approach and Hesitant Fuzzy MOOSRA." Journal of Cleaner Production 275 (2020): 122587.

[30]Khadija Al-Omran, Asma Abahussain, and Ezzat Khan. "Integrated Environmental Assessment of Medical Waste Management in the Kingdom of Bahrain." Sustainability 15, no. 3 (2023): 2397.

[31]Narendra Singh, Oladele A. Ogunseitan, and Yuanyuan Tang. "Medical Waste: Current Challenges and Future Opportunities for Sustainable Management." Critical Reviews in Environmental Science and Technology 52, no. 11 (2022): 2000–22.

[32]Jae-Hyun Ha and Hyun Ju Lee. "Nursing Students' Environmental Consciousness and Medical Waste Related Knowledge and Attitudes." Journal of Korean Academy of Community Health Nursing 30, no. 2 (2019): 174–82.

[33]World Health Organisation "Weekly epidemiological update - 29 December 2020", https://www.who.int/publications/m/item/weekly-epidemiological-update---29-december-2020?utm_source=chatgpt.com accessed 24th February 2025

[34]World Health Organisation "Weekly epidemiological update - 29 December 2020

deaths counted about 165,000 and by July this year, it had probably crossed the 650,000 mark. Nevertheless, even burying the recovery rates, by the close of the year, over 59 million survivors had fought their infection[35]. The overall pressure mounted on healthcare systems and flagged the urgent requirement to enhance medical waste management and sustainable healthcare to subdue their risks both to the environment and to health (WHO, 2020).

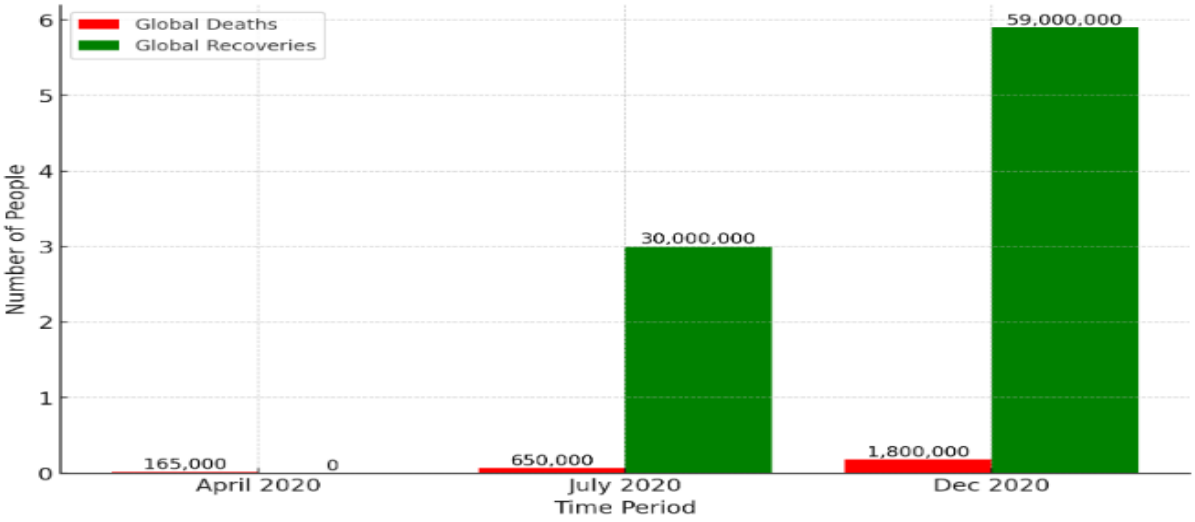

Figure 1: Showing the death and recoveries of COVID-19 patient
Sources: World Health Organisation[36]

The COVID-19 pandemic has resulted in the increased production of medical waste resulting in increased environmental pollution problems within the global environment. For example, between the period of March 2020 and November 2021, the World Health Organisation acquired about 87,000 tons of personal protective equipment used to support countries' responses to the pandemic, which would eventually all become waste. Such waste has overwhelmed the current waste management system, most especially in developing and underdeveloped countries in Africa and Asia that do not have the necessary facilities for waste[37]. For instance, the first wave of the COVID-19 pandemic increased medical waste production by 17% in India, creating many challenges in rural areas. The Philippines also recorded an increase of 25% in its figures for infectious and hazardous waste, with an additional 70 tons that was added by 51 hospitals operating in the country[38]. It suffices to state that this is a 12% increase compared to the levels of infectious waste generated before the pandemic. One of the reasons for the hazardous nature of medical waste is because of the infectious character of the waste generated due to COVID-19, which makes most health facilities reduce their recycling[39]. For example, in Taiwan, it was observed that the recycling figure for most medical waste reduced from

[35]World Health Organisation "Weekly epidemiological update - 29 December 2020
[36]World Health Organisation "Weekly epidemiological update - 29 December 2020
[37]Paul Atagamen Aidonojie (2023). Environmental Hazard: The Legal Issues Concerning Environmental Justice in Nigeria, Journal of Human Rights, Culture and Legal System, 3(1), pp. 17-32, https://doi.org/10.53955/jhcls.v3i1.60
[38]Kayleigh Bateman "COVID-19 has caused a surge in medical waste. Here's what needs to be done", https://www.weforum.org/stories/2022/02/medical-waste-plastic-environment-covid/?utm_source=chatgpt.com accessed 24th February, 2025
[39]Chih-Kai Yang, Hwong-Wen Ma & Mei-Hua Yuan. Measuring circularity potential for medical waste management – a dynamic circularity performance analysis. Sustain Environ Res 33, 29 (2023). https://doi.org/10.1186/s42834-023-00188-5

33.1% in 2019 to 12.2% in 2020[40], most especially medical waste emanating from the COVID-19 treatment equipment. This reduction has been attributed to the increased use of an item such as disposable masks, test kits, gloves, syringes, face shields, and those related to vaccine supplies, given their infectious nature which automatically made them hazardous[41]. In this regard, it suffices to state that the increased production and disposal of COVID-19 materials has placed severe stress on the available waste management system, especially in developing and developed countries[42].

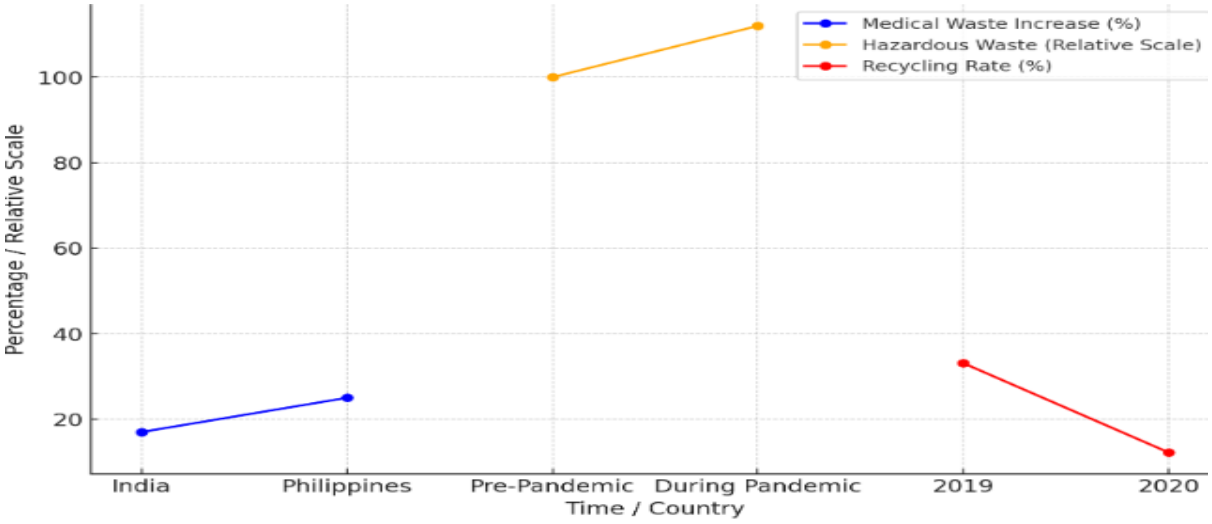

Figure 2: Shows the decline of the recycling of COVID-19 medical waste
Sources: Kayleigh Bateman; Chih-Kai Yang; World Health Organisation

From the above graphical representation, India and the Philippines the blue line shows the level of COVID-19 medical waste and the level of recycling. Also, the orange line shows the hazardous nature of COVID-19 waste Philippines. Furthermore, the red line shows a high level of reduction as it concerns medical waste recycling in Taiwan.

The COVID-19 medical waste issue has cruelly extended its tentacles to soil and water pollution[43]. The careless disposal of face masks and PPE has visibly increased plastic pollution in urban areas, rivers, and oceans. The fish and other marine life are severely affected, as they accidentally swallow such materials or entangle themselves in them[44]. Accumulation of medical waste in landfills increases the risk of soil contamination, which ultimately affects agricultural productivity and food security[45].

[40]World Health Organisation "Tonnes of COVID-19 health care waste expose urgent need to improve waste management systems" https://www.who.int/news/item/01-02-2022-tonnes-of-covid-19-health-care-waste-expose-urgent-need-to-improve-waste-management-systems?utm_source=chatgpt.com accessed 24th February, 2025
[41]Erfan Babaee Tirkolaee and Nadi Serhan Aydın. "A Sustainable Medical Waste Collection and Transportation Model for Pandemics." Waste Management & Research 39, no. 1_suppl (2021): 34–44.
[42]Florin-Constantin Mihai. "Assessment of COVID-19 Waste Flows during the Emergency State in Romania and Related Public Health and Environmental Concerns." International Journal of Environmental Research and Public Health 17, no. 15 (2020): 5439.
[43]Yeliz Sürme, Gülseren Maraş, and Gökçen Aydın Akbuğa. "Environmental Sustainability, Medical Waste Management, Energy and Medicine Consumption of the Surgical Intensive Care Nurses: A Qualitative Study." Nursing in Critical Care, 2025.
[44]Paul Atagamen Aidonojie, Idahosa M. Ekata, Agbale O. Patient, and Oyedeji A, Ifeoluwa, (2022), The Environmental Conservation, and Ethical Issues concerning Herbal Products in Nigeria, Journal of Environmental Science and Economics, Vol. 1(3), 26-32 DOI: https://doi.org/10.56556/jescae.v1i3.124
[45]Klepan Padmanabhan and Debabrata Barik. "Health Hazards of Medical Waste and Its Disposal." In Energy from Toxic Organic Waste for Heat and Power Generation, 99–118. 2019.

This issue was made worse by the non-strict disposal policies about waste during the pandemic when hundreds of healthcare institutions and households utilized unprofessional disposal methods. Air Pollution is a critical problem emanating from COVID-19 medical wastes[46]. The most common incineration of medical waste leads to the air with toxic contents like dioxins and furans. These are contaminants that lead to air pollution and health hazards in surrounding communities[47]. Most instances were when the incineration facilities were deficient in a way that led to the uncontrolled burning of medical waste, thus leading to an increase in emissions of greenhouse gases and toxic pollutants[48].

The long-term effect of such air pollution is a growing concern for environmental health experts. Penalty and policy challenges have recently added complexity to the management of waste arising from COVID-19 due to preexisting frameworks and poor existing infrastructures in many countries for managing such scaled biomedical waste[49]. Thus, some countries are found to have practiced disposal haphazardly regarding biomedical waste. Such agencies like WHO give maximum guidance, but enforcement varies at the national and even local levels[50]. Regarding training, the shortage of training-related inadequacies is often exploited by staff in improper disposal cases[51]. Also, the issue regarding public awareness led to improper disposal, which increases the chances of environmental contamination. Those are the various types of mitigation of such issues, such as adopting sustainable waste management mechanisms[52]. Biodegradable replacement applications for PPE and medical equipment will minimize plastic waste considerably[53]. Therefore, coming up with advanced waste treatment technologies such as pyrolysis and autoclaving will ensure the safe disposal of medical waste. It also strengthens policies and regulations on medical waste disposal alongside awareness campaigns on proper waste management practices[54]. Collaboration between governments, industries, and environmental organizations will also ensure proper management of waste disposal[55].

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[46]Cassandra Thiel, Paula Duncan, and Noe Woods. "Attitude of US Obstetricians and Gynaecologists to Global Warming and Medical Waste." Journal of Health Services Research & Policy 22, no. 3 (2017): 162–67.

[47]Adiue Awad and Firas Al Bajari. "Environmental Impacts of Medical Waste Treatment and Management by Burning Inside Health Facilities." International Journal of Civil Engineering and Technology 9, no. 5 (2018): 41–53.

[48]Anne Woolridge and Selin Hoboy. "Medical Waste." In Waste, 517–30. 2019.

[49]Jade Megan Chisholm, Reza Zamani, Abdelazim M. Negm, Noha Said, Mahmoud M. Abdel Daiem, Mahdieh Dibaj, and Mohammad Akrami. "Sustainable Waste Management of Medical Waste in African Developing Countries: A Narrative Review." Waste Management & Research 39, no. 9 (2021): 1149–63.

[50]Zhipeng Bai, Xi Liu, and Wenbao Ma. "Public Attitudes toward Medical Waste: Experiences from 141 Countries." PLoS One 19, no. 5 (2024): e0302498.

[51]Iris Borowy. "Medical Waste: The Dark Side of Healthcare." História, Ciências, Saúde-Manguinhos 27, suppl. 1 (2020): 231–51.

[52]Shakira Mukhtar, Hamna Khan, Zainab Kiani, Saba Nawaz, Sana Zulfiqar, and Noshabah Tabassum. "Hospital Waste Management: Execution in Pakistan and Environmental Concerns—A Review." Environmental Contamination Review 1, no. 1 (2018): 18–23.

[53]Sang M. Lee and DonHee Lee. "Effective Medical Waste Management for Sustainable Green Healthcare." International Journal of Environmental Research and Public Health 19, no. 22 (2022): 14820.

[54]Lynda Andeobu, Santoso Wibowo, and Srimannarayana Grandhi. "Medical Waste from COVID-19 Pandemic—A Systematic Review of Management and Environmental Impacts in Australia." International Journal of Environmental Research and Public Health 19, no. 3 (2022): 1381.

[55]Emily Chia-Yu Su and Yi-Tui Chen. "Policy or Income to Affect the Generation of Medical Wastes: An Application of Environmental Kuznets Curve by Using Taiwan as an Example." Journal of Cleaner Production 188 (2018): 489–96.

In these terms, pollution caused by the environment is induced by waste generated from COVID-19 hospitals, which creates great challenges that require urgent and coordinated responses[56]. Long-term disposal of medical waste inappropriately contaminates the soil and water, together with air pollution and threats to biodiversity[57]. Thus, they require a combination of strategies, such as regulatory reforms, technology investments, and enhanced public understanding[58]. Incorporating sustainable waste management solutions can help societies mitigate environmental impacts associated with COVID-19 medical waste while preparing for upcoming health crises[59].

Legal and Policy Framework on COVID-19 Medical Equipment Waste Disposal

It is no doubt that the COVID-19 pandemic has caused severe health havoc to the global health system.[60] However, as a result of treatment of COVID-19 patients through the use of medical equipment has increased medical waste. This is concerning the fact that most nations of the global environment, especially developing nations lack the necessary technology to address or recycle and properly manage and dispose of this hazardous waste. However, before the advent of the COVID-19 pandemic, there have been several international environmental laws tend to curtail the incidence of hazardous waste. In this regard, it will be relevant to consider and examine some of these laws as they concern the management, disposal, and recycling of hazardous waste.

One of the earliest laws concerning waste control and management is the Basel Convention adopted in 1989. This treaty is a global law that through its introductory part requires member states and the global environment to ensure they minimize the level of waste generation and effectively manage and dispose of waste. This is concerning because the global community considers waste to be harmful to the health of man and the global environment. Hence, article 1 of the Basel Convention in the classification of hazardous identifies infectious medical waste as harmful and hazardous. Hence, by article 4 of the Basel Convention requires states within the global environment to adopt sustainable practice that offer a sound environmental disposal of such hazardous waste.[61] However, the global community is aware that in the case of import and export, it could result in the transboundary movement of waste. In this regard, article 6 of the Basel Convention, requires member states to ensure prior consent is obtained before exporting any product that could result in an illegal transboundary movement and dumping of waste within countries[62]. Hence, this provision is geared towards curtailing the incidence of illegal movement of waste. However, one major weakness of the Basel Convention is the weakness and the inability to introduce necessary and adequate sanctions against

[56]Saifur Rahman Tushar, Md Fahim Bin Alam, ABM Mainul Bari, and Chitra Lekha Karmaker. "Assessing the Challenges to Medical Waste Management During the COVID-19 Pandemic: Implications for the Environmental Sustainability in the Emerging Economies." Socio-Economic Planning Sciences 87 (2023): 101513.

[57]Saifur Rahman Tushar et al.

[58]Saifur Rahman Tushar et al.

[59]Saifur Rahman Tushar et al.

[60] Bayu Dwi Anggono, Fahmi Ramadhan Firdaus, "Handling of The Covid-19 Pandemic by The Government in View From The Legal Products Formed", Trunojoyo Law Review, 5(1), https://doi.org/10.21107/tlr.v5i1.19410

[61] Paul Atagamen Aidonojie, Nosakhare Okuonghae, Aisha Najjuma, Omobolanle Omolola Ikpotokin, Eregbuonye Obieshi, "Legal and Socio-Economic Challenges of E-Commerce in Uganda: Balancing Growth and Regulation", *Trunojoyo Law Review*, 7(1), 1-32. https://doi.org/10.21107/tlr.v7i1.27704

[62]Jinquan Ye, Yifan Song, Yurong Liu, and Yun Zhong. "Assessment of Medical Waste Generation, Associated Environmental Impact, and Management Issues After the Outbreak of COVID-19: A Case Study of the Hubei Province in China." PloS One 17, no. 1 (2022): e0259207.

erring nations. Hence, the Bamako Convention a regional African treaty was meant to cure this defect inherent in the Bamako Convention. In this regard, it suffices to state that personal protective medical equipment and other medical equipment used in the treatment of COVID-19 patients can be classified as hazardous waste that is identified by the Basel and Bamako convention that should be adequately managed and disposed of to avert possible environmental consequences and pollution. However, safer treatment of waste facilities is lacking in many developing countries, particularly in Africa and Asia. Consequently, these countries often depend on international support or deprive themselves of a proper solution by resorting to informal practices such as open burning and landfill burying, further endangering both the environment and public health.

Also, another notable international law that concerns the regulation of waste, including medical waste is the Stockholm Convention on Persistent Organic Pollutants known by the acronym POPs[63]. This convention was adopted in 2001 and was considered a major international environmental law to address harmful chemicals emanating from human and industrial activities. In this regard, article 5 of the POPs Convention requires member states to curtail the incidence of organic pollutants by reducing the level of waste burning that could result in the emission of persistent organic pollutants. Also, article 3 of the POPs Convention stipulates that parties to the convention must endeavor to take administrative and legal measures to eliminate and eradicate any intentional emission or production of organic pollutants. Article 6 was more explicit in the adoption of the best method and strategies for curtailing the incidence of waste by adopting a sound and friendly environmental method of disposing of products, substances, and items containing or likely to produce organic pollutants. Concerning this article 6 further stipulates the following best method for a proper and effective waste disposal which includes reclamation, direct reuse where the product is not infectious, and recycling. Furthermore, article 10 of the POPs convention requires member states to embark on education and sensitization on the dangers and effects of organic pollutants that are persistent. In essence, the provision of the POPs convention seems to strictly apply to medical waste. In this regard, member states affected by the COVID-19 disease are bound by the POPs convention and by implication must ensure that all waste emanating from the medical equipment in the treatment of COVID-19 diseases should be adequately disposed of in a sound environmental manner. However, during the COVID-19 pandemic, burning medical waste was preferable given the infectious level of the medical equipment and the poor level of technology in the proper disposal and recycling of waste. As a result of this, there has been an increase in the emissions of dioxins and furans, both very toxic pollutants that are a health and environmental concern.

It must be noted that there are several international environmental policies concerning the safety and protection of the global environment. However, the outbreak of the COVID-19 pandemic resulted in an increase of medical waste as a result of the heavy use of medical equipment in the treatment of COVID-19 patients. This waste was considered very hazardous and harmful given the high rate of infectious nature of the COVID-19 diseases. In this regard, an interim guideline was issued by the World Health Organisation (WHO) in the year 2020 to curtail the increase of medical waste during the pandemic, thereby restating and stressing the importance and the need of proper

[63]Hai-Long Zhao, Lei Wang, Fang Liu, Han-Qiao Liu, Ning Zhang, and Yu-Wen Zhu. "Energy, Environment and Economy Assessment of Medical Waste Disposal Technologies in China." Science of the Total Environment 796 (2021): 148964.

isolation, effective and safe disposal of personal protective equipment (PPE) use in the treatment of COVID-19 patient, and the use of non-incineration technologies.

These guidelines present best practices of waste treatment and disposal which include microwaving, autoclaving, and chemical disinfection from an extensive range within the range or place of treatment or where people are residence. WHO also emphasizes the importance and relevance of adequate health training for health workers and other stakeholders also involved in waste management, to adhere strictly to safe disposal methods. However, many developing nations especially in Africa and Asia were severely vulnerable in their attempts to implement WHO waste management guidelines because of poor, inadequate and ineffective infrastructure, technology and limited funding. This led to improper disposal practices, including open burning illegal landfilling, and uncontrolled incineration, furthering the already dangerously polluted environment and public health. Such limited access to waste treatment facilities has also been a source of non-compliance compounded in rural areas by already overburdened health systems.

Challenges Concerning Legal Framework on COVID-19 Medical Equipment Waste Disposal

The liability cast by the COVID-19 pandemic increases inapprehensible magnitude regarding waste management. It is mostly attributable to enormous usage of personal protective equipment, testing kits, and other single-use medical items, which results in increased medical waste. Several international laws and policies govern hazardous waste management; however, the pandemic unveiled some loopholes in the existing legal frameworks concerning medical waste disposal. Most developing countries lack infrastructure, technology, and enforcement mechanisms to manage and dispose of COVID-19-related medical waste. Improper disposal practices such as open burning, illegal dumping, and landfill burying aggravate public health risk with environmental degradation. The non-existence of a clear enforceable global policy regarding pandemic-related medical waste management has worsened these situations, which have called for stronger regulations and better compliance mechanisms.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989) is an international law governing hazardous waste disposal. It classifies infectious medical wastes as wastes in its definition and details the obligations of states to sustainable waste management practices. Article 4 of the Convention obliges countries to ensure sound disposal of this waste, while Article 6 requires the regulation of the transboundary movements of hazardous waste to avoid illegal dumping. The fact remains that the Convention does not provide for stringent enforcement mechanisms on the non-compliance states, which means that they go scot-free. The Bamako Convention (1991), a regional treaty adopted by African nations, was incorporated to remedy the above defects of the Basel Convention through tougher regulations and penalties.

Most of the developing countries are devoid of requisite waste treatment facilities, which forces them to use unsafe disposal methods and thus pollute and create health hazards in times of the COVID-19 pandemic. The Stockholm Convention on Persistent Organic Pollutants (POPs) (2001) goes further, highlighting the importance of ensuring the control of hazardous waste emissions mainly from the incineration of medical wastes. By Article 5 of the Convention, member states are required to reduce, if not eliminate, unintentional POP emissions, including dioxins and furans produced when burning

COVID-19 medical waste. Member states shall adopt BAT and BEP for waste disposal to prevent this under Article 6 of the Convention, which promotes recycling and direct reuse, as well as chemical treatment, as alternatives. However, because the waste needs to be handled urgently as an infectious waste during the periods of a pandemic, incineration often becomes a preferred method for dealing with waste, increasing the number of toxic emissions. The lack of infrastructure for non-burn technologies, especially in poorer countries, complicates things further in terms of compliance with the Stockholm Convention.

The World Health Organization (WHO) Interim Guidance on COVID-19 Waste Management called out to immediate management with medical waste increases that came with COVID-19. It is mostly laid down and followed by the right procedure that should be followed for segregating, collecting, and disposing of waste attached to COVID-19. Where waste is treated, alternatives such as autoclaving, microwaving, and chemical disinfection are recommended to overcome environmental and health nuisances. WHO emphasizes the five-day training of health workers and waste-management personnel about safe disposal. Implementation challenges are consistency, particularly in developing countries, which lack finances and logistical developments. With inadequate waste management infrastructure, in addition to poor training and lack of awareness, most populations do not comply with WHO guidelines, hence polluting their environments, which translate into health hazards.

Meanwhile, many international laws, including the Basel, Bamako, and Stockholm Conventions along with WHO guidelines, do create a base for COVID-19 medical waste management and disposal. Yet, there are many challenges related to these frameworks: weak enforcement mechanisms as well as poor infrastructure and financial constraints have hampered effective waste management by many developing countries. With the backdrop of a pandemic, countries have to find urgency to act with matured regulatory frameworks among members, heightening international cooperation, and mobilizing investments for waste management technologies that are sustainable. As a continuation, strengthening law enforcement mechanisms, coupled with the provision of financial and technical support to low-income nations, will be very important as well as promoting environmentally friendly disposal methods to reduce the long-standing implications of medical waste on public health and the environment due to the COVID-19 pandemic.

Conclusion

The COVID-19 pandemic has shown how inadequate the international legal regime on hazardous medical waste disposal is. Existing treaties on hazardous waste, including the Basel, Bamako, and Stockholm Conventions, have failed in the context of rising medical wastes brought about by the pandemic, especially in low- and middle-income countries. Outdated enforcement mechanisms have failed within these countries, along with insufficient waste management infrastructure, and thereby worsen the environmental and health hazards from COVID-19 medical waste. Further exacerbating the burden on developing countries is the transboundary movement of medical waste, exposing the weaknesses of the existing global legal frameworks in forbidding the controlled dumping of waste.

There is an immediate need to develop both the national and international legal frameworks with respect to the regulation of hazardous medical waste. Countries must adopt domestic laws for waste management with appropriate enforcement mechanisms, ensuring the conformity of these laws with those of international treaties. National

governments must provide funding for developing environmentally-friendly non-incineration disposal options for medical waste, such as autoclaving, microwaving, or chemical disinfection. Strong tracking and reporting mechanisms must prevent illegal transboundary shipments of hazardous waste and enforce international obligations. The development of sustainable waste management practices through international cooperation and knowledge-sharing must be supported by financial and technical assistance from high-income countries to developing countries that need better waste management infrastructure for advanced recycling technologies. The WHO and UNEP should coordinate standards, policies, and capacity-building programs to address this issue effectively. This concerted effort to strengthen the legal framework, invest in appropriate waste management technologies, and promote international collaboration will significantly mitigate the health and environmental hazards posed by hazardous medical waste, thus ensuring a safer and healthier post-pandemic world.

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References

Abl-Omran, Khadija, Ezzat Khan, Nisar Ali, and Muhammad Bilal. "Estimation of COVID-19 Generated Medical Waste in the Kingdom of Bahrain." Science of the Total Environment 801 (2021): 149642.

Abwad, Adiue, and Firas Al Bajari. "Environmental Impacts of Medical Waste Treatment and Management by Burning Inside Health Facilities." International Journal of Civil Engineering and Technology 9, no. 5 (2018): 41–53.

Adikkajit, Pensiri, Husna Romin, and Mongkolchai Assawadithalerd. "Assessment of Knowledge, Attitude, and Practice in Respect of Medical Waste Management among Healthcare Workers in Clinics." Journal of Environmental and Public Health 2020, no. 1 (2020): 8745472.

Adindeobu, Lynda, Santoso Wibowo, and Srimannarayana Grandhi. "Medical Waste from COVID-19 Pandemic—A Systematic Review of Management and Environmental Impacts in Australia." International Journal of Environmental Research and Public Health 19, no. 3 (2022): 1381.

Adwodele, Olufunsho, Aishat Abiodun Adewoye, and Azuka Cyril Oparah. "Assessment of Medical Waste Management in Seven Hospitals in Lagos, Nigeria." BMC Public Health 16 (2016): 1–11.

Aidonojie, Paul Atagamen, Anani O. Anthony, Agbale O. Patient, Olomukoro O. John, and Adetunji O. Charles. "Environmental Law in Nigeria: A Review on Its Antecedence, Application, Judicial Unfairness, and Prospects." Archive of Science & Technology 1, no. 2 (2020): 211–21.

Aidonojie, Paul Atagamen, Idahosa M. Ekata, Agbale O. Patient, and Oyedeji A. Ifeoluwa. "The Environmental Conservation and Ethical Issues Concerning Herbal Products in Nigeria." Journal of Environmental Science and Economics 1, no. 3 (2022): 26–32. https://doi.org/10.56556/jescae.v1i3.124.

Aidonojie, Paul Atagamen, Ikubanni O. Oluwaseye, Oyedeji A. Ifeoluwa, and Oyebade A. Akinsola. "The Legal Challenges and Effect Concerning Environmental Security in Nigeria: A Lesson from an International Perspective." Journal of Commercial and

Property Law 9, no. 1 (2022): 110–20.

Aidonojie, Paul Atagamen, K. Adebayo, Eregbuonye Obishie, and Wakili S. Abacha. “Breaking Legal and Socio-Economic Challenges to Plastic Waste Regulation in Nigeria: Lessons Learned from Singapore.” Yustisia 13, no. 1 (2024): 64–88.

Aidonojie, Paul Atagamen, Majekodunmi T. Akintola, Eregbuonye Obishie, and Adeyemi-Balogun O. Janet. “Potential and Legal Challenges of Metaverse for Environmental Awareness and Sustainable Practice in Nigeria: A Comparative Study with Singapore.” Administrative and Environmental Law Review 5, no. 1 (2024): 37–64. https://doi.org/10.25041/aelr.v5i1.3230.

Aidonojie, Paul Atagamen, Okuonghae Nosa, Moses-Oke O. Rose, and Majekodunmi T. Akintola. “A Facile Review on the Legal Issues and Challenges Concerning the Conservation and Preservation of Biodiversity.” Global Sustainability Research 2, no. 2 (2023): 34–46.

Aidonojie, Paul Atagamen, Ukhurebor E. Kingsley, Masajuwa Florence, Imoisi E. Simon, Edetalehn O. Idemudia, and Nwazi Joseph. “Legal Implications of Nanobiosensors Concerning Environmental Monitoring.” In Nanobiosensors for Environmental Monitoring, edited by R. P. Singh, E. Kingsley Ukhurebor, J. Singh, O. Charles Adetunji, and K. R. Singh. Cham: Springer, 2022. https://doi.org/10.1007/978-3-031-16106-3_21.

Aidonojie, Paul Atagamen, Ukhurebor E. Kingsley, Oaihimire E. Idemudia, Ngonso F. Blessed, Egielewa Peter, and Darmokoesoemo Hussein. “Bioenergy Revamping and Complimenting the Global Environmental Legal Framework on the Reduction of Waste Materials: A Facile Review.” Heliyon 9, no. 1 (2023). https://doi.org/10.1016/j.heliyon.2023.e12860.

Aidonojie, Paul Atagamen. “Environmental Hazard: The Legal Issues Concerning Environmental Justice in Nigeria.” Journal of Human Rights, Culture and Legal System 3, no. 1 (2023): 17–32. https://doi.org/10.53955/jhcls.v3i1.60.

Aidonojie, Paul Atagamen, Nosakhare Okuonghae, Aisha Najjuma, Omobolanle Omolola Ikpotokin, Eregbuonye Obieshi, “Legal and Socio-Economic Challenges of E-Commerce in Uganda: Balancing Growth and Regulation”, *Trunojoyo Law Review*, 7(1), 1-32. https://doi.org/10.21107/tlr.v7i1.27704

Al Hosari, Taha, Abdulla Al Mandous, Youssef Wehbe, Abdeltawab Shalaby, Noor Al Shamsi, Hajer Al Naqbi, Omar Al Yazeedi, Alya Al Mazroui, and Sufian Farrah. "The UAE Cloud Seeding Program: A Statistical and Physical Evaluation." Atmosphere 12, no. 8 (2021): 1013. https://doi.org/10.3390/atmos12081013.

Al-Omran, Khadija, Asma Abahussain, and Ezzat Khan. “Integrated Environmental Assessment of Medical Waste Management in the Kingdom of Bahrain.” Sustainability 15, no. 3 (2023): 2397.

Anani, Osikemekha A., Abel Inobeme, Osayomwanbo Osarenotor, Frances Ngozi Olisaka, Paul Atagamen Aidonojie, Emmanuel Olusegun Olatunji, and Aishatu Idris Habib. “Application of Microorganisms as Biofactories to Produce Biogenic Nanoparticles for Environmental Cleanup: Current Advances and Challenges.” Current Nanoscience 19, no. 6 (2023): 770–82.

Anani, Osikemekha Anthony, Maulin P. Shah, Paul Atagamen Aidonojie, and Alex Ajeh Enuneku. “Bio-Nano Filtration as an Abatement Technique Used in the Management

and Treatment of Impurities in Industrial Wastewater." In Bio-Nano Filtration in Industrial Effluent Treatment, 171–82, 2023.

Anthony, Anani O., Paul Atagamen Aidonojie, and Olomukoro O. John. "Environmental Principles and Ethics: Current Challenges in the Field of Bioscience and Law." In Ethics, Media, Theology, and Development in Africa: A Festschrift in Honour of Msgr. Prof. Dr. Obiora Francis Ike, 142–58. Geneva, Switzerland: Global.net Co-Publication & Others, 2022.

Anggono,, Bayu Dwi and Fahmi Ramadhan Firdaus, "Handling of The Covid-19 Pandemic by The Government in View From The Legal Products Formed", Trunojoyo Law Review, 5(1), https://doi.org/10.21107/tlr.v5i1.19410

Astuti, Frei Fitri and Laila Nur Jannah, Flexibility in Accessing Legal Information Through Social Media and its Implications for Law Enforcement. (2025). *Journal of Indonesian Constitutional Law*, *2*(1), 23-36. https://doi.org/10.71239/jicl.v2i1.37

Bai, Zhipeng, Xi Liu, and Wenbao Ma. "Public Attitudes toward Medical Waste: Experiences from 141 Countries." PLoS One 19, no. 5 (2024): e0302498.

Bakiu, R., and S. Durmishaj. "Medical Waste Effects and Management: Overview and Future Directions." SF Journal of Environmental Earth Science 1, no. 2 (2018): 1019.

Barua, Uttama, and Dipita Hossain. "A Review of the Medical Waste Management System at COVID-19 Situation in Bangladesh." Journal of Material Cycles and Waste Management 23, no. 6 (2021): 2087–2100.

Borowy, Iris. "Medical Waste: The Dark Side of Healthcare." História, Ciências, Saúde-Manguinhos 27, suppl. 1 (2020): 231–51.

Chew, XinYing, Khai Wah Khaw, Alhamzah Alnoor, Marcos Ferasso, Hussam Al Halbusi, and Yousif Raad Muhsen. "Circular Economy of Medical Waste: Novel Intelligent Medical Waste Management Framework Based on Extension Linear Diophantine Fuzzy FDOSM and Neural Network Approach." Environmental Science and Pollution Research 30, no. 21 (2023): 60473–99.

Chisholm, Jade Megan, Reza Zamani, Abdelazim M. Negm, Noha Said, Mahmoud M. Abdel Daiem, Mahdieh Dibaj, and Mohammad Akrami. "Sustainable Waste Management of Medical Waste in African Developing Countries: A Narrative Review." Waste Management & Research 39, no. 9 (2021): 1149–63.

Ghali, Hela, Asma Ben Cheikh, Sana Bhiri, Lamia Bouzgarrou, Mohamed Ben Rejeb, Imed Gargouri, and Houyem Said Latiri. "Health and Environmental Impact of Hospital Wastes: Systematic Review." Dubai Medical Journal 6, no. 2 (2023): 67–80.

Gunawardana, Kennedy Degaulle. "An Analysis of Medical Waste Management Practices in the Health Care Sector in Colombo." Management of Environmental Quality: An International Journal 29, no. 5 (2018): 813–25.

Ha, Jae-Hyun, and Hyun Ju Lee. "Nursing Students' Environmental Consciousness and Medical Waste Related Knowledge and Attitudes." Journal of Korean Academy of Community Health Nursing 30, no. 2 (2019): 174–82.

Ilyas, Sadia, Rajiv Ranjan Srivastava, and Hyunjung Kim. "Disinfection Technology and Strategies for COVID-19 Hospital and Bio-Medical Waste Management." Science of the Total Environment 749 (2020): 141652.

Imoisi, E. Simon, and Paul Atagamen Aidonojie. “Legal and Socio-Economic Issues Concerning Black Marketer's Activities of Petroleum Products in Nigeria.” Yuridika 38, no. 2 (2023): 61–84. https://doi.org/10.20473/ydk.v38i2.44999.

Imoisi, E. Simon, Paul Atagamen Aidonojie, and Edetalehn O. Idemudia. “Legal Issues and Innovations Introduced by the Petroleum Industry Act 2021 in the Nigerian Oil Industry.” Journal of Commercial and Property Law 10, no. 2 (2023): 229–43.

Kumar, A. Suresh, M. Muthukannan, R. Kanniga Devi, K. Arunkumar, and A. Chithambar Ganesh. “Reduction of Hazardous Incinerated Bio-Medical Waste Ash and Its Environmental Strain by Utilizing in Green Concrete.” Water Science and Technology 84, nos. 10–11 (2021): 2780–92.

Lee, Sang M., and DonHee Lee. “Effective Medical Waste Management for Sustainable Green Healthcare.” International Journal of Environmental Research and Public Health 19, no. 22 (2022): 14820.

Mendy, Ousu, and Ebrima Sarr. “The Judiciary in Governance: Understanding the Juridical Nature and Function of the Constitutional Court of Indonesia.” *Journal of Indonesian Constitutional Law* 2, no. 1 (March 2, 2025): 23. https://doi.org/10.71239/jicl.v2i1.45.

Mihai, Florin-Constantin. “Assessment of COVID-19 Waste Flows during the Emergency State in Romania and Related Public Health and Environmental Concerns.” International Journal of Environmental Research and Public Health 17, no. 15 (2020): 5439.

Mohiuddin, Adan. “Medical Waste: A Nobody’s Responsibility After Disposal.” International Journal of Environmental Science & Natural Resources 15, no. 2 (2018): 555908.

Mukhtar, Shakira, Hamna Khan, Zainab Kiani, Saba Nawaz, Sana Zulfiqar, and Noshabah Tabassum. “Hospital Waste Management: Execution in Pakistan and Environmental Concerns—A Review.” Environmental Contamination Review 1, no. 1 (2018): 18–23.

Narayanamoorthy, Sanda, Vilk Annapoorani, Daekook Kang, Dumitru Baleanu, Jeonghwan Jeon, Joseph Varghese Kureethara, and L. Ramya. “A Novel Assessment of Bio-Medical Waste Disposal Methods Using Integrating Weighting Approach and Hesitant Fuzzy MOOSRA.” Journal of Cleaner Production 275 (2020): 122587.

Oweis, Rami, Mohamad Al-Widyan, and Ohood Al-Limoon. “Medical Waste Management in Jordan: A Study at the King Hussein Medical Center.” Waste Management 25, no. 6 (2005): 622–25.

Padmanabhan, Klepan, and Debabrata Barik. “Health Hazards of Medical Waste and Its Disposal.” In Energy from Toxic Organic Waste for Heat and Power Generation, 99–118. 2019.

Sangkham, Sarawut. “Face Mask and Medical Waste Disposal during the Novel COVID-19 Pandemic in Asia.” Case Studies in Chemical and Environmental Engineering 2 (2020): 100052.

Singh, Narendra, Oladele A. Ogunseitan, and Yuanyuan Tang. “Medical Waste: Current Challenges and Future Opportunities for Sustainable Management.” Critical Reviews in Environmental Science and Technology 52, no. 11 (2022): 2000–22.

Su, Emily Chia-Yu, and Yi-Tui Chen. “Policy or Income to Affect the Generation of Medical

Wastes: An Application of Environmental Kuznets Curve by Using Taiwan as an Example." Journal of Cleaner Production 188 (2018): 489–96.

Sürme, Yeliz, Gülseren Maraş, and Gökçen Aydin Akbuğa. "Environmental Sustainability, Medical Waste Management, Energy and Medicine Consumption of the Surgical Intensive Care Nurses: A Qualitative Study." Nursing in Critical Care, 2025.

Thiel, Cassandra, Paula Duncan, and Noe Woods. "Attitude of US Obstetricians and Gynaecologists to Global Warming and Medical Waste." Journal of Health Services Research & Policy 22, no. 3 (2017): 162–67.

Tirkolaee, Erfan Babaee, and Nadi Serhan Aydın. "A Sustainable Medical Waste Collection and Transportation Model for Pandemics." Waste Management & Research 39, no. 1_suppl (2021): 34–44.

Tushar, Saifur Rahman, Md Fahim Bin Alam, ABM Mainul Bari, and Chitra Lekha Karmaker. "Assessing the Challenges to Medical Waste Management During the COVID-19 Pandemic: Implications for the Environmental Sustainability in the Emerging Economies." Socio-Economic Planning Sciences 87 (2023): 101513.

Ukhurebor, E. Kingsley, and Paul Atagamen Aidonojie. "The Influence of Climate Change on Food Innovation Technology: Review on Topical Developments and Legal Framework." Agric & Food Security 10 (2021): 50.

Ukhurebor, Kingsley Eghonghon, Uyiosa Osagie Aigbe, Robert Birundu Onyancha, Hussain Athar, Benedict Okundaye, Paul Atagamen Aidonojie, Benita Ebindu Siloko, Ismail Hossain, Heri Septya Kusuma, and Handoko Darmokoesoemo. "Environmental Influence of Gas Flaring: Perspective from the Niger Delta Region of Nigeria." Geofluids 2024 (2024): 17 pages. https://doi.org/10.1155/2024/1321022.

Woolridge, Anne, and Selin Hoboy. "Medical Waste." In Waste, 517–30. 2019.

Ye, Jinquan, Yifan Song, Yurong Liu, and Yun Zhong. "Assessment of Medical Waste Generation, Associated Environmental Impact, and Management Issues After the Outbreak of COVID-19: A Case Study of the Hubei Province in China." PloS One 17, no. 1 (2022): e0259207.

Zhao, Hai-Long, Lei Wang, Fang Liu, Han-Qiao Liu, Ning Zhang, and Yu-Wen Zhu. "Energy, Environment and Economy Assessment of Medical Waste Disposal Technologies in China." Science of the Total Environment 796 (2021): 148964.

Zhou, Haiying, Xiangyu Yu, Ahmad Alhaskawi, Yanzhao Dong, Zewei Wang, Qianjun Jin, Xianliang Hu, Zongyu Liu, Vishnu Goutham Kota, Mohamed Hasan Abdulla Hasan Abdulla, Sohaib Hasan Abdullah Ezzi, Binjie Qi, Juan Li, Bixian Wang, Jianyong Fang, and Hui Lu. "A Deep Learning Approach for Medical Waste Classification." Scientific Reports 12, no. 1 (2022): 2159.