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Environmental impact of COVID-19 Vaccine waste: A perspective on potential role of natural and biodegradable materials

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1. Introduction

The humankind is drenched into devastating health implications due to the outbreak of COVID-19 viral disease caused by a novel virus named ‘Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV-2)’ [1]. In post-pandemic era, scientific community have successfully promoted the counter measures to the contagion COVID-19 through repurposed antiviral drugs for treatment of the infected patients and prevention via attenuated vaccine administration [2]. After uplifting the lockdowns, the major focus was on production, deployment, and injection of COVID-19 vaccines. The WHO in collaboration with medical personnel is currently orchestrating equitable global vaccination campaigns for mass immunization against COVID-19 [3]. As per the ‘Our World in Data’ statistics on May, 1st 2022, 11.59 billion vaccination doses has been globally administered which means 65.4% of the world population has been vaccinated with at least one dose. Also, 10.09 million people are getting vaccinated each day globally and only 15.7% of population in low-income countries have administered single dose of vaccine [4].

The inevitable bulk manufacture of vaccines and massive vaccination programs are tempered with the challenge of biohazardous vaccine waste generation. Due to the poor and unready management systems, biohazardous vaccine waste may end up the environment, disrupting the ecosystem at an escalating pace. Since, the key components of vaccination programs are reliant on plastic-based equipment including syringes, needles, and empty vials, and dry ice are the major polluter generated via mass vaccination camps [5, 6].

The mass immunization is the prioritised post-pandemic phase offering preventive countermeasure for COVID-19 pandemic. However, it is crucial to tackle the environmental impact of COVID-19 vaccine waste for sustainable vaccination management because a prolonged immunisation campaign is expected. As the pace of vaccine production, distribution and mass vaccination has been expedited, there is a simultaneous rise in plastic derived vaccine waste including syringes, needles, used/unused vaccine vials, vaccine packaging, and protective gear (surgical facemasks, gloves, face shields, etc). Henceforth, in view of the repercussions of heaping plastic waste in the environment, this article provides a perspective on the usage of synthetic and natural materials as potential substituents for vaccination tools. The biodegradable polymeric gums such as cellulose, gellan, pectin, etc. have been successfully applied for the fabrication of surgical facemasks. The highly suggestive practice is replacement of conventional polypropylene based plastics with bioplastics or paper for vaccine packaging. The usage of biodegradable bio-plastics as packaging material along with environmentally friendly face masks can help to achieve the zero waste approach. The discussion in the article significantly highlights the necessity of opting sustainable solutions of disinfecting and substituting vaccination tools for an environment friendly ongoing vaccination campaign.

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and biodegradable materials as an immediate societal need. Sustainable vaccination equipment substitutes with recyclable, natural vaccine waste, we herein provide a perspective for the development of sustainable vaccination equipment substitutes with recyclable, natural biodegradable materials as an immediate societal need.

2. Current investigation on coronavirus vaccine waste

It is unknown the level in which vaccination consequences are impacting the environment due to the subsequent waste generation. The countries offering mass immunization campaigns are littered with hazardous biomedical waste [Fig. 1] including syringes, needles, and waste glass vial, as a threat to increase the rate of SARS-CoV-2 transmission [9, 10]. The consumption of preventive tools i.e. PPE kits and surgical face masks during the vaccination drive have added to the microplastics fibre accumulation in the aqueous and terrestrial environment [11,12]. In addition, the usage of safety gears is still necessary for healthcare workers in order to prevent the transmission of COVID-19 which is responsible for generating additional waste other than vaccination camps. To provide context, Omran et al., reviewed the amount of solid waste generated from the various COVID-19 related activities in the Kingdom of Bahrain, wherein the calculated amount of vaccine waste generated during the 1st dose of vaccine was 6 million g and above 9 million g after the 2nd vaccine dose against 813,728 and 602,390 vaccinated individuals, respectively until May 11, 2021 [13].

A plastic pollution survey in Bangladesh aquaculture systems have analysed 11 million metric tonnes of microplastics including, surgical gloves, face masks, polyethylene gloves, hand sanitizer bottles [14]. A life cycle assessment analysis was carried out to estimate the effects of face mask in UK, wherein if each individual used one disposable surgical mask every day for a year, it would cause 66,000 tons of contaminated waste [15]. In addition to the environment challenges induced by extensive use of protective face masks, the discarded vials (fully or partially used) containing thimerosal-mercury based preservative is much higher than production. Henceforth, recyclability is not economically and only a few companies have taken the initiative to recycle needles. In response to the relieving bottlenecks of non-biodegradable needles and syringes, it is suggestive to replace the recyclable needles. In response to the relieving bottlenecks of non-biodegradable needles and syringes, it is suggestive to replace the recyclable needles.

3. Potential substitutes: natural and biodegradable materials

The unprecedented surge in hazardous biomedical waste and SUPs has fostered the requirement to develop natural and biodegradable substitutes of vaccine tools. The reuse of bio-hazardous syringes and needles is not advisable undoubtedly because it could put patients in danger of getting infected with Hepatitis B, Hepatitis C, and possibly HIV and SARS-CoV-2, however the regulation of recyclability and biodegradability should be implemented [24]. Also, the syringes are composed of polypropylene and polyethylene plastics which if not recycled, their disposal may contribute substantially to the hazardous release of dioxins, vinyl chloride and toxic lead and cadmium metals into the soil that stunts the plant growth [25]. From the perception of investment and operation cost, the recyclability of needles and syringes is much higher than production. Henceforth, recyclability is not economical and only a few companies have taken the initiative to recycle needles. In response to the relieving bottlenecks of non-biodegradable needles and syringes, it is suggestive to replace the non-biodegradable needles and syringes with recycling natural and biodegradable alternatives such as that of bio-plastics.

The bio-plastics partly or wholly composed of oil-based equivalents,
sugar cane, pines, and other biological materials are future green innovative approaches to mitigate effects of conventional plastics [26]. With the current success on 3D printing technology the development of ultra-thin polylactic acid needles is fast-evolving and can be an encouraging resort for renewable, biodegradable thermoplastic-based needles. Also, the natural polymers including sodium alginate, cellulose, chitosan, gellan, pectin are potential substituents with high biodegradability for designing of face masks, anti-viral coatings, protective kits, etc [27]. Meneguzzo et al., extracted the flavonoids of citrus and lemon peels which exhibited high binding affinity to SARS-CoV-2 receptors for disinfection [28]. The next step towards redefining the vaccination programs towards sustainability is to redefine the vaccine packaging process. The repurposing of discarded surgical face masks by thermal blending it with concrete aggregate for pavement base application resulted in co-benefits of waste management and high tensile strength of concrete due to polypropylene [29]. A zero waste approach as the co-benefit of waste management, that promotes the minimising, recovering, and treatment of waste, rather than directly disposing it in landfill or incinerators can also be opted to get rid of burgeoning plastic waste globally. Thus, it is inevitable that the manufacturing industries should emphasis more on the usage of biodegradable or compostable materials (bags etc.) like bio-plastics with considerable degradability and recycling efficiency [30,31]. Nevertheless, the efforts of short time window availability of multiple anti COVID-19 vaccines are undeniable yet, the use of eco-friendly sustainable substituents for vaccine tools as detailed in [Fig. 2] should be the imminent subject of research.  

4. Conclusions

The advent of COVID-19 mass vaccination programmes has stretched the already existing waste management system beyond capacity. It is imperative to address the issue of massive COVID-19 vaccine waste generation including needles, syringes, vaccine vials, vaccine packaging, single-use-plastic personal (surgical facemasks, gloves, etc.) and protective equipment. Plastic waste pollution was already an enormous challenge, however pandemic and post-pandemic era has alleviated this issue. To nullify the backfiring effects on the environment, the waste management system is practicing disinfection and disposal strategies for instance, incineration, pyrolysis, gasification, dumping in landfills, etc. However, currently there are no 100% effective waste-management technologies for tackling the burgeoning COVID-19 vaccine waste. Consequently, the present research seeks for substitution of the plastic derived surgical face masks, personal protective equipment, and vaccine tools to avoid the further transmission of COVID-19 through vaccine waste. Also, the existing waste management plants and infrastructures must be equipped with artificial intelligence, machine learning, and internet of things in order to improve the segregation and recycling of plastic waste. The recycling of waste via mechanical methods followed by sterilization should be encouraged with appropriate policy design for better circular economy. Moreover, chemical conversion of mixed plastic waste into value-added fuels and chemical products is another potential alternative for circularity. Additionally, considerable focus on natural and synthetic polymers such as gums, cellulose, chitosan and bioplastics which are biodegradable and environmental friendly are important substitute to replace the conventional plastic-based products. The discussion delves into the current practices and future possible sustainable solutions for ongoing COVID-19 vaccination programmes with minimal environment impact.

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.

References

[1] I. Woldometer, Covid-19 Coronavirus Pandemic, (Accessed 24 August 2021) (2021).
[2] J.J. Kleme

[3] K. Al-Omran, E. Khan, N. Ali, M. Bilal, Estimation of COVID-19 generated medical waste in the Kingdom of Bahrain, Sci. Total Environ. 801 (2021), 149642.
[4] A. Sarker, D.M. Deepo, R. Nandi, J. Rana, S. Islam, S. Rahman, M.N. Hossain, M. S. Islam, A. Baroi, J.-E. Kim, A review of microplastics pollution in the soil and...
terrestrial ecosystems: a global and Bangladesh perspective, Sci. Total Environ. 733 (2020), 139296.

[15] A.W.L. Lee, E.R.K. Neo, Z.-Y. Khoo, Z. Yeo, Y.S. Tan, S. Chng, W. Yan, B.K. Lok, J.S. C. Low, Life cycle assessment of single-use surgical and embedded filtration layer (EFL) reusable face mask, Resour. Conserv. Recycl. 170 (2021), 105580.

[16] O.O. Fadare, E.D. Okofio, Covid-19 face masks: a potential source of microplastic fibers in the environment, Sci. Total Environ. 737 (2020), 140279.

[17] P. Kurzweil, A. Müller, S. Wahler, The ecological footprint of COVID-19 mRNA vaccines: estimating greenhouse gas emissions in Germany, Int. J. Environ. Res. Public Health 18 (14) (2021) 7425.

[18] K.R. Vanapalli, H.B. Sharma, V.P. Ranjan, B. Samal, J. Bhattacharya, B.K. Dubey, S. Goel, Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic, Sci. Total Environ. 750 (2021), 141514.

[19] A.D. Zand, A.V. Heir, Emerging challenges in urban waste management in Tehran, Iran during the COVID-19 pandemic, Resour. Conserv. Recycl. 162 (2020), 105051.

[20] G. Velvizhi, S. Shanbhakumar, B. Das, A. Pugazhendhi, T.S. Priya, B. Ashok, K. Nanthagopal, R. Vignesh, C. Karthick, Biodegradable and non-biodegradable fraction of municipal solid waste for multilayered applications through a closed loop integrated refinery platform: paving a path towards circular economy, Sci. Total Environ. 731 (2020), 138049.

[21] A.M. Zakaria, O.A. Labib, M.G. Mohamed, I. Waflaa, A.H. Hussein, Assessment of combustion products of medical waste incinerators in alexandria, J. Egypt. Public Health Assoc. 80 (3&4) (2005), 259207.

[22] J. Ye, Y. Song, Y. Liu, Y. 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 (1) (2022), 259207.

[23] J. Thornton, M. McCully, P. Orris, J. Weinberg, Dioxin prevention and medical waste incinerators, Occup. Health Ind. Med. 1 (36) (1997) 11.

[24] K. Padminabhan, D. Barik, Health hazards of medical waste and its disposal, energy from toxic organic waste for heat and power generation, Elsevier 99–118 (2019) p.

[25] B. Le Dare, A. Bacle, R. Lhermitte, F. Lesourd, Y. Lurton, Increasing vaccine supply with low dead-volume syringes and needles, Int. J. Pharm. 608 (2021), 121053.

[26] N.J. Rowan, J.G. Laffey, Unlocking the surge in demand for personal and protective equipment (PPE) and improvised face coverings arising from coronavirus disease (COVID-19) pandemic—implications for efficacy, re-use and sustainable waste management, Sci. Total Environ. 752 (2021), 142259.

[27] S. Mallakpour, E. Azadi, C.M. Hussain, Protection, disinfection, and immunization for healthcare during the COVID-19 pandemic: role of natural and synthetic macromolecules, Sci. Total Environ. 776 (2021), 145989.

[28] F. Meneguzzo, R. Ciriminna, F. Zubini, M. Pagliaro, Accelerated production of hesperidin-rich citrus pectin from waste citrus peel for prevention and therapy of COVID-19, (2020).

[29] M. Saberian, J. Li, S. Kilmartin-Lynch, M. Boroujeni, Repurposing of COVID-19 single-use face masks for pavements base/subbase, Sci. Total Environ. 769 (2021), 145527.

[30] N. Parashar, S. Haur, Plastics in the time of COVID-19 pandemic: protector or polluter? Sci. Total Environ. 759 (2021), 144274.

[31] N.J. Rowan, J.G. Laffey, Unlocking the surge in demand for personal and protective equipment (PPE) and improvised face coverings arising from coronavirus disease (COVID-19) pandemic—implications for efficacy, re-use and sustainable waste management, Sci. Total Environ. 752 (2021), 142259.