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# An Assessment of Biomedical Waste (BMW) Production and Management and its Impact on the Environment and Disease Transmission Amidst the COVID-19 Pandemic in the Philippines

**Lian Patrice C. Barayang[1], Ignacius Carell A. Cruz[1], Kimberly Joyce G. de Vera[1], Janel Christine F. Inumerable[1] and Zeba F. Alam[1,2]**

[1]De La Salle University Integrated School Manila
[2]Head, EBRU, CENSER DLSU, Department of Biology.
*Corresponding Author E-mail: Zeba.alam@dlsu.edu.ph

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**The study aimed to analyze the impact of pandemic-related BMW production and management in the Philippines and its potential role in transmitting the COVID-19 virus via a mixed-methods analysis of data from surveys of different sectors (consumers of medical waste, deliverymen, and medical workers) and using secondary sources. The results revealed that the most common types of PPE used in the country are disposable face masks and face shields, wherein all respondents reported an increase in the consumption of medical materials. An improper disposal of an estimated 85 million disposable face masks and 50 million face shields in the Philippines poses a serious threat to the environment and health in the Philippines, a biodiversity hot spot. There was a strong correlation between the increased exposure to BMW and laxer degrees of implementation of proper BMW disposal practices. The paper also established an estimated consumption of ˜ 120.5 million face masks, ˜ 71.4 million face shields, ˜ 38 million disposable gloves, and ˜ 4.1 million full-body suits per day in the Philippines. The actual output of biomedical waste in the country drastically increased in a year, comprising an average daily output of 3,390 tons of BMW (˜ 482 tons for face masks, ˜ 2,544 tons for face shields, ˜ 198 tons for disposable gloves, and ˜ 167 tons for full-body suits which is an important discovery regarding the biomedical waste in the country. These estimates were found to be higher than those reported by the Asian Development Bank in 2020. All sectors reported low awareness levels and confidence in the country's effectiveness in implementing current BMW management practices.**

**Keywords:** Biomedical Waste; BMW management practices; COVID-19 pandemic; Environment; Philippines.

The ongoing coronavirus disease (COVID-19) pandemic has led to an increase in the production of biomedical waste, with states, health institutions, and companies struggling to cope with the management of the huge volumes of biomedical waste. There are about 3.4 billion single-use face masks/face shields discarded daily around the globe because of the COVID-19 pandemic[1]. This massive increase in production, use, and improper disposal of PPEs face masks, and face shields have further contributed to marine plastic pollution[2,3]. Aside from this, the improper or insufficient treatment and disposal of healthcare waste also pose a severe risk of disease transmission to waste pickers, waste

workers, health workers, patients, and the general community through exposure to infectious agents[4]. The city corporations, third-party actors, and non-governmental organizations primarily manage the hospital waste; however, these stakeholders' capacities do not meet the requirements of a proper, environmentally safe medical waste disposal mechanism[5].

Given that the United Nations Sustainable Development Goals (SDGs) place a premium on combatting environmental pollution and its impacts on human health(i.e., SDG 3.9, which seeks to "substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination." [6], sufficient evidence of inadequacy or harmfulness of country's waste management systems in mitigating the health and environmental impacts of the pandemic would warrant a paradigm shift into a strategic, state-of-the-art medical waste management system.

Since the Philippines is a biodiversity hotspot, there is a perceived threat to the ecosystem. Hence, there is a need for safe and effective BMW management practices to ease this concern. The frequent lockdowns and disrupted supply chain during the ongoing SARS covid-19 pandemic have impacted the types, volumes, and management practices in terms of frequency of collection of BMW[7]. Therefore, the first step towards finding solutions is to make an estimate of how much BMW is being generated in the country. Hence, this study focuses on analyzing the implications of BMW management on the environment and health in terms of virus transmission owing to the current BMW production and management practices in the Philippines. In the Philippines, to the best of the researchers' knowledge, this is the first attempt to make an estimate of the BMW generation to find sustainable solutions for the management of BMW.

## METHODOLOGY

### Study Design & Questionnaire

The study used a mixed-methods approach, combining descriptive and analytical quantitative methods using an online Google survey form comprising close-ended survey questionnaires dedicated to the general BMW consumer population (n=116), front liners comprising medical professionals and health workers (n=102), and delivery men (n=52) respectively. The online data collection was done between the period of October 2021- March 2022. with the respondents belonging to all three regions, Luzon, Visayas and Mindanao, though most of the respondents were from Luzon, which is the largest region in the country with a maximum concentration of the population. Following the guidelines of the Data Privacy Act (Republic Act No. 10173) of the Philippines[8], all relevant documents such as the Research Ethics Clearance Form, Research Information Sheet, and Informed Consent Form, were processed prior to data collection. To estimate the BMW generation for the entire population, the population figures were sourced from secondary sources such as the Philippines statistics authority for overall general consumers[9], the business world for a total number of frontline workers[10,] and sources quoted in the Rappler news agency for a total number of delivery men in the country[11]. The relevant questions were added in the google form to assess the awareness level among the respondents about the Health Care Waste Management Manual (HCWMM)[12] from the Department of Health, Govt of Philippines, which explains the policies and guidelines about BMW disposal,

### Statistical analyses

The coded data were cleaned, and the Chi-square test was used to test the correlation between COVID positivity and BMW exposure and implementing proper disposal practices. Means and standard deviations were used to analyze trends in BMW consumption. Based on the results of the survey, the total population of each sector was multiplied by the average (mean) consumption, Meanwhile, frequency distribution was used to show the most common type of PPEs used by respondents, respondents 'increase in BMW consumption, current BMW practices in the country, knowledge of the HCWMM respondents' overall confidence in these practices in terms of their mitigation of potential environmental and transmission risks, and perceived problems regarding BMW in the country.

## RESULTS

### Estimated BMW Production during COVID-19

The disposable face masks (as reported by 100% of front-liners and delivery men, and

92.1% of general consumers) and plastic face shields (as reported by 100% of delivery men, 99% of front-liners, and 62.3% of general consumers) were the most common type of waste in the BMW. Meanwhile, despite discouragement from health experts, cotton face masks are still in use (68.5% of delivery men, 36.52% of general consumers, and 7% of front-liners). Notably, the use of disposable gloves was high among front-liners (95.1%) but significantly less among the other two sectors (6% of delivery men and 0% of general consumers). Other types of PPE prevalent among front-liners include full-body suits (94.1%), disposable shoes (85.3%), goggles (48.1%), and respirators (20.6%). Data collected from all three sectors shows that 100% of respondents reported an increase in their consumption of either some (94% of general consumers, 68% of delivery men, and 13% of front-liners) or all (87% of front-liners, 32% of delivery men, and 6% of general consumers) of the enumerated BMWs (face masks, face shields, disposable gloves, disposable shoes, and full-body suits).

With the disposable face masks, face shields, disposable gloves, and full body suits identified as the most common or widely used types of PPE during the data collection period, their consumption in numbers across the Philippines

**Table 1.** Overall Estimated Weight of BMW Produced per Day

| BMW Type | Quantity Per Day | Approx. Weight (kg.) | Weight in Tonnes |
|---|---|---|---|
| Face Masks | 120,526,004 | 0.004 | 482.10 |
| Face Shields | 71,465,296 | 0.0356 | 2,544.16 |
| Disposable Gloves | 38,057,813 | 0.0052 | 197.90 |
| Full-Body Suits | 4,164,660 | 0.04 | 166.59 |
| Total per Day | | | 3,390.76 |

**Table 2.** Correlation between COVID Positivity and BMW Exposure

| Sector | Chi-square | p-value |
|---|---|---|
| General Consumers | 5.7256 | 0.0000 |
| Front liners | 18.888 | 0.0000 |
| Delivery Men | 9.3844 | 0.0000 |

**Table 3.** Correlation between COVID-Positivity and the Degree of Implementation of Proper BMW Disposal Practices

| Sector | Chi-square | p-value |
|---|---|---|
| General Consumers | 7.6409 | 0.0000 |
| Front liners | 8.5019 | 0.0000 |
| Delivery Men | .4577 | 0.0000 |

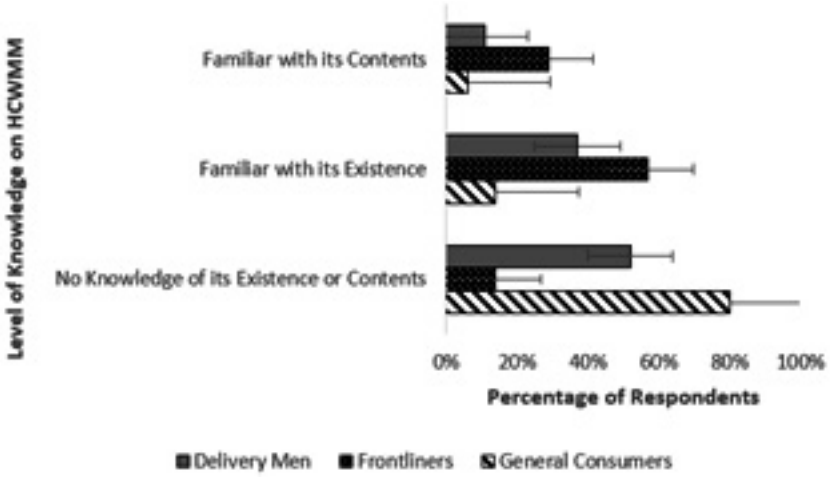


**Figure 1.** Awareness Level About the DOH's HCWMM

throughout the pandemic period was estimated. General consumers, front liners, and delivery men reported a staggering amount of disposable face masks (H" 120.5 million pieces), face shields (H" 71.4 million pieces), disposable gloves (H" 38 million pieces), and full body suits (H" 4.1 million pieces) consumed per day. Table 1 shows that the actual output of BMW in the Philippines has drastically increased within a year with a daily output average of 3,390 tons of BMW (H" 482 tons for face masks; H" 2,544 tons for face shields; H" 198 tons for disposable gloves, and H" 167 tons for full-body suits. In line with this, in the country, only around 29% of the total generated BMW is treated and disposed of properly because of the limited capacities of the waste treatment program

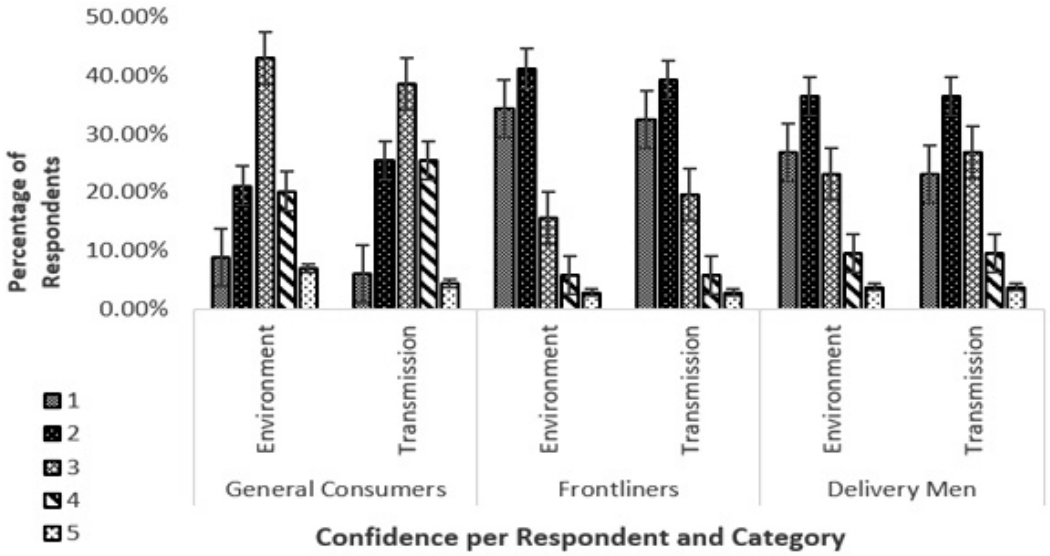


**Figure 2.** Confidence Levels of respondents in the Current BMW Management Practices in the Philippines

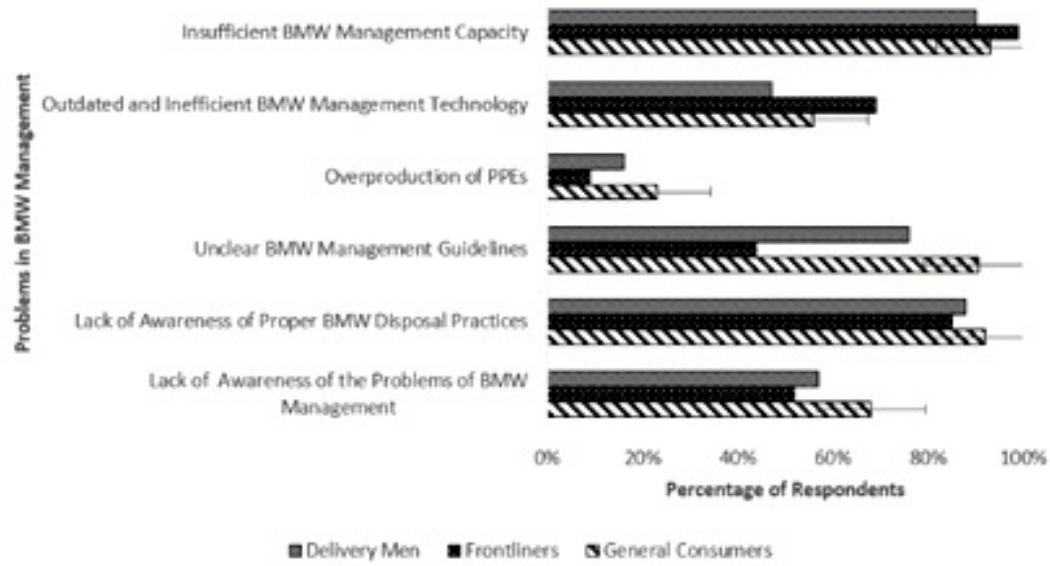


**Figure 3.** Perceived Problems in BMW Management

and disposal facilities and the procedures involved in giving permission to waste haulers to operate legally[12]. Upon application of this percentage, the estimates would imply that about 85 million disposable face masks, 50 million face shields, 27 million disposable gloves, and 3 million full body suits are improperly disposed of. However, as the percentage of treated BMW refers to the totality of all BMW collected, the amount of untreated BMW will exceed this amount.

**Awareness levels of Current BMW Management Practices**

The Philippines' Department of Health (DOH) created and continuously revised the "Health care waste management manual" (HCWMM), which serves as a set of guidelines on the safe management of waste generated from healthcare activities tailored for the use of all individuals, public and private establishments, and other entities[12]. However, when enquired about their knowledge regarding the HCWMM, only 14% of general consumers, 36.9% of delivery men, and 57% of front-liners said they knew of its existence, while a significantly less portion of each sector (6% of general consumers, 11% of delivery men, and 29.42% of front-liners) established that they were familiar with the manual's contents (Figure 1).

When prompted to pick which of the enumerated practices for BMW management are being observed, to their knowledge, in their respective work environments, the top three practices implemented across the three sectors include the segregation of used PPEs from residential waste ( 80.4% of front-liners, 76.9% of delivery men, and 53.5% of general consumers), disinfection of used PPEs (83% of front-liners, 44% of general consumers, and only 38.5% of deliverymen), and placing used PPEs in sealed bags/containers before disposal (100% of frontline workers and 59.6% of delivery men but only a mere 36% of general consumers).

Alarmingly, although the manual also requires the registration of waste generators, waste transporters, and operators of toxic and hazardous waste treatment facilities with the Environmental Management Bureau (EMB), only 19.6% of front-liners and no percentage of delivery men and general consumers reported knowledge of its practice in their work environments. 18.4% of general consumers, 1% of frontline workers, and 17.3% of delivery men accounted that none of the enumerated BMW disposal guidelines were being observed in their work environments.

**BMW Exposure and Implementation of Disposal Practices as Predictors of COVID-19 Positivity**

Table 2 shows the correlation between COVID positivity and BMW Exposure. The general consumers, front liners, and delivery men all had a $p < 0.05$ which showed that there is a significant relationship between COVID positivity and increased exposure of the respondents to BMW. A correlation between COVID positivity and implementation of proper BMW disposal practices was also observed (Table 3). With $p < 0.05$, the result showed that those who reported lax policies for BMW management in their workplaces had been more likely to get infected, which is the case for front liners, deliverymen, and general consumers.

**Confidence in BMW Management Practices**

When enquired to rate their confidence level in the Philippines' BMW management practices concerning their effectiveness in mitigating potential environmental risks, front-liners and delivery men reported having relatively lower confidence than general consumers did. Based on the results of the survey, 43% of general consumers showed they were moderately confident of the environmental soundness of the country's BMW management. In contrast, most front liners posited somewhat being unconfident (41.2%) to completely unconfident (34%), while 36.50% of delivery men reported being slightly unconfident, while 26.90% were completely unconfident.

The similar trend is observed in the respondents' confidence in the Philippines' BMW management practices in terms of their effectiveness in mitigating further virus transmission. On average, general consumers (38.6%) reported moderate confidence in the country's current practices with an equal percentage of respondents (25.4% each) who accounted as either somewhat confident or somewhat unconfident. In contrast, front-liners posted an overall lower confidence level with 39.2% feeling somewhat unconfident and 32.4% being completely unconfident. Meanwhile, 36.5% of delivery men said they were somewhat unconfident and 26.9% said they were moderately confident. Figure 2 includes the overall confidence levels of the sectors involved in the country's

current BMW management practices to mitigate both potential environmental and COVID-19 transmission risks.

The most significant problem identified by all sectors namely frontline workers (99%), general consumers (93%), and delivery men (90%) in BMW management in the country was insufficient BMW management capacity. The lack of awareness of proper BMW management practices followed this as identified by 92% of general consumers, 88% of delivery men, and 85% of front-liners. Unclear and confusing BMW management guidelines rank third among other significant problems, based on the results, including ambiguous BMW management guidelines, lack of awareness of the problems of BMW management, and use of outdated and inefficient BMW management technologies. Figure 3 presents the data about the most common problems of BMW management faced in the country.

## DISCUSSION

The most common types of personal protective equipment (PPEs) used in the country are disposable face masks and face shields. Further, the frontline workers mainly use and dispose of disposable gloves, full-body suits, disposable shoes, goggles, and respirators. All respondents from all sectors reported an increase in their BMW consumption because of the pandemic; thus, increasing Philippine and global plastic pollution, which is in line with other reported studies [13,14]. The present study calculated an estimated H" 120.5 million face masks, H" 71.4 million face shields, H" 38 million disposable gloves, and H" 4.1 million full body suit consumption per day in the Philippines. The actual output of BMW in the Philippines has increased within a year, with a daily output average of 3,390 tons of BMW. The much widely quoted study by ADB only reported the BMW data collected from the area around the capital Metro Manila, the National Capital Region (NCR) producing an average of 280 metric tons of BMW, which is a 469% increase from the pre-pandemic 47 metric tons[15]. Given that only around 29% of the total generated BMW is properly managed owing to limited capacities, the rest of it well over 85 million disposable face masks, 50 million face shields, 27 million gloves, and 3 million PPE suits are not disposed of properly. Ultimately, this will lead to an expected increase in national and global plastic pollution as most PPEs are made up of single-use plastic material that breaks down into smaller microplastics and poses potential risks to ecosystems and organisms.

Since the virus survives on medical waste and plastic, the increase in BMW will not only lead to increased air, water, and soil contamination but also heightened risks to human health[16, 17]. The results presented in this paper also established a significant relationship ($p < 0.05$) between exposure to BMW and laxer degrees of implementation of proper BMW disposal practices and COVID infection. The virus transmission among the sanitary workers exposed to BMW while handling and recycling is already reported in countries like the USA[18], Singapore[19], and China [20], it is important to focus attention on the proper disposal of BMW in the country to contain the pandemic.

Furthermore, only 6% of general consumers, 11% of delivery men, and 29.42% of front-liners were familiar with the contents of the HCWMM, which shows the low level of awareness of Filipinos' on handling BMW. Respondents identified insufficient BMW management capacity and lack of awareness of proper BMW management practices as the most significant problem for BMW management in the country. Front-liners and delivery men reported that they have low confidence in the country's effectiveness in using current BMW management practices in mitigating potential environmental and virus transmission risks. The low awareness levels of biomedical waste management practices are a common problem in many developing countries[21].

In terms of implementation, the most observed BMW management practices include the segregation of used PPEs from residential waste, disinfection before disposal, and placing used PPEs in sealed containers before disposal. Since the frequent lockdowns, and increased hospitalization of corona-infected patients has been reported[22] to further exacerbate the BMW management problem, continuous monitoring of BMW generation in the country needs to be carried out. Further, an analysis of strategies and technologies from different countries and their local applications will help the country shift to a more modern, effective, and

consistent BMW management scheme. Increased funding for the research and development of eco-friendly and safe disposal mechanisms can relieve the strain of increased BMW production. The knowledge of the contents of the HCWMM should be readily available to all households, hospitals, and general offices. A proper and fast pandemic response must be prioritized to ease the demand for PPEs to address the root of the issue. Some disposal methods such as shredding (done in India and other countries to avoid the reuse of BMW) and incineration (practiced in Japan, Sweden, and Denmark) to reduce landfills and destroy potentially dangerous bacteria) are too cost-prohibitive for a developing country like the Philippines. Hence, the BMW management practices need to be specific to the Philippines considering all the specific variables.

## CONCLUSIONS

All respondents from all sectors reported an increase in their BMW consumption because of the pandemic; thus increasing Philippines and global plastic pollution. The use of disposable gloves, full-body suits, disposable shoes, goggles, and respirators was mainly observed among frontline workers. The data collected in this study revealed a far higher estimated volume of BMW in the Philippines as compared with the reported estimates in other studies. With the actual output of biomedical waste in the Philippines drastically increased within a year, with an average daily output of 3,390 tons of BMW (H" 482 tons for face masks; H" 2,544 tons for face shields; H" 198 tons for disposable gloves, and H" 167 tons for full-body suits, the BMW management practices need immediate attention of the stakeholders for safe disposal of BMW. Furthermore, only 6% of general consumers, 11% of delivery men, and 29.42% of front-liners reported familiarity with the contents of the HCWMM, which shows the very low level of awareness of Filipinos on handling and guidelines on management of BMW. In terms of implementation, the most observed BMW management practices include the segregation of used PPEs from residential waste, disinfection before disposal, and placing used PPEs in sealed containers before disposal, which would be conducive to an overall decrease in the community transmission. Respondents identified insufficient BMW management capacity and lack of awareness of proper BMW management practices as the most significant problem for BMW management in the country. The paper established a significant relationship ($p < 0.05$) between exposure to BMW and laxer degrees of implementation of proper BMW disposal practices and COVID infection, leading to heightened risks to human health. Front-liners and delivery men reported low confidence in the country's effectiveness in using current BMW management practices in mitigating potential environmental and virus transmission risks. Hence, an overall review of the current BMW management practices is urgently needed and highly recommended.

**Recommendations**

Since the pandemic is still going on, continuous monitoring of the BMW generation needs to be done to devise the best BMW management practices in the Philippines to control the transmission of the virus through BMW. The knowledge of the contents of the HCWMM must be made readily available to all households, hospitals, and general offices to raise the awareness of general consumers regarding the safe disposal of BMW. As the UN SDGs aim for sustainable consumption and production, as well as reduction of pollution and pollution-related illnesses and fatalities, the Philippines must mainstream the knowledge of the proper BMW disposal practices and adopt other nations' technologies and strategies to shift to a more modern, effective, and consistent BMW management practices such as shredding, incineration, etc. though there are going to be huge financial constraints. Using 'onsite waste burial pit' [23] adopted by several developing nations to address the BMW is not suitable for the typhoon-prone Philippines as there is a danger of leaching out hazardous materials during the rainy season and strong inland ocean currents. For Biodiversity hotspot countries like the Philippines, an integrated approach involving thermal treatment, use of biocidal materials, and safe recycling methods need to be adopted to manage BMW. Further, a strong thrust towards research and development of eco-friendly and safe disposal mechanisms for BMW is needed to reduce viral and bacterial transmission because of unsafe BMW management practices.

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