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REGIONAL CASE STUDY

Face mask and medical waste generation in the City of Baguio, Philippines: its current management and GHG footprint

Marcelino N. Lunag[1] · Alexander S. Abana[2] · Juco P. Agcaoili[2] · Jillien Kaith T. Arellano[2] · Coleen Angela G. Caluza[2] · Nick Brylle V. Decena[2] · Emmanuel R. Dela Paz[2] · Lyka Angela B. Delgado[2] · Aaron F. Obero[2] · Don Miguel E. Ocampo[2] · Charlene Ann D. Sacdalan[2]

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Abstract

The daily use of facemask to prevent virus transmission increases the negative effect on the environment because of improper waste disposal. Due to the absence of baseline data, the impact of facemask and medical waste generation, as well as the community's management practice, should be studied to avoid further environmental degradation. In this study, we surveyed 384 respondents and conducted computational analysis to provide an overview of the household's facemask usage and ecological footprint in combating Covid-19. Results showed that most respondents (48.7%) use two facemasks per day. Thus, an estimated 417,834 facemasks are disposed daily, generating 3,585 kg/day of additional waste. The average medical waste of Covid-infected individuals is 3.29 kg per day per capita. This yields 22,438 kg. of CO_2 eq., which could contribute to the global warming potential; however, there is also a potential recovery of 61.572 gigajoules of energy for power generation. Most respondents are aware of proper facemask waste management practices, but some lacks application regarding responsible waste disposal. Despite the contribution of facemask to the overall solid waste generation, the city's current management remains a challenge since disposable facemasks are potentially mixed with other types of waste from its storage, collection, and disposal.

Keywords Facemask · Waste generation · Environmental impact · Energy recovery · Baguio city

Introduction

The need to mitigate and suppress the virus transmission brought by the Covid-19 pandemic led to a rapid change in nature and volume of waste generation in various countries. In China, there was a 30% reduction in municipal solid waste in their major cities during the pandemic [1, 2]. However, a tremendous 370% increase in medical waste generation containing mostly plastics in Hubei province [2], while in Wuhan, the epicenter of the virus outbreak, registered a surge of medical waste from 40 tons per day (t/d) to 247 t/d (600% increase) [3, 4]. Similar experiences are also observed in other Asian cities such as Bangkok, Kua Lumpur, Hanoi, Manila, and even across the United Kingdom (UK) [5–7]. Plastic waste management was a severe environmental issue even before the pandemic. According to Bondaroff and Cooke [8], about 8–12 million tons of mismanaged plastics ended up in oceans in 2018, contributing to overall plastic pollution. However, the ongoing onslaught of the virus outbreak led to increased manufacturing, production, and procurement of Personal Protective Equipment (PPE), such as face masks, face shields, and other medical materials to mitigate and avoid viral transmission from individual-to-individual or within the community. A recent study by Benson et al. [9] estimated that plastic waste had been generated at a pace of 1.6 million tons per day, aggravated by 3.4 billion single-use face masks and face shields discarded daily because of the Covid breakout. The extensive use of protective gear creates great supply chain outbursts and additional waste disposal concerns, which worsened global plastic pollution [10–12]. In addition, plastic waste increases due to online orders of food and grocery items such as the case of Thailand (from 1500 t/d to 6300 t/d) [13]. This massive

Marcelino N. Lunag
mnlunagjr@slu.edu.ph

[1] Faculty, School of Engineering and Architecture, Saint Louis University, 2600 Baguio City, Philippines

[2] School of Engineering and Architecture, Saint Louis University, 2600 Baguio City, Philippines

consumption of PPEs by medical health workers and the general public has led to an increase in disposal facilities of up to ten times [14, 15]. With more than 8 million tons of pandemic-related plastic waste generation, it was estimated that more than 25,000 tons end up in our global ocean [16].

The Philippines is not an exception to this global problem. The country alone generates 2.7 million tons of plastic waste in 2019, which is reported to be the 4th largest solid waste generator among ASEAN neighbors, with 15 million tons of solid waste per year [17]. But due to the virus outbreak, the Department of Environment and Natural Resources (DENR) in the country have reported that around 634,687.73 tons of healthcare waste was generated from June 2020 to June 2021 and projected to annually produce 8,218,580.85 tons of plastic waste as the Covid-19 pandemic continues [9, 18]. Indeed, there is a surge in hospital waste and solid waste, according to Analiza Teh, the Environment Undersecretary, mentioned in her interview. She noted that around 52,000 tons per month of medical waste have so far been generated amid the health crisis, which she likened to about 2 million sacks of rice equivalent. Still, of the total figure, only 14,000 tons were treated [19]. The country's city capital Manila reported that it produced 280 tons per day of medical waste, which needs the hasty establishment of additional waste treatment facilities [20]. Existing laws are being emphasized, such as the Republic Act (RA) 9003 or the Ecological Solid Waste Management Act of 2000 and the Toxic Substances, Hazardous, and Nuclear Waste Control Act of 1990 (RA 6969), which mandate the proper treatment and disposal of solid, medical and hazardous wastes. However, the mere presence of legislation does not ensure compliance, adequacy, and effectiveness [21]. Hence, additional directives are provided during the pandemic to resolve the issue by implementing sustainable zero-waste strategies such as repurposing used facemasks for cement production industries [18]. However, the rise of facemasks and medical waste impedes the success of these projects [22]. Results showed from the recent study of Apostol et al. [23] that it demonstrates weak fulfillment in monitoring and evaluation; hence, the country's current waste management policies still need room for improvement to ensure effectiveness during this pandemic. This overwhelming problem extends beyond every city and municipality throughout the country.

Baguio City, the summer capital of the Philippines, faces a similar scenario. Waste disposal remains a problem because of no established engineered sanitary landfill in the city. For this reason, all residual wastes are brought to the nearest landfill, which is located in Urdaneta, Pangasinan (around 80 km from the city), which costs a considerable amount of money from the city's annual budget for its collection, hauling, and transportation. However, the Department of Environment and Natural Resources- Environment Management Bureau (DENR-EMB) ordered the closure of the said nearest landfill in 2021 due to several violations, such as operating as an open dumpsite instead of a sanitary landfill [24]. Hence, the city council shifted Baguio's waste to Metro Clark Waste Management Sanitary Landfill which is 160 km away from the city, entailing a higher tipping fee [25]. With these, environmentally sound solutions are needed to prevent threats of environmental degradation. Interventions were pitched to ease the waste problem before the pandemic, such as the "Plastic and Styrofoam-Free Baguio City Ordinance," which resulted in a 30% reduction of plastic waste in the city [26]. During the pandemic, there was a 17% decrease in garbage collection, from an average of 180–185 tons of residual waste per day to around 150–155 tons per day. This was attributed to the strict implementation of community lockdowns and quarantine across the country [27]. Despite these, the city continues to face problems relative to its waste management, especially with the closure of landfill as mentioned above and the unknown amount of generated used face masks and other medical waste mixed with other garbage.

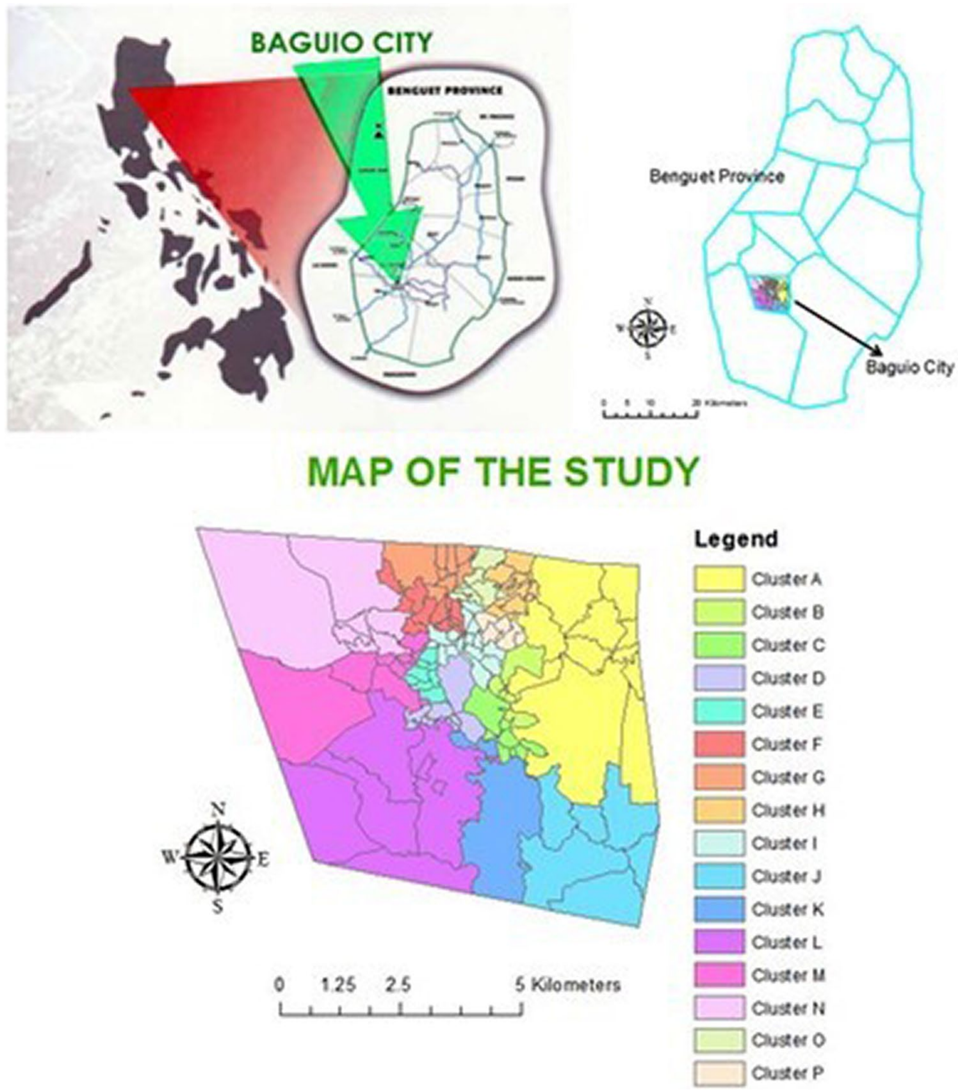
As plastic pollution continues to increase due to personal protective equipment (PPEs), specifically face masks and medical waste brought by the pandemic, the need for further studies is paramount in establishing reliable baseline data. However, no studies have been made regarding facemask and medical waste generation in the city of Baguio. The deficiency of such data, especially in a developing country like the Philippines, limits the government, policymakers, and various stakeholders from understanding the nature and scale of the problem, hindering them from creating evidence-based strategies for addressing the issue. Thus, this study was conducted to provide information regarding potential face masks, medical waste generation, and corresponding GHG emissions. Moreover, assess the community's practices and the potential environmental impact of this toxic waste, which could hopefully be used in coming up with a sound environmental solution.

Materials and methods

Study area

The City of Baguio is a Highly Urbanized City (HCU) located at 16° 25' North, 120° 36' East, on the island of Luzon, Northern Philippines, 245 km away from the capital city Manila. Elevation at these coordinates is estimated at 1445.3 m or 4740.7 feet above mean sea level. It is a chartered city administered independently from the province of Benguet as shown in Fig. 1 below [28]. Baguio City has a total population of 366,358 with 62.4% urban population as of the 2020 Census of Population and Housing issued by the Philippine Statistics Authority (PSA). It is one of

Fig. 1 Map of the study



the leading centers for commercial trading, investment, and business opportunities in Northern Luzon. Moreover, the city is a tourist destination because of its cool climate, so many people are expected to visit for leisure and other activities. Hence, it became the melting pot of diverse people and cultures from the Cordillera Administrative Region (CAR). It has a total land area of 57.5 sq km, comprising most of the land use allotted for residential areas (56.35%).

Sampling and data collection

There are 129 barangays of the city divided into 16 clustered barangays (Cluster A to P), as shown in Table 1. A sample size of 384 out of the 366,358 total population was determined using the OpenEpi sample size calculator with a 95% confidence level, which was available online. The sample size was then equally proportioned among the 16 clustered barangays of Baguio City using the stratified random sampling method based from Lunag et al. [29]. Data collection involves using the online survey methods composed of questionnaires supported by Mejjad et al. [30]. Due to health threats concerning the COVID-19 virus, the local government unit of Baguio has imposed strict protocol measurements during the survey, which was conducted from April 1 to 10, 2022. Hence, survey forms are done online for easier access, similar to the study of Selvaranjan et al. [31]. The survey was divided into three sections. The first part was composed of the general information from the respondents. The second part focuses on the type and number of facemasks they used. The remaining sections of the survey focused on the respondent's awareness, perception, and practices regarding the handling, storage, and disposal of PPE waste. All the participants were informed about the confidentiality of their responses during data gathering. The researchers also collected secondary data specifically from available

Table 1 Population in different clustered Barangays of Baguio City

Cluster	Population
A	31,853
B	8,532
C	13,686
D	10,355
E	13,557
F	20,024
G	22,979
H	18,910
I	13,006
J	31,813
K	22,046
L	41,148
M	34,055
N	63,371
O	9,845
P	11,178
TOTAL	366,358

[a]Data source [29]

[b]Data source: retrieved on May 12, 2022, from: https://www.philatlas.com/luzon/car/baguio.html

online datasets of government reports, previous studies, and other published data.

Data processing, computation, and analysis

The information was processed and analyzed using IBM SPSS (Statistical Package for Social Sciences) to interpret the results. For the computations, the researchers adapted the proposed equations from related studies for the consistency and accuracy of the results. The number of daily face masks generation (DFM) in Baguio City was calculated using the equation which was based on the study of Nzediegwu & Chang [32], as can be seen below,

$$DFM = P \times \frac{Up}{100\%} \times \frac{FM_{ar}}{100\%} \times FM_u \quad (1)$$

where: DFM is the daily face mask generated, P refers to the population of the area of study (refer to Table 1), U_P = urban population of the locale in percentage (%) (62.4% was used based on PSA), FM_{ar} is the face mask acceptance rate in percentage (%) calculated from each cluster by taking the percentage of respondents who accepted or agreed wearing face mask is a must, and FM_u is the average quantity of face mask used daily based on the survey.

On the other hand, the estimation of medical waste generation is equivalent to the number of Covid-infected individuals multiplied by the average medical waste generation rate, as supported by the study of Sangkham [33]. The number of Covid-infected individuals was extracted from the city's public information website [34], while the 3.4 kg/bed/day medical waste generation rate was based on reports from Asian Development Bank (ADB) [35, 36]. Hence, the infectious medical waste in hospitals and medical facilities could be determined using Eq. 2 as shown below,

$$ME = \frac{Nci}{30} \times MWgr \quad (2)$$

where: *MW* refers to the medical waste generation in kilogram per day (kg/day/capita), *Nci* is the average Covid-infected individual using the Covid bed facility per month, and *MWgr* stands for the medical waste generation rate (recommended value is 3.4 kg/bed/day as per ADB).

For the estimation of environmental impact (GHG Emission), According to Klemeš et al. [10], the N95 mask has 0.05 $kgCO_2$ eq. Per single use [37] with potential energy recovery of 0.28 MJ per piece [2], for a surgical mask (0.059 $kgCO_2$ eq. per single use [38] with 0.04 MJ per piece for energy recovery [2]), a reusable cloth mask has 0.036 kgCO2 eq. per usage [38]. With that, the derived equations to determine greenhouse gas emission and energy recovery will now be:

$$GHG = DFM \times CF_1 \quad (3)$$

$$PER = DFM \times CF_2 \quad (4)$$

where: *GHG* refers to the amount of greenhouse gas emitted in $kgCO_2$ eq., *DFM* is the daily face mask generated, *PER* refers to the potential energy recovery in megajoule (MJ), CF_1 stands for the conversion factors of face mask's GHG emission as mentioned above [37, 38] while CF_2 is the conversion factors for the amount of potential energy recovery based on the types of face mask from the study of Klemeš et al. [2]. The conversion factor sought from the study of Klemeš et al. [10], which evaluated the environmental footprint of face masks, was based on the Life Cycle Assessment (LCA) of PPEs, encompassing everything from material extraction to waste disposal. The study of Klemeš et al. mainly highlights energy and environmental footprint issues during this pandemic, which could be used as a starting point for discussion. Hence, these factors were also used by other published studies such as Mejjad et al. [30] and Selvaranjan et al. [31] to discuss further the face mask GHG and energy footprints in their areas.

Results and discussion

Demographic profile of the respondents

Table 2 below shows the demographic profile of the participants. The survey results showed that most of the respondents who participated represented different demographic characteristics in terms of sex, age, category, and the number of members per household. In this study, male participants comprise 51.3% of the respondents, while female participants represent 49% of the sample population. In terms of age bracket, most respondents are in their adult stage. Moreover, 11.7% were frontline workers in health-related services, 7.6% of the respondents were persons with comorbidities, 9.9% were frontline personnel in essential sectors, 12.2% were other government workers, 11.7% were from other essential working sectors, 33.1% are students including student frontliners, and lastly, 13.8% were from the rest of the population that were not included in the list. Based on the survey conducted, most of the respondents were students or student frontliners. As also reflected in the table below, most of the respondents belong to 4–6 persons per household, which is the typical average number per household in the country.

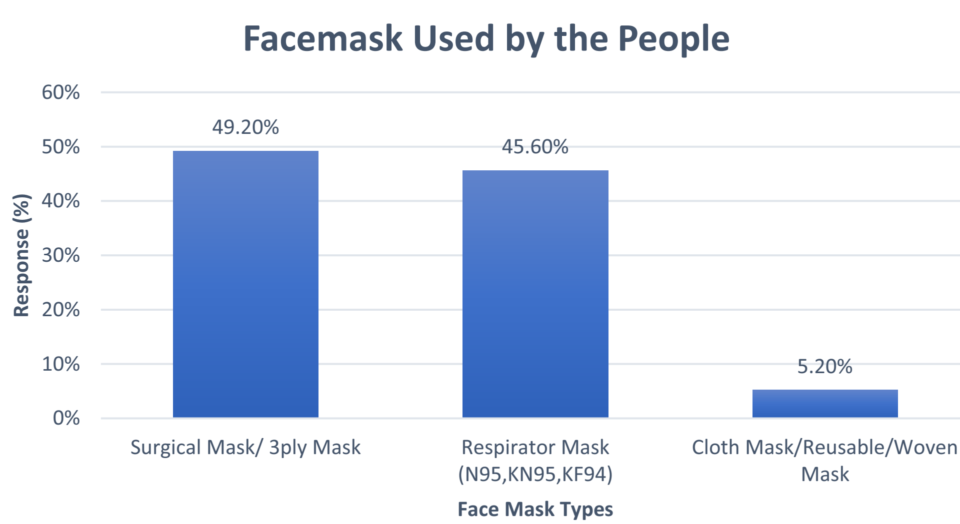
Table 2 Demographic profile of the respondents

Characteristics	Number of participants $n=384$	Percentage (%)
Sex		
Male	197	51.3
Female	187	48.7
Age		
18 and below	12	3.1
19–24	163	42.4
25–34	139	36.2
35–44	34	8.9
45–54	31	8.1
55 and above	5	1.3
Category		
Frontline Personnel in essential sectors, including uniformed personnel	38	9.9
Other Government workers	47	12.2
Other Essential workers	45	11.7
Students, Student Frontliners	127	33.1
Rest of the Filipino population not included in the above groups	53	13.8
Number of members per household		
One to three members	69	17.9
Four to six members	183	47.7
Seven and above	132	34.4

Face mask usage and perception

The survey showed that all respondents (100%) have face masks in their households, while 70.6% of the participants have face shields, 23.7% have PPE suits, and only 15.9% use goggles. Since the study focuses on the use of face masks, the survey gathered what type of mask they usually used. It showed in Fig. 2 below that a large portion of the respondents uses a surgical mask (49.2%) or any respirator mask (45.6%) such as N95, while only 5.20% use cloth/woven masks which could be reusable. The reason why there are very few who are using cloth masks is because of the Department of Health (DOH) recommendation to use medical grade facemask instead of cloth mask since most of the studies show that cloth has lower filtration efficiency compared to surgical masks. Regarding the frequency of using facemasks, the study shows that 48.7% of the participants

Fig. 2 Type of face mask used



use two facemasks per day, while 28.1% only use one facemask per day. Moreover, 16.7% of the respondents used three face masks per day, while some chose four (3.6%) and above four face masks per day (2.9%). However, with the lingering threat of Covid-19, some 8.6% of the respondents still disagreed with wearing face masks, 7.6% were unsure if facemask could significantly reduce the spread of the virus, and 1.8% thought that it does not help at all. On a positive note, most respondents agreed that people should wear facemasks because 88.5% of the participants believed it could lower the possibility of virus transmission. The higher preference for using facemasks is due to the massive campaign strategy of the local government officials on different offline and online platforms, specifically social media.

Face mask and medical waste generation

Table 3 below summarizes the estimated facemask generation in the city based on the acquired parameters mentioned above. The result showed that around 417 834 pieces of facemask are being disposed of daily, with cluster N as the most significant contributor since it has the largest population among the clustered barangays. According to Benson et al. [39], the average weight of a facemask is approximately 8.58 g. Thus, the facemask waste generation in the city is 3,585 kg per day or 1308.5 tons/year that could be released into the various environments, which might cause environmental pollution, as supported by Mejjad et al. [30]. On the other hand, the medical waste generation was computed based on the formula given by Sangkham [33]. From the government data released from April to June 2022, the total number of beds allotted for Covid patients is 379, and the average infected patient who makes use of the facility is around 29 persons per month, resulting to an average healthcare utilization rate of 7.65% for the city of Baguio. With these, results from the computation showed that an average of 3.29 kg per day per capita is being generated from the medical waste of Covid-infected individuals, which could contribute to the increase of medical waste in the city. Note that the number of Covid-infected people could vary due to the surge of Covid positive; hence, the computation may also vary accordingly. The determination of the amount of waste generation, especially for this type of waste, is critical baseline information for future projections.

Environmental GHG emission and potential energy recovery

The potential environmental impact due to the facemask generation needs essential consideration. Using the environmental GHG footprints and estimated possible energy recovery (PER) of each mask type from Klemeš et al.[10] study, the researchers computed the emission for each cluster in the city. Table 4 below shows the GHG emission in terms of carbon dioxide equivalent and their potential energy recovery due to the disposed facemask. Results showed that a total of 22,438 kg of carbon dioxide equivalent (kg CO_2Eq.) is produced daily. In this study, the highest potential emission

Table 3 Estimated face mask generation in the city

Cluster	Population	Urban Population (%)	Rate (%) of Facemask Acceptance Rate	Number FM Usage/day	Estimated Daily Facemask Disposed	The Estimated Weight of Facemask (kg)
A	31,853	62.4	83	2	32,995	283
B	8,532	62.4	79	2	8,412	72
C	13,686	62.4	63	2	10,760	92
D	10,355	62.4	92	2	11,889	102
E	13,557	62.4	88	2	14,889	128
F	20,024	62.4	92	2	22,991	197
G	22,979	62.4	79	2	22,655	194
H	18,910	62.4	88	2	20,768	178
I	13,006	62.4	100	2	16,231	139
J	31,813	62.4	100	2	39,703	341
K	22,046	62.4	96	2	26,413	227
L	41,148	62.4	92	2	47,244	405
M	34,055	62.4	92	2	39,101	335
N	63,371	62.4	100	2	79,087	679
O	9,845	62.4	92	2	11,304	97
P	11,178	62.4	96	2	13,392	115
TOTAL	366,358				417,834	3,585

Table 4 Environmental GHG emission and potential energy recovery in the city

Cluster	No. of Surgical Mask	No. of Resp. Mask (N95)	No. of Cloth Mask	kg CO2 Eq. (Surgical Mask)	kg CO2 Eq. (N95)	kg CO2 Eq. (Cloth Masks)	Total kg CO2 Eq	PER for Surgical Mask (MJ)	PER (N95) (MJ)	Total Potential Energy Recovery (PER)- MJ
A	16,233	15,046	1,716	958	752	62	1,772	649	4213	4862
B	4,139	3,836	437	244	192	16	452	166	1074	1240
C	5,294	4,907	560	312	245	20	578	212	1374	1586
D	5,849	5,421	618	345	271	22	638	234	1518	1752
E	7,325	6,789	774	432	339	28	800	293	1901	2194
F	11,311	10,484	1,196	667	524	43	1,235	452	2935	3388
G	11,146	10,331	1,178	658	517	42	1,217	446	2893	3339
H	10,218	9,470	1,080	603	474	39	1,115	409	2652	3060
I	7,986	7,402	844	471	370	30	872	319	2072	2392
J	19,534	18,104	2,065	1152	905	74	2,132	781	5069	5851
K	12,995	12,044	1,373	767	602	49	1,418	520	3372	3892
L	23,244	21,543	2,457	1371	1077	88	2,537	930	6032	6962
M	19,237	17,830	2,033	1135	891	73	2,100	769	4992	5762
N	38,911	36,064	4,113	2296	1803	148	4,247	1556	10,098	11,654
O	5,561	5,154	588	328	258	21	607	222	1443	1666
P	6,589	6,107	696	389	305	25	719	264	1710	1973
TOTAL	205,574	190,532	21,727	12,129	9,527	782	22,438	8,223	53,349	61,572

comes from a surgical mask (12.13 kt CO_2Eq.), followed by the N95 mask with 9.53 kt CO_2Eq. The least GHG emission comes from cloth masks, amounting to 0.782 kt CO_2Eq. In addition, cloth mask has also shown a lower environmental footprint in other studies, such as the studies of [30, 31, 40]. Greenhouse gas emissions have long been a problem because they are the primary cause of global warming. With the increase in demand for a facemask, producing and disposing of this kind of waste mainly contributes to the overall Global Warming Potential (GWP) [41]. From manufacturing to the disposal of a face mask, carbon dioxide is emitted into the atmosphere. Although the face mask itself may not contribute directly to the carbon dioxide emission, the harmful gas may come from manufacturing and transportation [42]. According to Kumar et al. [43], transporting a 10-ton of PPE waste—including face masks, to a 10 km disposal site could result in a GWP impact of 2.76 kg CO_2Eq. In addition, improper treatments and disposal of the facemask is also a factor that contributes to GHG emission [44].

Another critical environmental parameter is the determination of its energy recovery [30]. The PER used for a surgical mask is 0.04 MJ per piece, while 0.28 MJ per piece for N95 mask types [10]. Table 3 below shows the total potential energy amounting to 61,572 Megajoule (MJ), which could be an essential consideration for power generation potential. In the table, higher possible recovery was seen from respiratory masks such as N95 compared to surgical masks, which is expected because of their energy content difference, as seen above. The results of this study could help manage and treat facemask and other medical waste through the incineration method as per the recommendation of Cudjoe et al.[45]. Moreover, the recent study by Skrzyniarz et al. [46] concluded that pyrolysis is an effective and alternative environmental solution since facemasks have a high calorific value of up to 47.7 MJ per cubic meter. The information from this study is also timely since the city has been pushing for an establishment of waste-to-energy to curb the growing solid waste management problem.

Current household management: perception, handling, storage, treatment, disposal, and collection

Based on the gathered survey data, most respondents are aware of the impacts of improper facemask waste practices in terms of health (86.7%), environment (87.8%), and economic (68%). Regarding legislation or regulations about proper facemask waste management, 20.6% of the respondents do not know of such rules, while the remaining percentage have some knowledge about it. Regarding handling facemask, 80% of the survey says that respondents practice disinfection or washing of hands after facemask removal. However, most (69.5%) do not wear gloves when handling facemask waste and do not wrap the facemask in a separate container before disposing it in the garbage bins. The type of garbage storage where they put their facemask wastes is a garbage bag (71.9%), a container with a secure lid (16.7%), an open container (9.4%), and an open pile outside the house (2%). Although a majority (92.1%) agreed that facemask must be separated and labeled as household healthcare waste, (73%) of them do not label or give any warning sign before disposal. Only the health front liners are labeling their garbage containers as hazardous waste. In addition, 78.9% of the participants answered that there is none or are unsure if there is a hazardous waste storage area in their barangay. The wastes are generally stored for about 1 to 7 days before the garbage is collected. While many respondents (53.9%) do not have a problem storing their facemask inside, 46.1% answered they have a problem with it.

In the matter of proper household treatment, 85.7% have awareness, but in terms of doing or practicing it, more than 50% do not practice appropriate treatment. For those who are practicing treatment methods (48%), the most common that they do is sanitization or chemical disinfection (71.1%), while 23% are doing handwashing, 17.1% pour boiling water, and only 9.1% practice burning on a discarded facemask, which most of them immediately do it after use. The low percentage of the burning practice is because a majority (60.4%) disagree with the burning process. Regarding having centralized waste treatment facilities within their barangay, 50.8% say they do not know, while 31.8% answered they have none, and only 17.4% say they have the facilities for treatment in their barangay.

With regards to facemask household disposal, 88.8% of the respondents agreed that facemasks must be disposed of after their first use, while only 11.2% disagreed. In which 90.9% say they need to dispose it in to separate covered bin. They also agree that a separate waste bin should be allotted for facemask and other Covid-related protection, while only 25.8% disagreed. Concerning the city's collection, 91.7% are aware of the garbage collection schedules, but some 8.3% say they are unaware of the collection service. In addition, more than half, 55.5% of the respondents, answered that the current service for waste collection is not enough, while 44.5% said it is just enough. Although the current collection service is once a week, the majority of the respondents, 60.7%, recommended that their waste be collected twice a week, followed by once a week (19.3%), and only 18.5% said it should be daily. From the gathered information above, the current household practices relative to facemask management showed high awareness and positive feedback about proper treatment and disposal. However, when it comes to actual practices, some showed unsatisfactory results. These outcomes were also seen in the other study by Limon et al. [47], which is within the Philippine context.

Conclusions and recommendations

The continued persistence of the COVID-19 pandemic led to an unprecedented need, consumption, and generation of the primary personal protective equipment such as the facemask to prevent the spread of the disease. It abruptly created substantial environmental concerns and challenges due to extensive usage and waste mismanagement. This study was conducted to gather pertinent data on the potential facemask and medical waste generation, which could be an additional burden to the burgeoning garbage problem of the city. Moreover, an assessment of how the general public perceives and acts regarding the proper management of facemask. With these, it showed that more than four hundred thousand facemasks are being generated every day in the city, with additional medical waste from Covid-infected individuals generating an average of 3.29 kg/day/capita. The impact on the city's current environmental landscape increases due to the GHG emission brought by the creation and utilization of the facemasks. It could contribute at least 22,438 kg of carbon dioxide equivalent if there are no proper interventions and sustainable management resolutions that will be made. The need for further study on an innovative proposal and practical solution is of great importance, especially in recovering potential energy amounting to 61,572 MJ that could be possibly extracted from this type of waste, yielding a gainful circular economy. The current household facemask management showed adequate knowledge and awareness about the proper waste disposal from the respondents, but some lack the actual practice. Hence, the local government unit must empower every barangay by continuously coordinating and conducting awareness and educational programs to the public about the proper handling of facemasks through various platforms. Most respondents suggest that collection should be done twice a week to avoid piling up garbage and mixture with other types of waste. This study also recommends that authorities designate a place in each barangay for treatment, and decontamination services are intended for infectious waste. During the study, challenges have occurred, such as having areas in granular lockdown due to the threat of Covid-19 virus, thereby making it challenging to allow a face-to-face survey and proper distribution. Thus, the researchers were limited only to online surveys and secondary data, which might create variations on the above information. However, despite these limitations, this study provides vital data for policymakers to hopefully develop worthwhile environmental endeavors that are long-term measures.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10163-023-01601-2.

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Data availability All data generated or analyzed during this study are available from the corresponding author upon reasonable request.

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