Personal protective equipment use during COVID-19 pandemic and associated waste management in households in Sri Lanka

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Abstract

The use of personal protective equipment (PPE) is compulsory when accessing public places due to the ongoing COVID-19 pandemic in many countries. Facemasks are the most common PPE used, however, some people use face shields and gloves. Frequent hand sanitizing is also recommended aiming to control the spread of the disease. All these activities generate a large amount of plastic waste daily. In Sri Lanka, it is estimated that 12 million facemasks are used daily, while 0.22 million gloves and 0.29 million face shields are used. Out of 12 million facemasks, 10 million are surgical or N95 masks. In addition, 0.79 million sanitizer bottles are used in a day, leaving empty plastic bottles. The most common method of disposing of facemasks in Sri Lanka is open burning by the users at their homes (55%). The rate of burning is comparatively low for other PPE. Although nearly 30% of people handover used facemasks to the municipal solid waste collection, there are no special precautions taken for separate collection and safe disposal. Guidelines are in place for handling healthcare waste generated in households under self-quarantine, but they are not applied for PPE waste generated in other households. Major drawbacks in PPE waste management is identified and mitigation measures were proposed. The estimate of waste plastics generated due to PPE use is 88.5 tonnes per day in the country. Energy recovery via pyrolysis may be a viable alternative to landfilling and affordable for developing countries.

Introduction

The COVID 19 pandemic condition changed many aspects of human life. Travel restrictions, social distancing and lockdown of countries or cities were exerted to control the spread of the disease by many governments around the world (Selvaranjan et al. 2021). However, since the complete lockdowns were unable to be extended for prolonged periods, the general public was requested to use Personal Protective Equipment (PPE) and engage in economic and any other necessary activities. Facemasks are the main PPE in use to control of the spread of COVID-19 from person to person. Nevertheless, use of gloves, face shields, sanitizers has also been increased to reduce community spread of the disease (Selvaranjan et al. 2021; Zand and Heir 2021). Almost all of them are usable for a short period and made of polythene and plastic, hence leaving heaps of non-degradable waste (Abbasi et al. 2020; Selvaranjan et al. 2021). Hence, global attempts were made to estimate the generation of waste due to excessive PPE use because of global pandemic condition and made proposals for better waste management practices (Abbasi et al. 2020; Nzediegwu and Chang 2020; Sangkham 2020; Al-Omran et al. 2021; Selvaranjan et al. 2021). In particular, the focus of most of the previous research has been mainly single-use facemasks (Eg: Nzediegwu and Chang 2020; Selvaranjan et al. 2021; Torres and De-La-Torre 2021), while health recommendations guide people to use face shields, gloves, and hand sanitizers depending on the requirement. Hand sanitizer usage was an uncommon practice in Sri Lanka before the COVID-19 situation. However, the use of hand sanitizers skyrocketed during the pandemic, thus leaving heaps of plastic bottles in the waste stream. Although not widespread, in addition to medical staff, supermarket workers, food and bakery sector workers, etc., who handle the money and food started to wear plastic gloves. Face shield usage has also become a practice common among young children and senior citizens. However, a segment of younger adults has also started to use them. Therefore, this study focuses on the increase in waste due to all of these activities. Meanwhile, many studies assume that facemask use is one per day or two per day, but have not quantified it with data collected from individuals (ex: Nzediegwu and Chang 2020; Sangkham 2020). In developing countries, where there are affordability issues, usage patterns of PPE might be influenced by income; hence we approached to collect data from general public on the use of PPE during a month and the frequency of using a new facemask.

There are two main concerns on management of waste associated with PPE use. First, this waste may contribute the spread of the disease if safe disposal practices were not adopted because viruses can remain alive on the PPE materials for several days (Kampf et al. 2020; Nzediegwu and Chang 2020). The second is most of this waste is single use plastics; hence release of micro-plastics into the environment when they are degraded. This is more prolonged impact (Abbasi et al. 2020). Therefore, many studies focus on PPE waste management and disposal methods. Many studies report improper waste disposal practices by general public such as roadside dumping, abandoned face masks on ground, entering them into marine environment etc. (Akhbarizadeh et al. 2021; Selvaranjan et al. 2021; Torres and De-la-Torre 2021) and open dumping and open burning of collected waste, in developing countries (Benson et al. 2021). Further, research studies report on COVID 19 related biomedical waste management mainly focus on contaminated waste generated in hospitals and other healthcare facilities, than in household level (Sangkham 2020; Al-Omran et al. 2021). However, there is a high possibility that PPE associated waste discarded by households may contaminate with the virus.

In global rich countries, household PPE related waste disposal may not an issue, because of well-established municipal solid waste management practices and availability of sanitary landfilling or incineration of municipal solid waste (Nzediegwu and Chang 2020). However, regarding developing countries, which have poor solid waste management systems, household waste management is a significant issue even under normal circumstances. Hence, developing countries are in a more vulnerable situation in pandemic because solid waste collection is not well established and waste disposal techniques are not always environmentally safe and sound (Nzediegwu and Chang 2020). In addition, the use of manual labor in the waste collection is high in developing countries hence exposing human into probably contaminated PPE (Nzediegwu and Chang 2020). Therefore, under pandemic conditions, the fate of PPE related waste generated in household level has a significant impact on the country's environment and public health.

Therefore, this study aims to estimate PPE usage associated waste generation thorough collected data and investigate disposal methods used by households in a developing country in South Asia. Further, study evaluates the application of waste disposal guidelines in the country and identifies major drawbacks.

Methodology

The study is based on a questionnaire survey. The questionnaire was distributed via email and social networks using the referral-sampling method. People living in all nine provinces of Sri Lanka participated in the survey and the participation was entirely voluntary. Care was taken to reach all income groups because income determines the affordability of PPE. The study was focused on collecting data on the number of face masks, face shields, gloves, and sanitizer bottles utilized by a family during a month and the disposal method used for each item, separately. In addition, province of residence, family income, number of family members, and number of people who need to go out regularly for economic activities as well as socio-demographic characteristics of the respondent (gender and age) are also included. The questionnaire was conducted during April - September 2021. The sample size required for this survey was

determined according to the suggestion of Kotrlik and Higgins (2001). Accordingly, when population size is more than 100000, approximate sample size required is 400. Questionnaire was conducted with 851 respondents for this study.

Estimation of daily use of PPE

Nzediegwu and Chang (2020) propose to estimate daily facemask use using the Eq. 1.

$$Totaldailyfacemasks = populationxurbanpopulation(\%)xfacemaskacceptancerate(\%)$$

$xaveragedailyfacemaskspercapita / 10{,}000$ - (1)

They use Eq. 1 for estimating daily facemask use in several African states and assume that the average daily facemasks per capita is 2 and the facemask acceptance rate is 80% for several African states.

Torres and De-la-Torre (2021) propose a modification for this estimate and develop Eq. 2, considering economically active population.

$$Totaldailyfacemasks = populationxurbanpopulation(\%)xfacemaskacceptancerate(\%)$$

$xaveragedailyfacemaskspercapitaxEconomicallyactivepoputaion(\%) / 100{,}000$ – (2)

These equations were used to estimate the daily facemask waste generation in Sri Lanka, assuming that the number of facemasks per capita per day is one, the facemask acceptance rate is 80% and compared with the data collected from respondents. We used the number of facemasks per capita per day as one because it is the most common assumption made in estimating daily facemask use in South Asian countries (Sangkham 2020; Haque et al. 2021).

In this study, we collected the number of family members, number of family members participating in economic activities, (thus, go out daily) and monthly facemask use of the corresponding family. Thereafter, we used the following equations to estimate the daily facemask use in Sri Lanka.

$Totaldailyfacemasks = \text{Monthlyfacemaskuseinthefamily*Population / (Numberoffamilymembers*30), assumingamonthhas30days}$ - (3)

$Totaldailyfacemasks = \text{Monthlyfacemaskuseinthefamily*Monthlyfacemaskuseinthefamily*Economicallyactivepopulation / (Numberofeconc}$ - (4)

In addition, our study collected data on the use of face shields, gloves and hand sanitizer bottles. All of these items were newly added to use because of the health guidelines issued due to COVID 19. We estimated daily use of those items as,

$\text{Faceshields / Gloves / Sanitizerbottlesuse(Dailytotaluse) = Monthlyuseinafamily*Population / (Numberoffamilymembers*30)}$ – (5)

Results And Discussion

There were 851 respondents for the survey. Socio-demographic information of the sample is shown in Table 1. Respondents were mainly young people, since the questionnaire was conducted online. The younger population is more likely to use social networks and participate in other online activities than the older population. However, each respondent provided details on the behavior of their own family related to the use and disposal of PPE. Respondents represented all provinces of the country.

Table 1
Socio-demographic characteristics of the sample (n=851)

Characteristic	Number	Percentage
Respondent's age		
18-24 years	448	52.64
25-34 years	356	41.83
35-44 years	19	2.23
45-54 years	24	2.82
Above 55 years	4	0.47
Respondent's gender		
Female	436	51.23
Male	415	48.77
Family size		
3 members or less	135	15.86
4 members	308	36.19
5 members	294	34.55
6 or more members	113	13.28
Income of the family		
Below 25000 LKR	112	13.32
Between 25000-50000 LKR	239	28.42
Between 50000-100000 LKR	302	35.91
Above 100000 LKR	188	22.35
Province of residence		
Western province -W	177	20.80
Central province - C	77	9.05
Southern province -S	83	9.75
Northern province -N	79	9.28
Eastern province - E	72	8.46
North Western province -NW	68	7.99
North Central province - NC	51	5.99
Uva province - UVA	173	20.33
Sabaragamuwa province - SA	71	8.34

Estimation of daily use of PPE

In Sri Lanka, three types of facemasks are used; surgical masks, N95 masks and cloth masks. Within the sample, 40% of families do not use cloth masks, 1.2% of families do not use surgical masks, and 9.4% of families do not use N95 masks. There were no families who do not use both surgical masks and N95 masks, i.e. families who do not use surgical masks use N95 only and vice versa. The most common calculation used in estimating the number of facemasks used per day is Eq. 1, proposed by Nzediegwu and Chang (2020). Many researchers have adopted that equation for estimating daily facemask use in many different countries (Ex. Al-Omran et al. 2021; Torres and De-la-Torre 2021; Haque et al. 2021; Zand and Heir 2021). As per Nzediegwu and Chang (2020), if it is assumed that one mask per capita per day and an 80% mask acceptance rate, the Sri Lankan population will use 3.19 million single-use masks per day (Table 2). If the modification by Torres and De-la-Torre (2021) is adopted, the value will reduce to 1.23 million masks per day (Table 2). However, our data shows that 1.35 ± 1.05 facemasks per capita per day will be used if an economically active population is taken into account. It will be reduced to 0.54 ± 0.56 per capita per day if the entire population is considered. Both calculations result in an estimate of nearly 12 million facemasks per day (Table 2). However, this includes fabric/cloth masks, hence single-use facemasks per day being used in Sri Lanka is 10 million (0.46 ± 0.46 single use facemasks per capita per day). A leading facemask manufacturer was contacted by the authors to obtain the manufacturers' estimate of market demand and he stated that expected demand of surgical and N95 masks together in Sri Lanka varies between 10-12 million per day. Besides, Selvaranjan et al. (2021) estimate that the Sri Lankan population uses 14 - 70 million facemasks per week, and our estimates reach the maximum of their estimate, reaching 70 million per week.

Table 2
Population statistics and estimated use of facemasks, gloves, face shields, and hand sanitizer bottles (nationally and provincially)

Sri Lanka and provinces	Sri Lanka	Western province (W)	Central province (C)	Southern province (S)	Northern province (N)	Eastern province (E)	North Western province (NW)	North Central province (NC)	Uva province (UVA)	Sabaragamuwa province (SA)
Total population (2020) (Million) [a]	21.92	6.17	2.78	2.67	1.15	1.75	2.56	1.39	1.39	2.07
Urban population [b] (%)	18.20	38.80	10.50	10.60	16.70	25.10	4.10	4.00	5.50	6.00
Economically active population (%) [b]	38.60	39.97	38.17	38.12	33.07	32.76	38.42	40.25	40.81	40.94
Estimates made using Eq. 1 and Eq. 2 (Total number of items used daily)										
Estimates based on Eq. 1(Millions)	3.19	1.91	0.23	0.23	0.15	0.35	0.08	0.04	0.06	0.10
Estimates based on Eq. 2 (Millions)	1.23	0.76	0.09	0.09	0.05	0.11	0.03	0.02	0.02	0.04
Estimates made using gathered data (Total number of items used daily)										
Facemasks - Considering whole population (Millions) – Eq. 3	11.76	3.31	1.49	1.43	0.62	0.94	1.38	0.74	0.74	1.11
Facemasks - Considering economically active population (Millions) – Eq. 4	11.43	3.33	1.43	1.37	0.51	0.77	1.33	0.75	0.76	1.14
Gloves (Millions) – Eq. 5	0.22	0.06	0.03	0.03	0.01	0.02	0.03	0.01	0.01	0.02
Face shields (Million) – Eq. 5	0.29	0.08	0.04	0.04	0.02	0.02	0.03	0.02	0.02	0.03
Empty sanitizer bottles (Millions) – Eq. 5	0.73	0.21	0.09	0.09	0.04	0.06	0.09	0.05	0.05	0.07

Sources: a- Brinkhoff (2021). https://www.citypopulation.de/en/srilanka/cities/; b- Department of Census and Statistics, Sri Lanka, 2012.

Several estimates made on the number of facemasks discarded per day for seven countries in Asia are compared in Table 3. All estimates were made using Eq. 1. Hantoko et al. (2021) does not display the values used for facemasks acceptance rate and daily facemask use per capita per day. However, calculations indicated that they have used 80% facemask acceptance rate and two masks per capita per day. Sangkham (2020) and Haque et al. 2021 have used 80% facemask acceptance rate and one mask per capita per day. Hence, Hantoko et al. (2021) estimates twice higher values than Haque et al. (2021) for India, Pakistan, Bangladesh and Indonesia.

Table 3
Comparison of several estimates made by previous studies on facemask use

Facemasks use (Number per day) (Estimate by Sangkham 2020) (Millions)	17	381	61.7	99.1	10.22	159	989
Facemasks use (Number per day) (Estimate by Haque et al. 2021) (Millions)	-	386.4	61.8	51.4	-	122.5	-
Facemasks use (Number per day) (Estimate by Hantoko et al. 2021) (Millions)	6.18	777	125	103	57	246	1404
Population (Millions)	21	1387	223	165	70	273	1439
Urban population (%)*	18 (100)	35	35	39 (75)	51 (18)	56 (73)	61 (86)

* *Values obtained from* https://www.worldometers.info/population/asia/ *are shown outside of the parenthesis. Sangkham (2020) used different percentages of urban population and values used by him were shown in parenthesis when they are different. Hantoko et al. 2021 and Haque et al. 2021 has used values outside of the parenthesis.*

However, Sangkham (2020) different values than other two for urban population percentage (Table 3), hence his estimates are different from others. For example, Sangkham (2020) uses Eq. 1 to estimate daily facemask use in Sri Lanka and the estimate is 17 million per day. But, Sangkham (2020) use the percentage of the urban population in Sri Lanka as 100%. Yet, it is not accurate for Sri Lanka according to available data and author's experience. The urban population in Sri Lanka is 18.2% (Department of Census and Statistics-Sri Lanka 2012; Worldometer 2021), hence considered as a country with a low urbanized population. The definition of urban areas in Sri Lanka is areas controlled by municipal councils and urban councils (Department of Census and Statistics Sri Lanka 2010). The other non- urban areas fall on to the category of divisional councils. However, there are many divisional councils with higher population densities and populations that travel to work. Therefore, the estimated daily use of facemasks considering the percentage of the urban population in Sri Lanka is very low compared to the data collected by our study.

Finally, Table 3 shows that estimates made with different assumptions for the same country are drastically varied depending on the assumptions made by the studies. In Sri Lanka, we observed that repetitive use of surgical and N95 facemasks (Fig. 1), hence resulting 0.5 masks per capita per day, when entire

population is considered. This might be similar to the other developing countries where income is low, hence having affordability issues. Regrettably, surgical facemasks, which were supposed to use once, are used for two days or more by nearly 20% of the sample (Fig. 1).

Torres and De-la-Torre (2021) propose a modification to Eq. 1 adding economically active populations as a parameter to the equation. Daily facemask use estimated by Eq. 2 in Peru is equivalent to half of the population (Torres and De-la-Torre 2021) because the percentage of the urban population is higher (nearly 70% on average in Peru) and EAP is also higher compared to Sri Lanka (56% on average in Peru and 38% on average in Sri Lanka). But, Eq. 2 reduces the estimate further for Sri Lanka. Hence, we suggest that Eq. 1 and Eq. 2 will estimate lower values of facemask usage in countries when percentage of urban population is considered to be low.

Regarding gloves, face shields and hand sanitizer bottles, 66%, 34%, 18% families do not use them respectively. Therefore, the probability of usage of gloves as a safety measure is very low. However, use of face shields and use of hand sanitizers is much higher. According to the observations made in society, senior citizens and children use face shields the most. As per the observations, except healthcare professionals, people who handle cash, super market workers etc. use gloves as a safety measure. Monthly per capita use of gloves, face shields and sanitizer bottles can be estimated as 0.34 ± 0.69, 0.43 ± 0.63 and 0.97 ± 0.83, respectively. Hence, 0.2-0.3 million gloves and face shields and 0.7 million empty hand sanitizer bottles are used in Sri Lanka within a day (Table 2). Although many studies limited to estimate the use of facemasks, Haque et al. (2021) estimates that Bangladesh discard 1.6 million empty hand sanitizer bottles, 6.3 million surgical gloves and 40.5 million single use polythene gloves per day.

Provincial variation in PPE use is estimated (Table 2) because population density variation across provinces influences in the difference in the number of PPE used per day. The western province generates the highest amount of PPE associated waste, because it is the most populated area in the country, although the land extent is comparatively low (Fig. 2). However, western province has the highest solid waste collection rate and benefited with the best solid waste management methods in the country.

There are 4,063,685 school students in Sri Lanka as of 2020 (Statistics Branch of Ministry of Education of Sri Lanka 2020), and schools were fully closed for 28 weeks and partially closed for 15 weeks as of March 2021(UNESCO 2021) due to the pandemic situation. However, as of November 2021, schools were not yet fully open for the second term. Hence, the use of facemasks and other PPE by school children may not be counted under our estimation, since school children remain at home for a long period. Therefore, we can assume that the opening of schools will result in a further increase in the use of PPE and the use of hand sanitizers.

Current practices in disposal of waste associated with PPE use in household level

In almost all provinces of Sri Lanka, burning is the most common disposal method of used facemasks, followed by handing over to municipal solid waste collection (Fig. 3). Only a small percentage of households bury their waste in pits. The only exception is the Eastern province, where 55% of families hand over used facemasks to municipal solid waste collection and only 30% burn them (Fig. 3). As far as gloves, face shields, and sanitizer bottles are considered, the rate of burning is low. Yet, out of the families who use gloves, face shields and sanitizer bottles, 33% of families burn used gloves, 18% of families burn used face shields and 13% of families burn hand sanitizer bottles island wide. Very small percentages of people declare that they throw away PPE related waste without care (0.03%), while it is raised to 0.08% when it comes to plastic sanitizer bottles (Fig. 3).

In fact, different provinces in Sri Lanka have different municipal solid waste collection rates, leading different percentages of people who are left out to manage solid waste on their own. The western province has the highest municipal solid waste collection rate in Sri Lanka at 51%, and the second highest is the Eastern province at 44%. Thereafter, the northern province has 31%, followed by all the other provinces vary from 16-23%, with the north-central province having the lowest, at 15% (JICA 2016). Within a particular province, solid waste collection rates vary dependent on the type of local authority controlling the area. Accordingly, municipal solid waste collection services are provided to 50-90% of the population living in municipal council and urban council areas, while 20-75% of people receive solid waste collection facilities when they are living in divisional council areas (Unpublished data). The variation is very large because the level of service is drastically different in different provinces. The most common solid waste collection frequency in the country is once a week, while there are small numbers of families that receive the collection service twice a week or daily.

Municipal solid waste collected by many local authorities in Sri Lanka is dumped in open dumps; there are only very few exceptions where sanitary landfills are used. The Greater Colombo and Colombo Metropolitan areas in western province generate the largest amount of waste and dispose the waste into Aruwakkalu sanitary landfill and Kerawalapitiya incineration plant. Therefore, in most of the occasions, disposal of used PPE, especially facemasks with other municipal solid waste, may pose a threat to public health in different ways. Handling solid waste by collection crews may expose them to the virus, openly dumped waste may be accessed by waste pickers for recyclable materials, stray animals may gain access to waste dumps, and contact with contaminated PPE will increase the risk, as suggested by Nzediegwu and Chang (2020). However, more serious and prolonged issues might be created due to the generation of PPE-associated waste in the long run, because most of them are single-use plastics (Sangkham 2020; Torres and De-La-Torre 2021). Most importantly, disposed face masks are a potential source of micro plastic fibers that may be released into the environment (Fadare and Okoffo 2020). However, open burning of PPE also causes harmful gases and toxins to be released into the environment (Sarkodie and Owusu 2021). Therefore, emerging challenges in managing waste associated with PPE need to be addressed during the pandemic as well as after the pandemic. Thus, improvements to waste handling policies as well as clear guidelines on separation, collection, and disposal of PPE-associated waste should be added to the pandemic control guidelines.

Drawbacks identified and recommendations

Currently, there is a guideline issued by Central Environmental Authority of Sri Lanka to handle healthcare waste generated in households under self-quarantine and key information in the guideline are shown in Fig. 4 (CEA 2021). Even though it is in place for households under self-quarantine, there is no any guidance provided to the general public to dispose their PPE related waste otherwise. In our study, 66.5% of families stated that they separate their PPE related

waste from other municipal solid waste; yet, separate collection is not taken place. Unidentified and symptomless, but infected people are there in the society and contaminated PPE used by them enter into municipal solid waste because of this practice.

Major drawbacks identified in disposal of PPE associated waste in household level in Sri Lanka is discarding PPE related waste with household waste, no use of sealed bags, not ensuring storage period of 72 hours before handing over to collection facilities and improper disposal of this waste with collected municipal solid waste. As per author's knowledge no local authority practice the collection and disposal of household healthcare waste separately under pandemic conditions.

Since expensive measures are impossible under current economic condition of the country, we suggest implementation of waste management guidelines and practices utilizing existing resources (Table 4). If PPE associated waste is collected separately issuing clear guidelines to the people, then coverage of waste collection (only for PPE associated waste) within the country can also be increased hence reducing self-management methods such as open burning. However, above-mentioned recommendations only address the issue of spread of COVID 19 through PPE waste and unable to tackle increase of plastic waste generation due to pandemic condition.

Table 4
Recommendations for facemask and gloves waste management to minimize possibilities of the spread of COVID 19 via solid waste in Sri Lanka

Issue identified	Recommendations	Goal
Multiple use of surgical face masks and N95 face masks (Our data shows nearly 20% of people reuse surgical/N95 masks for more than 2 days.)	Clear guidance to general public on reuse of facemasks (Heat treatment, Steaming), hence increasing public awareness.	Reduce waste generation by reuse of facemasks, while ensuring public health
41% of families do not use fabric masks.	Providing clear guidance on the safety of using fabric masks under which condition. (UN (2020) recommends the use of fabric/cloth masks for the general public.)	General public is afraid using fabric/ cloth masks believing they are not providing them required safety. Hence, if public awareness improved then rate of reusable masks can be increased reducing waste generation.
Dumping household healthcare waste with municipal solid waste	Local authority shall issue waste separation guidelines similar to households under self-quarantine.	
Collection of mixed solid waste with less or no precaution	Separated waste can be collected as a special waste collection in a pre informed day. Providing special bins in public places and designated collection points for people to dump PPE waste only.	This may help in increasing the coverage of waste collection service only for waste associated with PPE. This will ensure collection crew will use PPE, because in Sri Lanka there are instances collection crew does not use protective cloths except gloves. Separate collection will increase their vigilance.
Open dumping of PPE associated waste with other waste	Once separation takes place the amount of waste needed to handle with care is well-identified and low quantity. Then safe burying or applying thermal treatment will be feasible.	This may reduce the risk exposure of general public and scrap collectors come into contact with this waste.
Large population is left out for self management of PPE associated waste	Collect PPE waste on specially pre-allocated dates. Providing special bins in public places and designated collection points for people to dump PPE waste only.	Increase the coverage of waste collection service for PPE associated waste only.

Handling plastic waste

Facemasks are the major component of PPE associated waste and the one liable to contaminate the most. Among the other PPE associated waste, face shields and sanitizer bottles are most probably less contaminated, but made of plastics. According to our estimates Sri Lanka generates 65 metric tonnes per day facemask waste and 88.5 metric tonnes of plastic waste due to PPE use (Table 5). It should be noted that this is in addition to the plastic and polythene waste generated under normal circumstances. Further, packaging waste quantity may have been increased because of elevated online purchase rates during pandemic situation.

Table 5
Estimate of generation of plastic waste in Sri Lanka due to PPE use

Item	Material	Weight of a unit (g)	Number of items used per capita per month [d]	Waste generated (Metric ton/day)	Waste generated (Metric ton/year)
Surgical Face masks	Polypropylene	3.5[a]	11	26.95	9836.75
N 95 Face masks	Polypropylene	18.14[a]	3	38.09	13904.31
Face shield	Polycarbonate and Polyester	33.6[b]	0.4	9.97	3638.32
Single Use polyethylene gloves	Polyethylene	2.5[c]	0.3	0.53	191.63
Sanitizer bottles	Polyethylene tetraphthalate	18.5[c]	12.95	4726.75	
Note: Weights were as given by Slevaranjan et al. 2021 (a), Al-Omren et al. 2021 (b), Haque et al. 2021(c).					

Since incineration is not the general practice in the country for waste disposal, it is not that easy to implement the facilities in short term. However, implementation of small-scale incinerators can be considered, at least several units for a province specially targeted to dispose healthcare waste generated in households only, because we have now spent almost two years with pandemic condition hence generating 33,300 metric tonnes of PPE associated waste per year. Although this waste amount is small compared to other South Asian countries, Sri Lanka is a small country with 65,610 km^2 housing a population of 21 million.

As a solution to excessive plastic use, the concepts of production of bio based membranes for facemasks is initialized, but the cost of production may surpass that of conventional plastics, hence limiting the actual production (Terres and De-La-Torre 2021). However, energy recovery via pyrolysis may be a viable alternative to landfilling of plastic waste including medical waste (Qin et al. 2018) and affordable for developing countries.

Conclusion

The estimated daily use of facemasks, gloves, face shields and sanitizer bottles in Sri Lanka is 12 Mn, 0.22 Mn, 0.39 Mn and 0.73 Mn respectively. The estimates made in our study regarding facemask use in Sri Lanka are much higher than the estimations made by the most commonly used equations, and it is suggested that the use of percentage of the urban population as a parameter will underestimate the use of facemasks in countries with a low urban population. The percentages of families using gloves, face shields, and hand sanitizer bottles are 34%, 66%, and 82%, respectively. Regarding the disposal of used PPE, 55% of facemasks were burnt at their homes and open burning is the most common disposal method in Sri Lanka for facemasks and gloves. However, the vast majority of people hand over sanitizer bottles and face shields to municipal solid waste collectors at the end of use. Clear guidelines are available in Sri Lanka to handle PPE associated waste generated in households subjected to self-quarantine. However, they are not applied in handling PPE associated waste generated in other households. It is recommended to handle waste associated with PPE according to guidelines, making sure discarded PPE may not impose threat of transmitting COVID 19 to society, specially, municipal waste collection crews. It is estimated that 88.5 metric tonnes per day additional plastic waste is generated in Sri Lanka a day due to COVID 19 induced PPE use and end up on land or subjected to open burning.

Declarations

Ethical Approval

Not applicable

Consent to participate

Participation in the study was completely voluntary.

Consent to publish

Not applicable.

Authors Contributions

All authors contributed to the study conception, design and data collection. K.C. Ellawala and R.D.U.I. Rajapakse performed material preparation and analysis. T. Nilojan prepared the figures. K.C. Ellawala and G.N. Samarasekara wrote the first draft of the manuscript. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

Abbasi SA, Khalil AB, Arslan M (2020) Extensive use of face masks during COVID-19 pandemic: micro-plastic pollution and potential health concerns in the Arabian Peninsula. Saudi J Biol Sci 27:3181–3186. https://doi.org/10.1016/j.sjbs.2020.09.054

Akhbarizadeh R, Dobaradaran S, Nabipour I, Tangestani M, Abedi D, Javanfekr F, Jeddi F, Zendehboodi A (2021) Abandoned Covid-19 personal protective equipment along the Bushehr shores, the Persian Gulf: an emerging source of secondary microplastics in coastlines. Mar Pollut Bull 168:112386. https://doi.org/10.1016/j.marpolbul.2021.112386

Al-Omran K, Khan E, Ali N, Bilal M (2021) Estimation of COVID-19 generated medical waste in the Kingdom of Bahrain. Sci Total Environ 801:149642. https://doi.org/10.1016/j.scitotenv.2021.149642

Benson NU, Fred-Ahmadu OH, Bassey DE, Atayero AA (2021) COVID-19 pandemic and emerging plastic-based personal protective equipment waste pollution and management in Africa. J Environ Chem Eng 9(3):105222. https://doi.org/10.1016/j.jece.2021.105222

Brinkhoff T (2021) Sri Lanka. https://www.citypopulation.de/en/srilanka/cities/. Accessed 26 October 2021

Central Environmental Authority (CEA) - Sri Lanka (2021). http://www.cea.lk/web/images/news/2020/MSW_Guide_Covid-19_11th_April_____final.pdf. Accessed 26 October 2021

Department of Census and Statistics, Sri Lanka (2010) Sri Lanka Census of Population and Housing - 2011. http://www.statistics.gov.lk/pophousat/cph2011/index.php?fileName=ConceptsandDefinitions&gp=StudyMaterials&tpl=2. Accessed 26 October 2021

Department of Census and Statistics - Sri Lanka (2012) Census of Population and Housing Sri Lanka - 2012. http://www.statistics.gov.lk/pophousat/cph2011/pages/activities/Reports/SriLanka.pdf. Accessed 26 October 2021

Fadare OO, Okoffo ED (2020) Covid-19 facemasks: A potential source of microplastic fibers in the environment. Sci Total Environ 737:140279. https://doi.org/10.1016/j.scitotenv.2020.140279

Hantoko D, Li X, Pariatamby A, Yoshikawa K, Horttanainen M, Yan M (2021) Challenges and practices on waste management and disposal during COVID-19 pandemic. J Environ Manag 286:112140. https://doi.org/10.1016/j.jenvman.2021.112140

Haque MS, Sharif S, Masnoon A, Rashid E (2021) SARS-CoV-2 pandemic-induced PPE and single-use plastic waste generation scenario. Waste Manag Res 734242X20980828. https://doi.org/10.1177/0734242X20980828

JICA (2016) Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka. https://openjicareport.jica.go.jp/pdf/12250213.pdf.

Kampf G, Todt D, Pfaender S, Steinmann E (2020) Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. J Hospital Infect 104 (3):246–251. https://doi.org/10.1016/J.JHIN.2020.01.022

Kotrlik J, Higgins C (2001) Organizational research: determining appropriate sample size in survey research. Inf Technol Learn. Perform J 19 (1):43

Nzediegwu C, Chang SX (2020) Improper solid waste management increases potential for COVID-19 spread in developing countries. Resour Conserv Recycl 161:104947. https://doi.org/10.1016/j.resconrec.2020.104947

Qin L, Han J, Zhao B, Wang Y, Chen W, Xing F (2018) Thermal degradation of medical plastic waste by in-situ FTIR, TG-MS and TG-GC/MS coupled analyses. J Anal Appl Pyrolysis 136:132–145. https://doi.org/10.1016/j.jaap.2018.10.012

Sangkham S (2020) Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. Case Stud Chem Environ Eng 2:100052. https://doi.org/10.1016/j.cscee.2020.100052

Sarkodie SA, Owusu PA (2021) Impact of COVID-19 pandemic on waste management. Environ Dev Sustain 23:7951–7960. https://doi.org/10.1007/s10668-020-00956-y

Selvaranjan K, Navaratnam S, Rajeev P, Ravintherakumaran N (2021) Environmental challenges induced by extensive use of face masks during COVID-19: a review and potential solutions. Environ Chall 3:100039. https://doi.org/10.1016/j.envc.2021.100039

Statistics Branch of Ministry of Education of Sri Lanka (2020) Annual School Census of Sri Lanka, Final report – 2020, Ministry of Education. http://www.statistics.gov.lk/Education/StaticalInformation/SchoolCensus/2020. Accessed 26 October 2021

Torres FG, De-la-Torre GE (2021) Facemask waste generation and management during the COVID-19 pandemic: An overview and the Peruvian case. Sci Total Environ 786:147628. https://doi.org/10.1016/j.scitotenv.2021.147628

UN (2020) Use of Masks for UN Personnel in Non-healthcare Settings in Areas of COVID-19 Community Transmission. Accessed 26 October 2021

UNESCO (2021) Education: From Disruption to Recovery. https://en.unesco.org/covid19/educationresponse#durationschoolclosures. Accessed 26 October 2021

Worldometer, 2021. Population: Asia. https://www.worldometers.info/population/countries-in-asia-by-population/. Accessed 26 October 2021

Zand AD, Heir AV (2021) Emanating challenges in urban and healthcare waste management in Isfahan, Iran after the outbreak of COVID-19. Env Tech 42(2):329-336. https://doi.org/10.1080/09593330.2020.1866082

Figures

Figure 1

Duration of using a surgical/N95 facemask

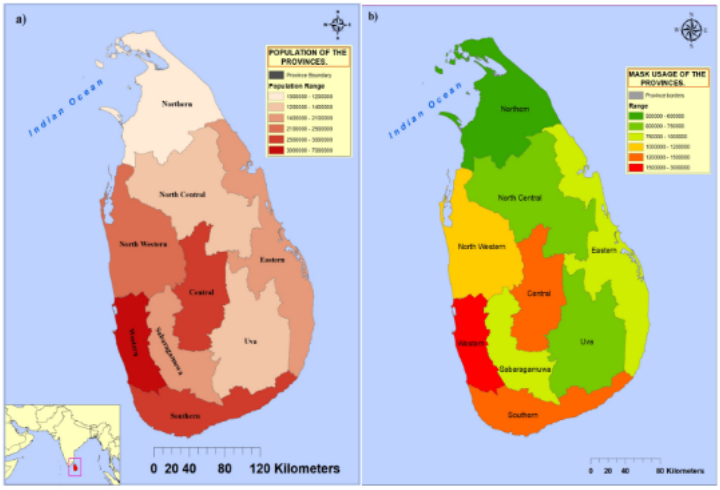

Figure 2

Map of Sri Lanka with provincial (a) population distribution and (b) facemask use

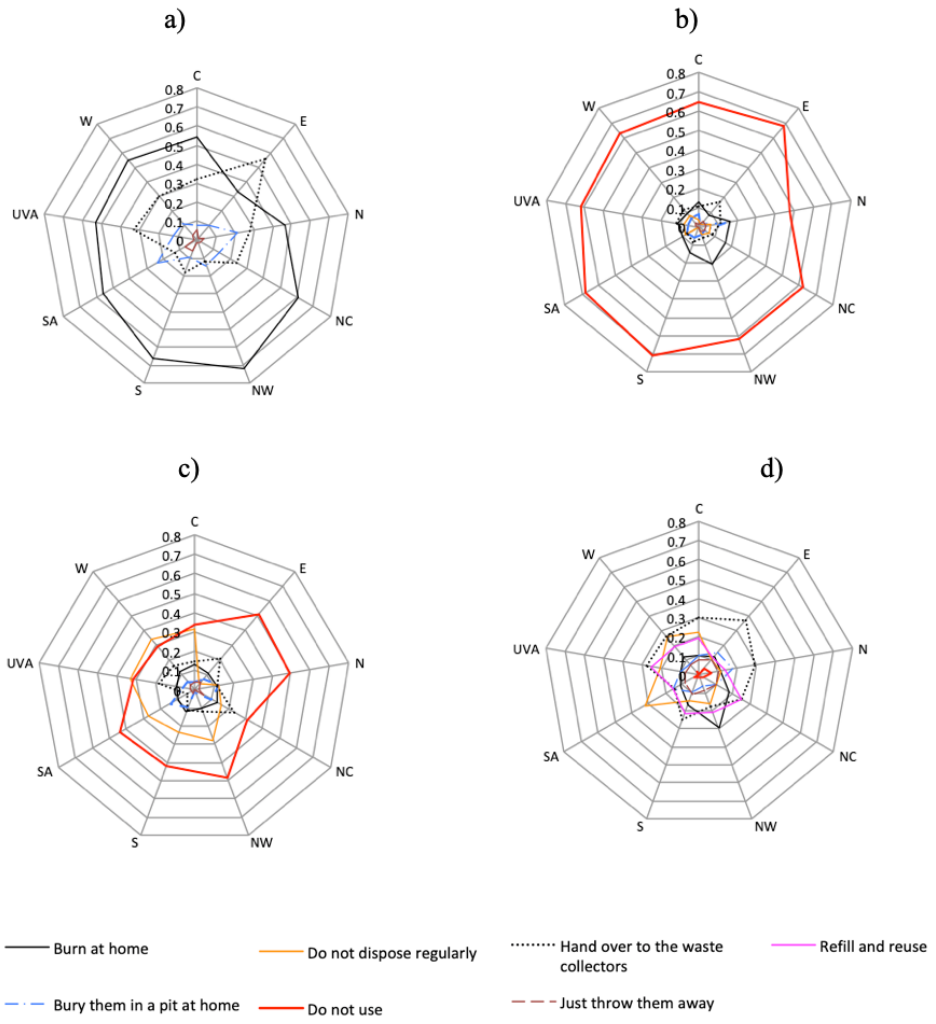

Figure 3

Disposal methods used for various types PPE and disposal distribution by province, a) facemasks, b) gloves, c) face shields, d) sanitizer bottles (Values shown are population share which use each disposal method)

Note: Western province –W, Central province – C, Southern province –S, Northern province -N, Eastern province – E, North Western province -NW, North Central province – NC, Uva province – UVA, Sabaragamuwa province - SA

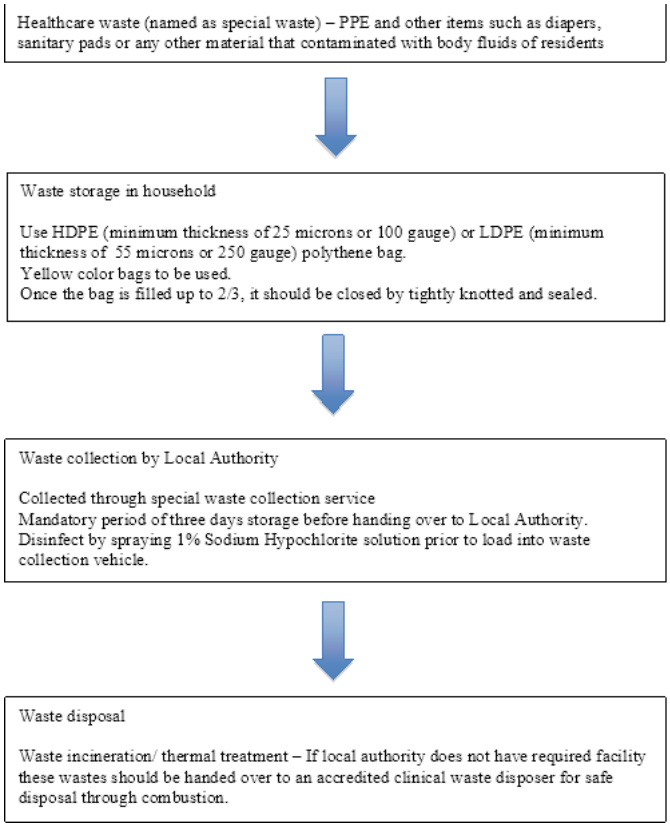

Figure 4

Sri Lankan guidelines issued for handling waste associated with PPE use in households subjected to self-quarantine