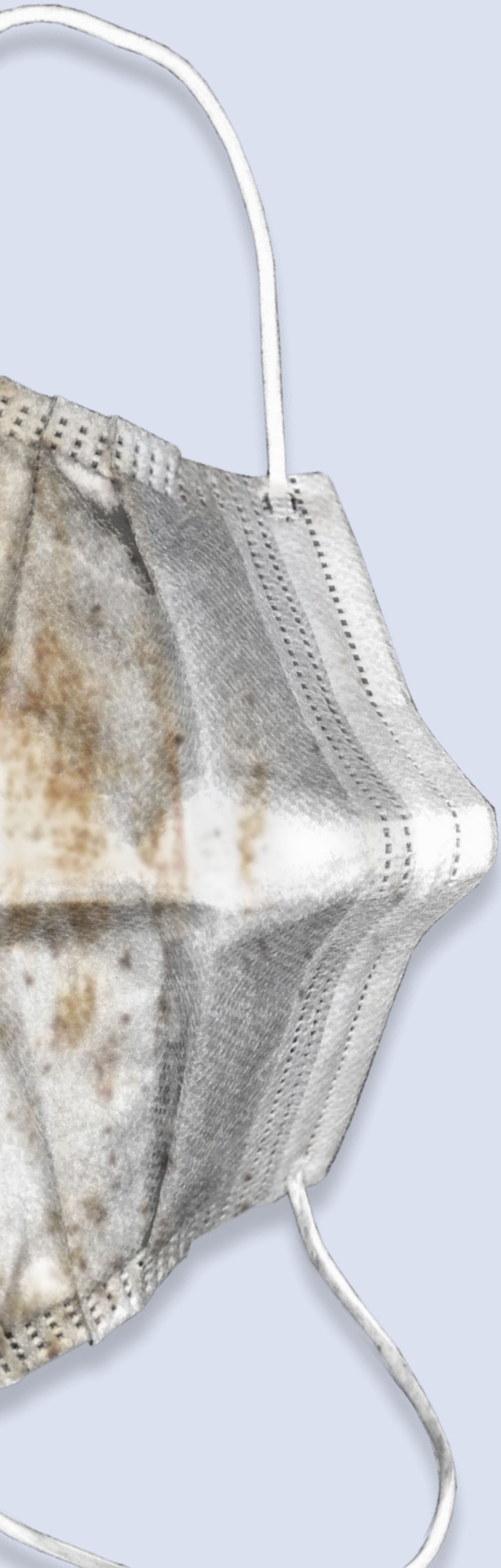

World Health Organization

GLOBAL ANALYSIS OF HEALTH CARE WASTE IN THE CONTEXT OF COVID-19

STATUS, IMPACTS AND RECOMMENDATIONS

GLOBAL ANALYSIS OF HEALTHCARE WASTE IN THE CONTEXT OF COVID-19: STATUS, IMPACTS AND RECOMMENDATIONS

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SUMMARY

Globally, safe waste management services for healthcare waste are lacking, especially in least developed countries. The latest available data (from 2019) indicate that 1 in 3 healthcare facilities globally do not safely manage healthcare waste. The COVID-19 pandemic has led to large increases in healthcare waste, straining under-resourced healthcare facilities and exacerbating environmental impacts from solid waste. This report aims to quantify the additional COVID-19 healthcare waste generated through the UN procurement system, describe current healthcare waste management systems and their deficiencies, and summarize emerging best practices and solutions to reduce the impact of waste on human and environmental health.

Healthcare waste volumes generated from personal protective equipment (PPE), COVID-19 testing and vaccinations from March 2020 to November 2021 are based on data from the United Nations (UN) COVID-19 Supply Portal. The analysis does not consider the much larger amounts of COVID-19 commodities that have been procured outside the UN system, nor COVID-19-related waste generated by the public, including use of medical masks.

Scalable and environmentally sustainable solutions exist and are drawn, in part, from country case studies.[1] These include manufacture and use of safe, reusable PPE items; reduced and more sustainable packaging; centralized treatment and use of non-burn waste treatment technologies; and local production and just-in-time shipments. Final recommendations include strengthening coordination, monitoring, training and behaviour change, and investments, and building on actions in the *WHO manifesto for a healthy recovery from COVID-19* (1), as well as a recent report by the International Finance Corporation Global PPE Platform (World Bank Group) on innovation in manufacturing PPE (2). They target the global, national and facility levels to promote a "win–win" scenario for keeping healthcare workers and health users safe while also supporting environmental sustainability.

[1] Case studies are drawn from Colombia, England, Ghana, India, Lao People's Democratic Republic, Liberia, Madagascar, Malawi, Nepal, the Philippines and Western Europe. Several of these elaborate on case studies shared in the WHO/UNICEF 2020 Global progress report on WASH in health care facilities (**https://www.who.int/publications/i/item/9789240017542**).

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ACRONYMS

CTC	COVID-19 treatment centre
DOH	Department of Health
GTC	guanidinium thiocyanate
PCR	polymerase chain reaction
PPE	personal protective equipment
SOP	standard operating procedure
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
WASH	water, sanitation and hygiene
WHO	World Health Organization

BACKGROUND AND CONTEXT

In March 2020, as the COVID-19 pandemic accelerated, the World Health Organization (WHO) warned that severe and mounting disruptions to the global supply of personal protective equipment (PPE) caused by rising demand, panic buying, hoarding and misuse posed a large risk to healthcare workers, patients and communities. Early in the pandemic, healthcare workers were at greater risk of COVID-19 than the general public, in part because of a lack of PPE supplies, limited training in infection prevention and control, inadequate access to basics such as water and soap for hand hygiene and cleaning, and inadequate sanitation.[2] It is estimated that at least 115 000 healthcare workers have died of COVID-19 *(3)*.

The immediate focus of global efforts was to increase availability of PPE. This included establishing a global supply portal, involving seven major United Nations (UN) partners that coordinated PPE donations and shipments according to country needs. In addition, the coalition of global partners aimed to increase PPE production by signalling predicted global needs to manufacturers. As the UN and its Member States grappled with the immediate task of securing supplies and assuring their quality, less attention and resources were devoted to the safe management of COVID-19-related healthcare waste. This was despite the evidence that the majority of healthcare facilities in low- and middle-income countries lacked the capacity to manage existing waste loads, let alone increases in waste volumes. Poor waste management has the potential to affect healthcare workers through needlestick injuries, burns and exposure to pathogenic microorganisms. It may also affect communities living in proximity to poorly managed landfills and waste disposal sites, through contaminated air, poor water quality or disease-carrying pests.

Meanwhile, the environment and climate crisis continues to accelerate. There is growing appreciation that healthcare investments must consider environmental and climate implications, including implications for how PPE is procured, used, managed and treated. The impacts of poor waste management and climate change are felt especially in impoverished communities that lack safely managed, resilient water and sanitation supplies, and have poor-quality health care. Furthermore, since the start of the COVID-19 pandemic, plastic production has more than doubled, raising concerns about both the short-term impacts on fresh water, oceans and air quality (from burning), and the longer-term impacts of persistent nano-plastic particles *(4)*.

This report outlines what is known about the current situation in relation to PPE in the context of the COVID-19 pandemic, highlights innovative solutions and lessons identified, and sets out recommendations for integrating better, safer and more environmentally sustainable waste practices into the current COVID-19 response and future pandemic preparedness efforts.

2 A study in 2020 in the United Kingdom found that healthcare workers were 7 times more likely than the general public to suffer from severe COVID-19 (**https://oem.bmj.com/content/78/5/307**).

WASTE VOLUMES AND PRACTICES ASSOCIATED WITH COVID-19

2.1 GLOBAL STATUS OF HEALTHCARE WASTE MANAGEMENT

Globally, 3 out of 10 healthcare facilities lack systems to segregate waste. In the least developed countries, less than 1 in 3 healthcare facilities have a basic healthcare waste management service *(5)*.[3] Climate change is exacerbating the challenges faced by many healthcare facilities around the world. The increased number and severity of extreme weather events disrupts health services and essential fundamentals for providing these services, including water, sanitation and waste management. At the same time, the healthcare sector is a substantial contributor to greenhouse gas emissions, accounting for approximately 4–5% of total emissions globally *(6, 7)*. Aware of the opportunity to decrease their emissions and related health and environmental damage, a total of 52 countries committed to building and supporting climate-resilient and low-carbon sustainable health systems as part of the official 26th United Nations Conference of the Parties (COP26) Health Programme *(8)*. Furthermore, the health sector is positioned to lead by example in reducing waste sent to landfills – in part because of great concern about the proliferation of plastic waste and its impacts on water, food systems, and human and ecosystem health. WHO guidance exists summarizing the overall approach and suggested interventions to strengthen climate resilience and environmental sustainability of healthcare facilities; this includes healthcare waste management as a key component *(9)*.

(c) WHO/Jin Ni

3 Basic waste management, as defined by the WHO/UNICEF Joint Monitoring Programme, is waste that is safely segregated, treated and disposed of.

2.2 HEALTHCARE WASTE ASSOCIATED WITH COVID-19

The COVID-19 pandemic led to a double burden of an increase in waste plus a reduced capacity of healthcare workers to manage waste because of increased patient loads, COVID-19 work and societal constraints. As a result, safe management of healthcare waste suffered. From March 2020 to December 2021, an estimated 251 788 329[4] confirmed COVID-19 cases have been reported. Many of these require use of PPE by carers. Each of these cases, as well as hundreds of millions more people – because of exposure to COVID-19, travel, work or leisure obligations – will undergo COVID-19 testing. Finally, 8 billion doses of COVID-19 vaccines[5] have been administered, covering 35% of the global population. Billions more are planned. These activities all produce an enormous amount of COVID-19-related waste, a proportion of which is potentially infectious.

Table 1 outlines the main types of healthcare waste related to COVID-19. According to an assessment by the United Nations Development Programme (UNDP) of five Asian cities, COVID-19 increased the amount of hazardous healthcare waste by 3.4 kg/bed/day *(10)*. This is approximately 10 times more than the average volume of hazardous healthcare waste, which ranges from 0.2 to 0.5 kg/bed/day *(11)*. Although such calculations are dependent on a number of variables, including how healthcare facilities classify waste, they highlight the large and sudden increases in waste volumes that have occurred in some cities and countries.

TABLE 1 — **Main types of COVID-19-related healthcare waste**

Item	Type of waste	Requires safe handling and treatment
Mask	Infectious	Yes
Gloves	Infectious	Yes
Gown	Infectious	Yes
SARS-CoV-2 rapid antigen test	Nonhazardous	Most components are recyclable; a very small volume of reagent may require safe handling and disposal if dealing with large numbers of tests.
PCR testing cartridge	Chemical	Yes (contains guanidinium thiocyanate)
Vaccine vial	Nonhazardous	No
Vaccine needle	Sharps	Yes (packaging material is recyclable)
Plastic packing and containers	Nonhazardous	No

Furthermore, public use of PPE globally, especially masks, has increased significantly since the start of the COVID-19 pandemic. One estimate suggests that, based on country mask mandates and public mask use, in 2020, up to 1 601 666 tonnes of masks were used and thrown away daily, or 584 608 090 tonnes in one year *(12)*. Most of the mask waste for disposal is plastic, and a sizeable proportion

4 Global confirmed cases as of 15 November 2021 (**https://covid19.who.int/**).
5 According to WHO, nearly 8 billion doses had been administered as of 7 December 2021 (**https://www.who.int/emergencies/diseases/novel-coronavirus-2019**).

of this waste, especially in low- and middle-income countries with limited waste management systems, ends up polluting terrestrial and marine ecosystems *(12)*.

The initial and sudden rise in COVID-19 cases globally in March 2020 led to major PPE shortages and huge price increases (up to 300%). Shortages were especially acute in low- and middle-income countries that lacked manufacturing capacity, partly because of stockpiling by high-income countries. At the same time, early in the pandemic, rates of infection of healthcare workers were 4 times greater than rates for the general public *(13)*. Thus, the lack of PPE became a life-or-death issue. As a result, UN agencies came together to focus on meeting supply needs. Perhaps understandably, but unfortunately, far less attention and fewer resources were dedicated to other necessary infection prevention and control requirements, to mitigating climate change and to supporting safe waste management. Furthermore, initial unknowns and misinformation about how COVID-19 was transmitted, virus survival in the environment and potential risks posed by COVID-19-related waste led to unnecessary use and overuse of PPE; this continues today (see Table 2 on appropriate use of PPE).

BOX 1 — Guidance on appropriate glove use

Although many of the activities listed in Table 2 do not require use of gloves, all require hand hygiene at the right time using the right technique. WHO guidelines show how to assess the appropriate use of gloves in relation to potential exposure to respiratory particles or other body fluids (14). In general, gloves are recommended for examinations where there is risk of direct exposure to blood, non-intact skin or mucous membranes. Gloves are not recommended for taking temperature and pulse, for vaccinations or for any vascular line manipulation in the absence of blood (refer to Annex 2 for the glove pyramid).

TABLE 2 — Appropriate use of PPE for COVID-19 and sustainable options

Activity	Mask standards and performance	Gloves	Other PPE
Screening patient with suspected COVID-19	Medical mask[a]	No, unless direct exposure to blood or mucous membrane	Depends on risk assessment (eye protection is indicated if physical distancing cannot be maintained)
Caring for patient with COVID-19 in consultation room or general ward	Medical mask	Depends on risk assessment (gloves are indicated as part of contact precautions if direct care is performed)[b]	Depends on risk assessment (gown and eye protection are indicated as part of contact/droplet precautions if direct care is performed)

Activity	Mask standards and performance	Gloves	Other PPE
Caring for patient with COVID-19 in intensive care unit, emergency department, or other area where aerosol-generating procedures are performed	Respirator[c]	Depends on risk assessment (gloves are indicated as part of contact precautions if direct care is performed)	Depends on risk assessment (gown and eye protection are indicated as part of contact/droplet precautions if direct care is performed)
COVID-19 testing	Medical mask	No	Depends on risk assessment (eye protection is indicated if physical distancing cannot be maintained)
COVID-19 vaccination	Medical mask in areas of known or suspected community cluster, or sporadic SARS-CoV-2 transmission. Risk-based approach in areas with no transmission of SARS-CoV-2.	No	Depends on risk assessment
Caring for patient with COVID-19 at home	Medical mask	Depends on risk assessment (gloves are indicated as part of contact precautions if direct care is performed)[b]	Depends on risk assessment (gown and eye protection are indicated as part of contact/droplet precautions if direct care is performed)
Waste worker	Medical mask	Rubber or rubber-coated gloves[d]	1. Fluid-resistant gown, or gown + apron 2. Rubber boots or closed work shoes 3. Eye protection (if risk of splash from organic material or chemicals)
Sustainable option	1. Compostable medical masks 2. Recycled applications exist, including for making moulded plastics or base road construction materials.	Up to 85% biodegradable exam gloves	Market-ready solutions are not widely available for nonwoven textiles; laminated product or films can be replaced with biodegradable polymers.

[a] Medical masks include ASTM F2100, levels 1–3; and EN 14683, types II or IIR.

[b] EN 455, if available; EN 374 in addition.

[c] Also known as a filtering facepiece respirator, N95 or FFP2.

[d] Rubber gloves should be compliant with the following requirements: EN374 for chemical resistance; EN374 minimum biohazard level 3 performance; EN388 minimum 3111 for abrasion, blade cut, tear and puncture; EN 420.

Sources: WHO *(15, 16)*.

Many facilities and countries mistakenly classified 100% of COVID-19 healthcare waste as hazardous, rather than the 10–15% level typically generated from routine health service provision. A number of major cities and countries that have experienced a large number of cases issued guidance that all waste generated by COVID-19 patients should be classified and treated as infectious. This is despite the fact that SARS-CoV-2 is an enveloped virus, which means that it is inactivated relatively quickly by environmental factors such as sunlight or heat. Most evidence indicates that the main route of transmission of the virus is directly from person to person through exhaled respiratory particles, not fomites. In New Delhi, for example, classifying all COVID-19 waste as infectious nearly quadrupled waste volumes during the peak of the outbreak in May 2021 *(17)*; however, the pause in many routine health services in New Delhi did reduce amounts of other healthcare waste. Since the beginning of the pandemic, WHO has stated that extra or special procedures beyond normal classification into infectious and non-infectious are not needed for waste from COVID-19 patients *(18)*.

(c) WHO/ Lisette Poole

2.3
GLOBAL SHIPMENTS OF PPE FOR COVID-19[6]

In March 2020, seven major UN and global health partners came together to create a common system to respond to requests for PPE for COVID-19.[7] Based on this system and the accompanying database, WHO has calculated the amount of PPE sent to countries to address COVID-19 testing, care and treatment. The amounts sent were according to country requests, which were often handled by WHO country offices on behalf of ministries of health and in-country health and development partners. The system serves (and continues to serve) as a "last resort" for countries that cannot procure PPE through usual channels. These PPE needs are in addition to what would be needed for routine delivery of healthcare services (e.g. childbirth, surgeries, trauma care).

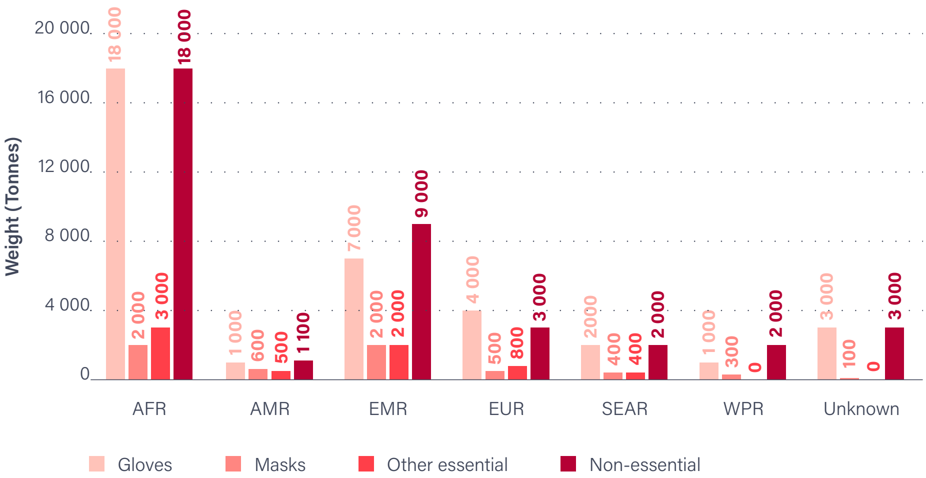
In this report, it is assumed that all single-use PPE will eventually become waste. The volume of testing kits and vaccines that will become waste is based on the components that are single use – largely packaging, vials and syringes.

Fig. 1 presents the global COVID-19-related PPE shipped to WHO regions as of November 2021, divided into essential items (e.g. masks, gloves) and non-essential items. In total, one and a half billion units of PPE, weighing approximately 87 000 tonnes, have been distributed. This is equivalent to 261 747 aeroplanes.[8] The WHO African region has received the largest share (47%), followed by the Eastern Mediterranean (23%), European (10%), South East Asian (6%), Western Pacific (4%) and American (3%) regions. An additional 7% has been distributed to a non-specified region.

Non-essential PPE constitutes slightly less than half (44%; 38 000 tonnes) of the total volume of PPE shipped. Essential PPE constitutes 56% or 49 000 tonnes (Fig. 1). It is important to note that other essential PPE such as goggles, reusable face shields and gowns are not included in this estimate because they are classified as reusable[9] and thus would not be contributing regularly to waste volumes.

6 For a list of countries in each WHO region, see **https://www.who.int/about/who-we-are/regional-offices**.
7 The COVID-19 Supply Portal was established in March 2020 and pulls together requests for, and shipments of, PPE, biomedical, diagnostic and medicine supplies for COVID-19 into one database. The portal facilitates requests for critical supplies from national authorities and all implementing partners supporting COVID-19 National Action Plans, and coordinates the procurement and distribution of supplies. For details, see **https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-operations**.
8 Mass of one 747 aeroplane is 333 000 kg (**https://bmjopen.bmj.com/content/bmjopen/11/7/e048687.full.pdf**).
9 The expected lifetime of reusable goggles, gowns and face masks depends on the product; the decontamination method; presence of excessive and persistent soiling; and degradation of straps, plastics, and so on. For more details, see the WHO guidance Rational use of personal protective equipment for COVID-19 and considerations during severe shortages(**https://www.who.int/publications/i/item/rational-use-of-personal-protective-equipment-for-coronavirus-disease-(covid-19)-and-considerations-during-severe-shortages**).

FIG. 1 — **Volume of COVID-19 gloves and masks shipped to regions, as of November 2021**



AFR: WHO African Region; AMR: Region of the Americas; EMR: WHO Eastern Mediterranean Region; EUR: WHO European Region; SEAR: WHO South-East Asian Region; WPR: WHO Western Pacific Region.

Notes: Masks include respirators and medical masks (three layers). Gloves include surgical and examination gloves. "Other essential" items include gowns, disposable face shields and apron protection. Non-essential PPE includes items such as hair, shoe and boot covers; coveralls; surgical caps; and gloves such as heavy-duty and some types of surgical and examination gloves. Figure includes items that have been prepared, are in transit and have arrived in the country. Unknown are items shipped but for which the ultimate destination was not recorded in the database.

Source: Data are drawn from the COVID-19 **Supply Portal.**

The quantities of gloves procured and delivered to most regions have decreased with time, as shown in Fig. 2(a). Similarly, the quantities of masks ordered through the COVID-19 Supply Portal have declined sharply in all regions, as seen in Fig. 2(b). The total quantity of masks shipped is 5900 tonnes, and the total quantity of gloves is 36 000 tonnes. For gloves, the reduction ranged across the regions from 10% (in the European Region) to 91% (in the Western Pacific Region). The reduction for masks ranged from 81% (in the European Region) to 98% (in the Region of the Americas).

There are a number of possible reasons for the significant decline. First, the majority of PPE was procured and stored at the beginning of the pandemic and then sent out gradually. Second, since the first global wave of COVID-19, supply chains have been strengthened, new manufacturers have been brought on board, and a number of countries are procuring PPE more quickly and cheaply outside the UN procurement system. Data for procurement outside the UN system are more diverse and difficult to obtain, and thus not included in this report. However, global estimates of the volume of disposable mask use by the public indicate that, as a proportion, the volumes of masks shipped by the UN represent a very small percentage (<0.1%) of waste increases due to COVID-19.

FIG. 2 — **COVID-19 PPE procurement by region, 2020 and 2021**

2a. Glove procurement trends by region 2020-2021

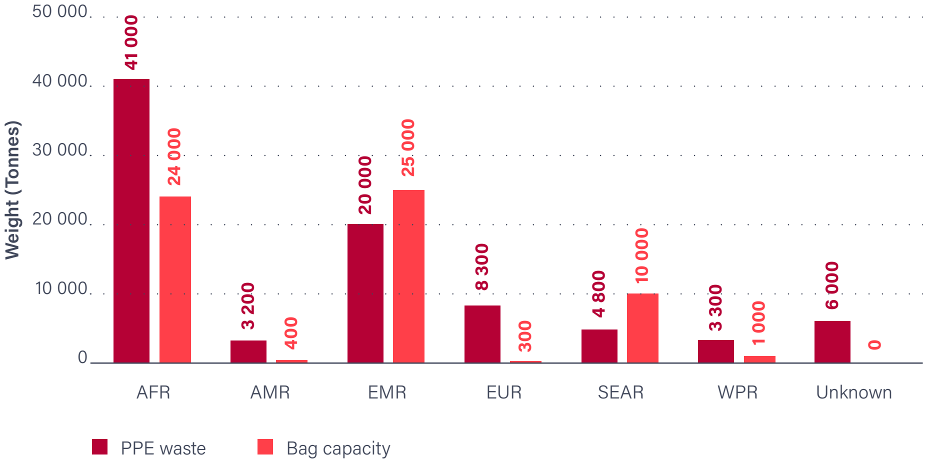
2b. Mask procurement trends by region 2020-2021

AFR: African Region; AMR: Region of the Americas; EMR: WHO Eastern Mediterranean Region; EUR: WHO European Region; Q: quarter; SEAR: WHO South-East Asian Region; WPR: WHO Western Pacific Region.
Note: Data for 2021 are only available up to November.

A comparison between the capacity of biohazard bags requested and the weight of all PPE (essential and non-essential) is shown in Fig. 3. Whereas approximately 87 000 tonnes of PPE (excluding PPE that can be reprocessed or decontaminated before reuse[10]) has been shipped, only 5 million bags, capable of handling 61 000 tonnes of waste, have been requested. This means that 26 000 tonnes of waste may have been generated that cannot be safely bagged or stored.

10 PPE items that can be reprocessed or decontaminated for reuse include apron protection, rubber boots, face shields, goggles, hoods, lab coats, trousers, tunics, triple packaging boxes, powered air purifying respirators (PAPR) and elastomeric respirators.

FIG. 3 — Capacity of biohazard bags versus PPE quantity

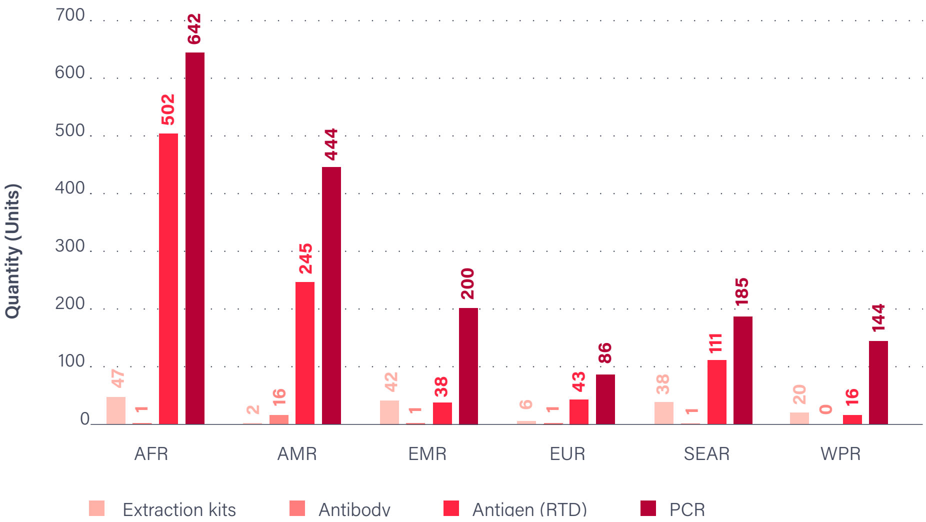


AFR: WHO African Region; AMR: WHO Region of the Americas; EMR: WHO Eastern Mediterranean Region; EUR: WHO European Region; SEAR: WHO South-East Asian Region; WPR: WHO Western Pacific Region.Add

Notes: Unknown are items shipped but for which the ultimate destination was not recorded in the database.

In addition, more than 140 million test kits (Fig. 4 shows the quantity of different types by region), with a potential to generate 2600 tonnes of general waste (mainly plastic) and 731 000 litres[11] of chemical waste – an equivalent of one third of an Olympic-size swimming pool – have been shipped. Approximately, 97% of plastic waste from tests is incinerated *(19)*. This puts a further burden on already strained waste management systems and increases pollution where incineration is not well controlled.

FIG. 4 — Types of test kits shipped, by region



AFR: WHO African Region; AMR: WHO Region of the Americas; EMR: WHO Eastern Mediterranean Region; EUR: WHO European Region; RDT: rapid detection test; SEAR: WHO South-East Asian Region; WPR: WHO Western Pacific Region. PCR: polymerase chain reaction.

As of 7 December 2021, WHO reported that nearly 8 billion doses of vaccine have been administered globally.[12] All vaccinations administered involve syringes and needles and must be disposed of in safety boxes – up to 79 million box-

11 The quantity of waste calculated from the test kits is based on the assumption that each test kit, except PCR kits, generates 11 g of plastic waste. A study by Celis et al. (19) found that each PCR test kit generates 37 g of plastic waste. Additionally, 5 mL of liquid chemicals is generated for all test kits. Refer to **Annex 1** for details.

12 Global estimates on vaccines administered based on WHO COVID-19 data site. **https://www.who.int/emergencies/diseases/novel-coronavirus-2019** Data on distribution of vaccine doses per region were not available at the time of writing.

es have been shipped. These vaccination activities will generate 143 tonnes of additional waste, comprising 87 tonnes of glass vials, 48 tonnes of syringes plus needles and 8 tonnes of safety boxes.

All vaccination efforts should include appropriate plans and resources for safely managing waste that is generated. Vaccination has an impact on PPE waste, which is often unnecessary; for example, WHO does not recommend glove use for vaccine administration, but this appears to be common practice *(20)*.

(c) WHO/ Chiara Luxardo

INNOVATIVE SOLUTIONS FOR IMPROVING ENVIRONMENTAL SUSTAINABILITY OF SAFE HEALTHCARE WASTE MANAGEMENT

Several practical and scalable solutions exist to safer and more environmentally sustainable management of healthcare waste in the context of COVID-19 and more broadly. These solutions include:

- reduction in the amount of unnecessary PPE through safe and rational use, including the application of other infection prevention measures such as hand hygiene;
- use of smaller quantities of, and more sustainable, packaging;
- development and use of safely reusable and easily disinfected PPE (gloves, aprons and masks);
- use of PPE made with a greater proportion of renewable, biobased or recyclable materials;
- investment in recycling systems for general healthcare waste;
- implementation of reverse logistics and centralized treatment of waste using non-burn technologies; and
- investment in local and regional PPE production, and just-in-time shipments.

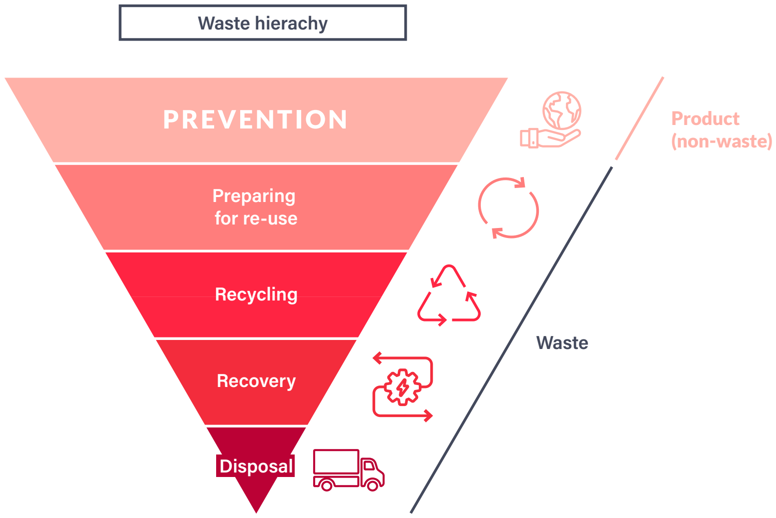
In addition, strengthening healthcare waste systems, through improved and more sustainable standards and regulation, regular monitoring and reporting, and increased investments in safe waste management, alongside other fundamental water, sanitation and hygiene (WASH) and energy infrastructure, and a well-trained, empowered workforce able to safely manage waste and appropriately use PPE are needed. These are further discussed in the global, national and facility recommendations in **section 4**.

Eleven case studies from diverse countries illustrate these innovations in practice (see **Annex 4** for details). For example, in **Madagascar** and Malawi, reverse logistics and centralized treatment allowed waste from smaller facilities to be autoclaved rather than burned. In India and Nepal, recycling of plastics from healthcare waste reduces volumes that need to be treated and generates revenue to support autoclaving. The recycling sector, however, needs to be prioritized and resourced, especially when waste volumes increase. This was not the case in western Europe, and the partial shut-down of the recycling sector had a ripple effect on manufacturers that depend on raw recycled goods. In England, a study detailing how 75% of COVID-19 waste could be avoided through rational use, local manufacturing and safe reuse helped strengthen an existing campaign to reduce unnecessary glove use and improve hand hygiene practices. Furthermore, waste systems strengthening, alongside upscaling of innovations, is important. This includes developing and implementing environmentally sustainable standards (Philippines); strengthening monitoring, accountability training and safe waste practices (Colombia Ghana, Liberia, Nepal and India); and engaging political leadership and effective national partner coordination to dedicate COVID-19 financing for sustainable waste solutions (Lao People's Democratic Republic).

3.1
REDUCTION IN AMOUNT OF UNNECESSARY PPE THROUGH SAFE AND RATIONAL USE

Overuse and misuse of PPE can contribute to spread of potentially pathogenic organisms, especially in the absence of hand hygiene. Preventing and reducing the amount of waste generated, through safe and rational use of PPE, is one of the most effective ways to manage and reduce human and environmental impacts. Sending waste to landfill should be a last resort (Fig. 5).

FIG. 5 — **Waste hierarchy for prioritizing actions to reduce environmental impacts of waste**



Source: European Union *(21)*.

Gloves are a particular PPE item that is often overused or misused. Gloves, in terms of volume, constitute the greatest proportion of PPE waste of all items procured by the UN COVID-19 global system. Understanding when to use gloves to mitigate risk of exposure to body fluids (in addition to hand hygiene) is a critical component of standard infection prevention and control precautions for patient and caregiver safety. Overuse of gloves was a longstanding problem even before COVID-19, resulting in unnecessary financial costs and adverse environmental impacts.

A multimodal approach is a proven way to address glove use and improve hand hygiene. This entails ensuring that appropriate amounts of supplies (including water and soap, or alcohol-based hand rub) are provided in the right places, providing feedback on use through targeted training and monitoring, role modelling, and providing specific reminders that are appropriate in specific settings *(22)*. For example, routine tasks undertaken by healthcare workers where use of gloves and other PPE is inappropriate can be targeted. It is important, however, that safety is not compromised and that supplies are planned for and available where glove use and multiple glove changes are needed in a single patient interaction. A 2021 WHO document aims to address this *(23)*. Similarly, a strategy is necessary to improve the appropriate use of aprons for infection prevention and control.

Safe and rational use of PPE will reduce environmental harms from waste, save money, reduce potential supply shortages and support infection prevention.

3.2 USE OF SMALLER QUANTITIES OF, AND MORE SUSTAINABLE, PACKAGING

Reducing packaging volumes and using more sustainable packing materials for healthcare commodities such as masks, gloves and vaccines is a practical and proven measure to reduce healthcare waste and its environmental impacts. For example, both gloves and masks are often wrapped in plastic bags with a limited number in each bag before these bags are packed into cartons, which are then boxed. Such packaging will lead to unnecessary extra waste and may slow down off-gassing (release of gases, some of which might be harmful) from the manufactured polymer product. Only items that are sterile, such as surgical gloves, should be individually packed. Furthermore, there should be a clear distinction between products sold for public use; those for general, low-risk medical interactions; and those for high-risk medical settings in which packaging as appropriate.

Many high-income countries have had regulations for vaccine packaging in place for more than a decade. These include requirements for more extensive and lower-cost recycling and reuse of packaging components. As with other measures for environmental sustainability, reducing packaging saves significant costs by reducing shipping volumes and weights, as well as handling and disposal of packaging waste. Innovations already in use that can and should be scaled up include using cornstarch-based foam to replace polystyrene in shipping coolers, reducing secondary packaging so that more vaccine vials and boxes can be included, and reusing cold-chain shipping containers *(24)*.

A number of recommendations for reducing packaging and vaccine waste have been under development for several years. One is to maximize vial capacity to increase the number of vaccine doses per vial (e.g. 20-dose vial). Vaccine stability needs to be improved to allow an increase in the number of doses per vial, lengthen shelf life and minimize vaccine wastage *(25)*. Consideration should be given to producing COVID-19 vaccines (and other vaccines) through approaches that do not use syringes and needles – for example, microarray patches and oral administration *(26)*. Microarray patches for vaccine delivery have been noted in the global Vaccine Innovation Prioritisation Strategy; they are a transformational innovation that has the potential to address many of the barriers to immunization identified by low- and middle-income countries, including waste management.[13]

13 The Vaccine Innovation Prioritisation Strategy was developed through a collaboration between the Gavi Secretariat, WHO, the Bill & Melinda Gates Foundation, UNICEF and PATH. See **https://www.gavi.org/sites/default/files/about/market-shaping/VIPS-Alliance-Action-Plan-for-MAPS_Public-Summary.pdf** for further information on vaccine microarray patches.

3.3
DEVELOPMENT AND USE OF SAFELY REUSABLE GLOVES, APRONS AND MASKS

Most high-quality, safe PPE is manufactured for single use. COVID-19-related PPE supply shortages forced both high- and low-income countries to adopt limited reuse of these single-use items. Inherent design elements of single-use items that limit reuse include fit, filtration performance, breathability and contamination. Reuse requires a decontamination process that is safe and standardized, reducing the pathogen burden, while not harming the fit or filtration performance of the PPE, or presenting a residual chemical hazard. In low-resource settings, any decontamination measures need to be simple; most safe decontamination practices currently require complex technology, regular power and water, and skilled operators. More efforts are needed to develop, distribute and use PPE that is designed for safe reuse (see **section 3.1**).

3.3.1
Designing reusable medical and respirator masks for safety and the environment

Current WHO guidance recommends use of either medical or respirator masks, depending on the type of patient interaction and procedure *(27)*. Most of these masks are currently single use. Depending on the number of patients examined, thousands of masks can be discarded in a single day in large hospitals. To combat supply shortages early in the pandemic, a number of complicated disinfection approaches were taken to reuse single-use masks. Evidence indicates that disinfection is costly, requires a context- and mask-specific approach, and offers limited safety *(28)*. Thus, except in the case of extreme shortages, reprocessing of single-use medical and respirator masks is not recommended.

Purpose-designed reusable medical and respirator masks may present a viable option to current single-use items. A number of such masks are currently being developed and piloted. For example, a company in Switzerland claims to produce a medical face mask that filters and deactivates bacteria and viruses – including SARS-CoV-2 – and prevents them from spreading by employing a polycationic surface on the mask.[14] If used daily and washed weekly, the mask can be used 210 times, replacing the need for 210 conventional masks *(29)*.

For aerosol-generating procedures, which pose a higher risk,[15] respirator masks are recommended. Reusable respirator masks are now available; they consist of an outer silicone rubber frame and contain an N95 filter that can be either discarded or sterilized after use. Initial findings on such masks indicate high performance, large cost savings and reductions in waste. A study conducted in the United States found that, if every medical worker used a reusable respirator mask instead of a disposable respirator mask, for all patients encountered during the first 6 months of the pandemic, US$ 4.9 billion would be saved and the waste volume would be reduced from 84 million kilograms to 15 million kilograms *(30)*. Introducing a new product will not solve the problem alone; resources, opportunity and motivation to ensure that reusable components are sterilized sufficiently are also needed.

14 Many countries, such as Japan, require that the antimicrobial layer is the external layer of the mask and does not touch the skin. Furthermore, end-of-life disposal should build in processes to separate the antimicrobial coating before incineration, to ensure that the additive does not break down into cytotoxic chemicals.
15 Examples of aerosol-producing procedures are tracheal intubation, non-invasive ventilation, dental cleaning and other dental procedures. For details, refer to WHO *(15)*.

3.4 USE OF PPE MADE WITH A GREATER PROPORTION OF RENEWABLE, BIOBASED OR RECYCLABLE MATERIALS

Standard, disposable PPE is manufactured using multiple kinds of polymers, rubber, metal and cotton, as well as additives for charge retention and stability. PPE also contains ortho-phthalates and accelerants (e.g. thiurams, thiazoles, carbamates), which lead to environmental harm both during the manufacturing process and in disposal *(31)*. Adverse health effects from these chemicals may include hormone disruption, reproductive and developmental impacts, and kidney toxicity. These materials are often nonrecyclable. However, such materials are important in PPE performance, and fully replacing them with biodegradable components may severely compromise the breathability and filtration capacity of PPE.

To reduce the environmental impacts of PPE, factors to consider include the type of material, production processes, disposal and recycling. Efforts should be made to replace nonfunctional components of PPE with biobased components while maintaining the intended function of the PPE, including safety, filtration and breathability. Less environmentally harmful alternative materials that also meet infection prevention and control standards are available – for example, nitrile, neoprene and polyurethane examination gloves, rather than those containing polyvinyl chloride (PVC) *(32)*. Some manufacturers are using biobased raw materials such as compressed hemp, bagasse, polylactic acid and cellulosic fibres in place of plastic to make medical textiles and masks *(2)*. Incorporating biobased materials into PPE may also lessen the harms from manufacturing and disposal. However, biodegradable materials ideally should be disposed of in separate waste streams to manage methane production; this is often done in high-income countries.

Various strategies to produce PPE that can be recycled are being piloted. Examples are as follows.

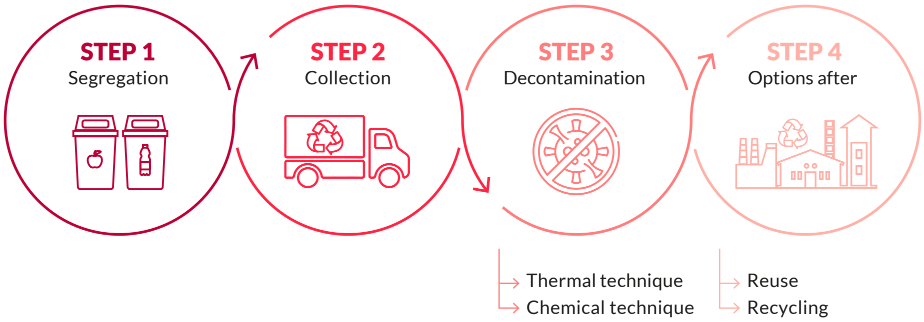
- **Compostable face masks.** These are being produced in France with locally produced hemp fibres with a filtration efficiency of 98% for 3 µm particles and air permeability of 165 L/m² per second for a depression of 100 Pa. The elastic band is recyclable and can be returned to the manufacturer in an airtight plastic bag *(33)*. In Spain, face masks (similar to FFP2 with a filtration capacity of more than 98%) made from natural raw materials have been produced, which are biodegraded within 22 days by industrial composting *(34, 35)*.

- **Recycling of surgical masks.** A company in France collects masks at specific collection points and then stores them for "quarantine" for 4 days. The masks are then ground into small pieces and exposed to ultraviolet light to support decontamination before recycling. The mask material is then mixed with a binding material and transformed into moulded plastic, integrated into textiles or used for building materials. The company recycled 50 000 masks within 3 months in 2020, producing 2000–3000 recycled products *(36, 37)*.

- **Recycling of used medical masks for repurposing as construction materials.** Researchers in Australia found that combining shredded medical masks, which were oven dried for 1 day at 105 °C, with construction materials used for road base and sub-base applications enhances the performance of the road material. It also addresses environmental challenges on two fronts: PPE disposal, and natural resource demand for construction materials, including quarry aggregates *(38)*.

In short, PPE should be made from materials that consistently meet target performance requirements, and that can be easily recycled and decontaminated before being put to other uses. The most widely recycled plastics are polyethylene (LPDE, HDPE), polypropylene (PP) and polyethylene terephthalate (PET). Fig. 6 illustrates the key steps in managing plastic waste from PPE in line with circular economy principles.

FIG. 6 — **Four key steps in managing plastic waste from PPE**



Source: IFC *(2)*.

3.5 REVERSE LOGISTICS AND CENTRALIZED TREATMENT OF WASTE USING NON-BURN TECHNOLOGIES

Reverse logistics uses existing medical supply systems that deliver medical goods (e.g. vaccines, medicines, equipment) to healthcare facilities to transport healthcare waste to a centralized location where it can be safely treated and disposed of. Because waste treatment technologies are expensive and operators need specialized training, it may not be practical or efficient for smaller primary care facilities that generate less waste to have their own systems. Modelling of reverse logistics for healthcare waste in the COVID-19 context has been conducted, providing insights on optimizing costs, better tracking waste volumes generated to ensure sufficient capacity for treatment, and developing organizational strategies for collecting COVID-19 waste from various places (e.g. hospitals, testing centres, quarantine centres), and transporting it to holding and eventual treatment centres *(39)*.

3.6 MORE LOCAL AND REGIONAL PRODUCTION, AND JUST-IN-TIME SHIPMENTS

In 2020, a combination of widespread supply chain disruptions and a surge in demand (by ~280%, from ~100 billion units in 2019 to ~380 billion in 2020) denied entire populations access to high-quality PPE *(40)*. Global platforms for distributing PPE have been critical to filling supply gaps, particularly in low- and middle-income countries. As the pandemic evolves and localized outbreaks become more common, establishing supply centres and portals that are closer to the destination of the PPE may reduce carbon emissions from shipping, and ensure that supplies arrive in a more timely manner to meet near-term needs. Production close to demand can also lead to simpler logistics, and products more appropriate for local settings and needs. More than 60% of global PPE production is in China and the United States – with the exception of gloves, which are mostly made in Malaysia and Thailand (~85%). Procurers should consider offering regional manufacturers preferential access to tenders. The procurement requirements and indicators should consider innovative products that meet the true needs of their users and are environmentally friendly – for example, by considering cost per use rather than initial purchase cost to effectively compare single-use and multiple-use PPE *(41)*.

Example:
Improving local access to certified medical equipment through the Africa Medical Supplies Platform

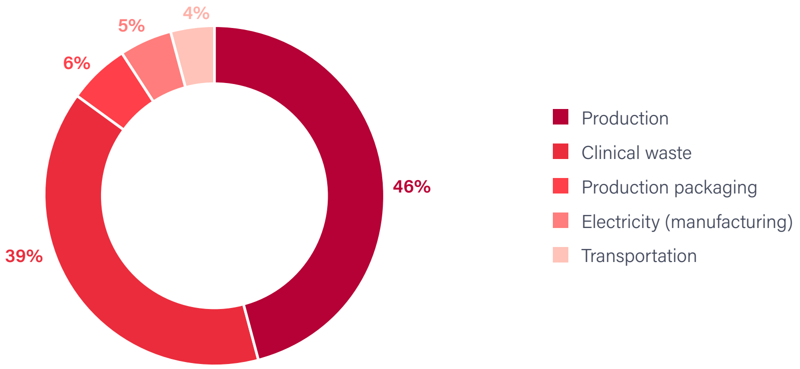
The e-commerce Africa Medical Supplies Platform is a not-for-profit initiative launched by the African Union as an immediate, integrated and practical response to the COVID-19 pandemic. It unlocks immediate access to an African and global base of vetted manufacturers and procurement strategic partners, and enables African Union Member States to purchase certified medical equipment such as diagnostic kits, PPE and clinical management devices with increased cost-effectiveness and transparency. The platform serves as a unique interface that enables volume aggregation, quota management, payment facilitation, logistics and transportation to ensure equitable and efficient access to critical supplies for African governments.[16] The idea is to connect medical suppliers with medical providers and eliminate intermediaries. Purchasing through the Africa Medical Supplies Platform is restricted to governments, national health systems, nongovernmental organizations and donor organizations. There is also a “made in Africa” section so that governments can support local manufacturers of medical supplies.

Example:
Local PPE production in Europe to reduce the health sector’s carbon footprint

A study in the United Kingdom used a “cradle to grave” life cycle assessment to determine the environmental impacts of PPE distributed to health and social care in England during the first 6 months of the COVID-19 pandemic. The base scenario assumed that all products were single use and disposed of as clinical waste in high-temperature incinerators for hazardous waste. At that time, about 80% of the PPE was shipped from Asia to the United Kingdom. The mean contribution to the overall carbon footprint of PPE items in the United Kingdom was 46% for production, 39% for clinical waste, 6% for production of packaging materials, 5% for electricity used in manufacturing and 4% for transport (Fig. 7) *(42)*.

16 The Africa Medical Supplies platform was established by the African Union and is supported by a number of foundations, donors and UN partners. Further details are available at **https://amsp.africa/about-us/**

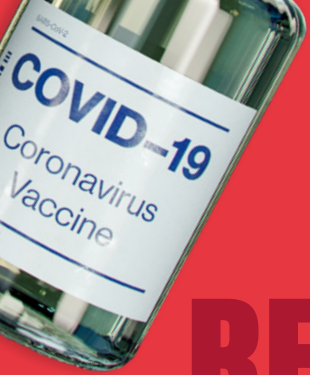
FIG. 7 — **Contribution of different stages of PPE production and use to PPE carbon footprint, United Kingdom**



Based on the calculation model, the carbon footprint of PPE could be reduced by 12% through manufacturing PPE in the United Kingdom, saving 12 491 tonnes of CO_2 equivalents over the 6-month study period. Reductions were due to the elimination of overseas travel (2.4%), alongside use of United Kingdom electricity (9.3%) (which has a higher proportion of renewable sources than most countries of origin assumed in the base scenario). The recent PPE strategy of the United Kingdom Government aims to build a United Kingdom manufacturing base so that there is a resilient domestic supply – with a target of 70% of PPE (excluding gloves) to be manufactured locally *(43)*.

In Germany, the response to PPE shortages was to tender for domestic manufacture of masks and to guarantee prices for all PPE produced until the end of 2021. Around 50 German companies, including technology firms, raw materials suppliers, manufacturers and distributors, have been included in the government scheme to produce 10 million respirator masks and a further 40 million surgical masks. Companies temporarily producing masks were also eligible for the government's subsidy programme, which provides funding of 40% of the cost of machinery, with an additional bonus of 10% if the end-product manufacturer commits to purchasing 70% of its raw materials within the European Union *(44)*.

(c) WHO/ Fabeha Monir



RECOMMENDATIONS

The COVID-19 pandemic has significantly disrupted health systems and, as this report has shown, strained already weak healthcare waste management systems. Although the health sector contribution to COVID-19-related waste is a small proportion compared with the increased volumes generated by the public, it does present an opportunity to direct COVID-19 resources and innovation to sustainably strengthen healthcare waste management, while also putting in place environmentally sustainable policies and practices. Indeed, waste minimization; green procurement; safe reuse, recycling and recovering; and safe healthcare waste management are all key prescriptions in the WHO manifesto for a healthy recovery from COVID-19 *(1)*. This report provides recommendations at three levels: global, national and facility.

4.1 GLOBAL

4.1.1 Strengthen coordination among global health donors, logistics, infection prevention and control, healthcare waste and environment actors

Establishing stronger links between those coordinating supply chains and shipments; those producing guidance on infection prevention and control, PPE, vaccines and diagnostics; those funding COVID-19 health commodities; and those supporting safe and sustainable healthcare waste management would allow better preparedness and budgeting for healthcare waste management. It could also help identify environmental innovations and actions, including eco-packing and reverse logistics, that could save costs and reduce environmental impacts.

4.1.2 Promote and invest in more environmentally sustainable PPE and waste systems

Multilateral institutions recommending use of and procuring PPE, diagnostics and vaccines – including WHO, UNICEF, the Global Fund, Gavi and the World Bank Group – along with bilateral donors and nongovernmental organizations, should better advocate for, develop policies and guidance for, dedicate resources to, and support safe and environmentally sustainable management of healthcare waste. More sustainable, safe, reusable PPE products need to be reviewed and included, as appropriate, in WHO guidelines and in subsequent global procurement systems. Governments need to be informed of the benefits of more sustainable PPE (and conversely the harms of overuse and disposables) so that they can demand such products. Innovation is happening quickly, especially for masks, and rapid systems need to be put in place (as has been done for vaccines), to approve, promote and support high-quality, environmentally sustainable PPE. A recent report by the International Finance Corporation details 20 multinational and national PPE manufacturers that are producing and selling high-quality, affordable products *(2)*. This indicates that much of the current supply of unsustainable PPE could be met with more sustainable and safe options.

4.1.3 Support behaviour change away from single use and overuse of PPE, to appropriate use and reusables, when feasible

Changing current practices of "more is better" and use of disposable PPE in healthcare settings will take dedicated leadership, consistent guidance and messaging, and a dedicated and focused effort, starting at the global level. Proof of concept needs to be demonstrated for different types of healthcare facilities in both high- and low-income settings. And, although there are large overall cost savings in using only the PPE required and switching to high-quality, reusable medical masks, this conversion will require ongoing investments in behaviour change, decontamination and reuse processes. Initially, it will also require a greater up-front investment.

4.1.4 Prioritize regional and national PPE manufacturers and shipping

Regional and national manufacturing and shipping hubs support greater resilience of supply chains by increasing supplies and reducing long-distance shipping, which is costly and contributes to high carbon emissions. This is especially true given ongoing COVID-19-related delays and disruptions to shipping and flight routes. As described in section 3.6, regional PPE manufacturing and shipping hubs can allow effective bundling of resources and provide certified, high-quality PPE at market prices. Furthermore, countries have called for greater sourcing of supplies from local and regional markets to increase both access and ownership *(45)*.

4.2 NATIONAL

4.2.1 Update, implement and regulate sustainable healthcare waste standards and practices

Addressing waste and climate change is no longer a "preferred" strategy, but an essential component of health systems planning. An important policy measure at the national level is to develop environmentally sustainable health infrastructure standards. As the Lao People's Democratic Republic and Philippines case studies highlight (see **Annex 4**), these standards can incorporate the latest environmentally sustainable technologies; they may focus on waste, but often also incorporate elements of energy, ventilation and procurement. Once adopted, these standards need to be disseminated and regulated as part of healthcare facility certification and validation. Of the 53 countries for which WHO and UNICEF have data on implementation of the key commitments in the 2019 World Health Assembly resolution on water, sanitation and hygiene in healthcare facilities, just over half (29 countries) have fully adopted and are implementing healthcare standards. Many of these feature sustainable and climate-resilient requirements for both technologies and practices *(46)*.

4.2.2 Invest in safe healthcare waste management and hand hygiene, as part of broader infection prevention and control, and WASH efforts

Any investment in COVID-19 PPE, testing or vaccination must be accompanied by investments in reducing and managing the waste from products used. Although a recent price tag analysis of WASH and waste in healthcare facilities in least developed countries[17] found that healthcare waste was the most expensive element (compared with hand hygiene, water and sanitation). In total, providing basic WASH and waste services in all health care facilities in the 46 least developed countries will cost US$ 6.5-9.6 billion over 10 years comprise. On a per capita basis, this is less than 3% of recurrent health spending by government in

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17 Least developed countries are low-income countries that are highly vulnerable to economic and environmental shocks. The criteria are established by the UN. The current (2021) list (**https://www.un.org/development/desa/dpad/least-developed-country-category.html**) contains 46 countries.

the least developed countries *(47)*. Safe healthcare waste management requires a trained and supported healthcare workforce to carry out segregation at points of care, and to safely transport, treat and dispose of healthcare waste. Waste workers are often under-resourced, with minimal training and PPE, and under-valued as staff in healthcare facilities.

Greater investments are also needed in more centralized waste treatment systems, to allow smaller facilities to safely transport their waste to larger facilities, and in non-burn technologies, such as autoclaves. Incineration of plastic containing healthcare waste produces persistent organic pollutants, which are harmful to human and environmental health. Meeting requirements in the global Stockholm Convention on Persistent Organic Pollutants and various WHO guidelines requires incrementally improving and replacing burning with cleaner technologies. Increasingly, a number of low-cost, energy-efficient autoclaves are becoming available, presenting a viable alternative to incineration (see the Lao People's Democratic Republic case study in Annex 4 for details).

The Water and Sanitation for Health Facility Improvement Tool (WASH FIT) *(48)*, now in use in more than 40 countries (see box), provides a framework for understanding WASH and waste risks, and developing and implementing an incremental improvement plan to address these risks.

Finally, COVID-19 provides an opportunity to promote infection prevention measures, including hand hygiene. Evidence-based infection prevention and control practices include safe and rational use of PPE, and thus can significantly contribute to waste reduction.

BOX 2 — **WHO/UNICEF Water and Sanitation for Health Facility Improvement Tool – WASH FIT**

WASH FIT is a risk-based management tool for healthcare facilities that enables them to develop, monitor and implement an improvement plan to prioritize tangible and achievable WASH improvements. The tool covers key aspects of water, sanitation, hand hygiene, environmental cleaning and healthcare waste management, as well as energy, building and facility management. It has a particular focus on building, upgrading and sustaining WASH and energy services that are climate resilient, equitable and inclusive. It facilitates multisectoral solutions by bringing together all those who share responsibility for providing WASH and waste services, including legislators and policy-makers, district health officers, hospital administrators, water engineers, waste technicians and users.

For more information, visit **www.washinhcf.org/wash-fit**.

4.2.3
Develop, implement and finance a multimodal improvement strategy for hand hygiene to reduce unnecessary glove use

Encouraging use of appropriate PPE and discouraging overuse of PPE, especially of gloves, needs to be part of systematic efforts to improve access to hand hygiene infrastructure and sustained behaviour change. Out of fear of infection, habit or a lack of hand hygiene infrastructure, gloves are often used when they are not needed. The multimodal improvement strategy for hand hygiene is a proven multifaceted approach to improve hand hygiene based on five elements: build it, teach it, sell it, check it, live it *(49)*. WHO states that the use of multimodal strategies at the national and facility levels is a strong recommendation and is a minimum requirement for infection prevention and control programmes. This shifts the focus from PPE to long-term improvement in proven infection prevention practices *(50, 51)*.

4.2.4 Include waste management in health budgets and invest in the recycling market

Regular health sector budgeting and external donor funding for PPE and other COVID-19 consumables must include line items for support of waste personnel, training in hygiene and infection prevention and control, and operation and maintenance of waste infrastructure. With most health budgets extremely constrained as a result of COVID-19 and the associated economic fallout, efforts in the near term will need to focus on incremental improvements; more efficient use of current, available budgets; and advocacy to demonstrate the cost savings from investing in more environmentally sustainable and safer healthcare waste systems. Viable recycling markets will require government investment and effective engagement with the private sector. In short, governments and partners should integrate safe and sustainable waste management into national climate strategies and funding mechanisms. A small fraction of the US$ 100 billion additional annual funding[18] given from richer to poorer countries for investment in climate resilience and mitigation efforts could make a large difference in improving waste management, recycling, and environmental and human health impacts.

(c) WHO/ Carlos Cesar

18 At previous UN Conference of the Parties (COP) climate summits, high-income countries pledged US$ 100 billion in climate financing annually to poorer countries. These commitments were revisited and renewed at COP 26, held in November 2021 (https://www.nature.com/articles/d41586-021-02846-3).

4.2.5
Regularly monitor and report on healthcare waste practices

Regular national monitoring and reporting on healthcare waste practices and systems is important for accountability, for targeting resources, and for greater impact of COVID-19 supplies and health commodities more generally. As part of regular health systems monitoring and external healthcare facility assessments, basic indicators on waste segregation and waste treatment should be tracked. Less than one third (58 out of 194) of the countries that adopted the World Health Assembly 2019 resolution have nationally representative data on basic healthcare waste management *(5)*.

With regard to COVID-19 and outbreak situations, there should be improved tracking of use, treatment and disposal of PPE. Electronic trackers and online databases could support real-time tracking. Such monitoring, if integrated with existing supply and health monitoring systems, could be done cost-effectively. Furthermore, mapping of available PPE supplies and waste infrastructure at the country level would allow a faster and more sustainable response to providing needed materials and support for safe waste management.

4.2.6
Encourage the most sustainable, safe options for PPE within and outside health care

Healthcare facilities must meet a high safety standard. Currently, this may limit an immediate and full switch to 100% sustainable PPE and waste practices. Outside healthcare settings, government public health policies and regulations should be informed by a balanced risk assessment that considers both human and environmental health. For example, widespread availability and use of disposable medical masks outside the healthcare setting may not be needed and may be fuelling increases in waste that are larger than those produced through health care. Governments must instead promote and support use of safe, reusable masks in the community and make disposable medical masks easily available only in settings where there is no other viable option.

4.2.7
Strengthen collaboration between health, environment and city planning

Greater intersectoral collaboration and action are needed among health, environment, climate and city planning entities to improve the quality of the entire waste chain and reduce its carbon footprint. In many low- and middle-income countries, municipal waste pickup and recycling are limited, and safely managed sanitary landfills are absent or insufficient.

4.3 FACILITY

4.3.1
Improve training, mentoring and investments for safe and sustainable waste management and waste workers

Healthcare facility administrators should value the role of waste workers through clearer job descriptions; regular training and mentoring; and advocacy for proper and sufficient PPE, regular immunizations and regular salaries. Waste practices should be included in quality improvement efforts; existing tools such as WASH FIT provide a risk-based framework for identifying and improving waste practices. Finally, all staff need to be supported to carry out proper waste segregation through training, recognition of good performance, and availability of bins for nonhazardous (both recyclable and nonrecyclable) and hazardous waste.

4.3.2
Support hand hygiene and appropriate PPE use

Many instances where gloves are currently being used (e.g. vaccinations, measuring temperature and blood pressure) do not require use of gloves. What is needed is hand hygiene at the right times, using the right technique. The multimodal improvement strategy provides a proven framework for improving the systems, especially within healthcare facilities, that facilitate this. Such efforts, in the context of infection prevention and control programmes, save a number of costs – costs of gloves, costs to the environment and costs of healthcare-associated infections. Even appropriate use of PPE, including gloves, can lead to infection risks when hands are not cleaned following exposure to body fluids. Indeed, hand hygiene has been identified as one of the five "best buys" for tackling antimicrobial resistance. Investments in improving hygiene in healthcare facilities, including the promotion of hand hygiene and better hospital hygiene, could pay for themselves within just 1 year and produce savings of about US$ 1.5 for every dollar invested thereafter *(52)*.

4.3.3
Incrementally improve environmental sustainability of waste treatment technologies

Healthcare facility managers and staff have an important role to play in advocating for, planning, implementing and maintaining safer and more sustainable healthcare waste treatment technologies *(53)*. The ultimate aim should be use of non-burn technologies, such as autoclaves, through either centralized or on-site treatment. In the short term, greater segregation to minimize waste that needs treatment, and improved design and operation of locally built incinerators (including pre-heating, employing dual chambers and not overloading) will achieve higher temperatures and less emissions of persistent organic pollutants. Flue gas treatment should be used on more advanced incinerators. Like any infrastructure, long-term operation of autoclaves and sustainable waste treatment technologies requires human and technological resources. Over time, non-burn technologies cost less (compared with advanced incineration) and allow recycling of treated healthcare waste; this can generate resources to fund, in part, operation and maintenance.

CONCLUSION

The COVID-19 pandemic has required an unprecedented global response, for which essential supplies, including PPE, diagnostics and vaccines, are critical components. Evidence on the amount of waste generated, the lack of resourcing to safely manage waste, and the incomplete attention to environmental and climate impacts demonstrates that a more holistic approach is needed. Addressing environmental concerns does not necessitate compromising on safety. In fact, a win–win is possible by strengthening basic infection prevention and control practices, improving safe and sustainable waste management, and protecting human and environmental health. As the pandemic response transitions into the next phase of endemicity, there is a need and opportunity to invest in resilient health systems, including the underlying systems supporting a strong healthcare workforce and waste infrastructure. Innovations in PPE design, vaccine packaging and delivery, and non-burn waste treatment, and the potential long-term cost savings they provide, indicate that it is not an either–or choice between COVID-19 and the environment. Putting in place the innovative solutions and recommendations from this report, now, will help ensure that responses to future climate and health emergencies will promote and protect human and environmental health – leading to safer and more resilient communities.

WHO/ Hannah Reyes Morales

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ANNEX 1
CALCULATION OF PPE VOLUME

General assumptions

- All PPE procured and in transit will eventually arrive at the destination.
- All procured PPE will eventually become additional waste.
- All reusable PPE has been excluded, but it is important to note that some of this may not be actually reusable.

Estimate of volume of PPE waste

- All gloves, and shoe and boot covers are assumed to be in pairs.
- The total weight of each PPE item was calculated by taking the total quantity from the database and multiplying by its unit weight.
- Unit weight of each PPE was determined based on existing literature, online articles and e-commerce shipping sites (see Table A1).

TABLE A1 — **Weights of different types of PPE**

Type of PPE	Unit weight (kg)	Reference
Surgical/exam gloves (pair)	0.018	https://www.indiamart.com/proddetail/surgical-gloves-19193866848.html
Heavy-duty gloves (pair)	0.2	https://itemscatalogue.redcross.int/support--5/personnel-security-equipment--16/body-protection--12/gloves-protection--APROGLOV.aspx
Average for gloves (pair)	0.11	This value has been used to calculate the weight of gloves.
Hair cover	0.0175	https://www.masksexport.com/sale-12812444-soft-pp-bouffant-disposable-head-cap-non-woven-round-light-weight-blue.html
Body bag	1.85	https://www.amazon.com/Heavy-Duty-Body-Bags-x-large/dp/B012U8SIL2?th=1
Coveralls	0.11	https://www.restauro-online.com/3M-4565-Disposable-Protective-Coverall
Gown (8.5 kg per 50 pieces)	0.17	https://www.signogroup.cn/product/disposable-isolation-clothes-sterilized-non-woven-consumable-hospital-medical-protection-surgical-gown-46.html
3-ply mask (0.25 kg per 50 pieces)	0.005	https://www.adesso.com/product/3-ply-disposable-face-mask-with-ear-loop-non-medical-pack-of-50/
Respirator	0.02	https://www.amazon.in/3M-Particulate-Respirator-8210-N95-Mask/dp/B003B39QEO
Shoe cover (0.31 kg per 50 pairs)	0.0124	https://www.amazon.com/Disposable-Pack%EF%BC%8850-Waterproof-Resistant-Booties/dp/B07CWV59QR

Type of PPE	Unit weight (kg)	Reference
Boot cover	0.0124	https://www.ticarehealth.com/non-woven-disposable-waterproof-sf-boot-cover_p96.html
Surgical cap	0.017	https://itemscatalogue.redcross.int/detail.aspx?itemcode=MMRECAPSDS&from=kit
Apron protection/plastic	0.18	https://itemscatalogue.redcross.int/health--3/medical-disposable-supplies--14/various-disposable-materials--120/apron-protective-single-use--MMREAPSU.aspx
Disposable face shield	0.0356	http://www.antechscientific.com/disposable-face-shield.html
Disposable lab coat	0.0554	https://www.amazon.com/Disposable-Lab-Coat-Green-PK30/dp/B076CBMMP5

- **Estimation of bag capacity:** The volume capacity (litres) and dimensions (cm2) of bags were defined in the database. Assuming 80% filling rate (to enable bags to be closed) and waste density of 0.2 kg/L, the following formulas were used to calculate the capacity of bags in tonnes:

    - a × 80% = b
    - (b × 0.2 kg/L)/1000 = c

  where

    - a = volume of bag (litres);
      b = volume of bag when it is 80% full;
      c = bag capacity (tonnes)

- **Estimation of diagnostic waste:** The weight of waste generated from each test kit was determined by weighing the various components of a rapid detection test. The results are presented in Table A2.

TABLE A2 — **Weights of rapid detection kits**

Item	Weight (g)	Weight of one test for disposal (g)
Reagent full	0.65	
Reagent empty	0.46	0.46
Liquid supplied	0.19	
Used vial	1.68	
Unused vial	1.61	1.61
Residual liquid	0.07	
Test kit plastic	4.6	4.6
Test strip	0.16	0.16
Liquid on strip	0.06	
Swab dry	0.5	0.5
Swab wet	0.56	
Liquid on swab	0.06	
Total weight of items supplied		7.33
Swab wrapper, lateral flow device wrapper, silica sachet		3.76
Total per kit, excluding outer packaging		11.09

Since there are no other sources of data, these values were assumed for both antibody and extraction kits. For polymerase chain reaction (PCR) tests, there is literature that provides the estimated quantity of all the components (see section 2.2). It has been assumed that all test kits generate 5 mL of liquid chemical waste per test, based on an observation made of a rapid detection test.

- **Estimation of vaccine waste:** This estimation was based on the total number of vaccines administered globally as of 9 October 2021: 6 364 021 792. Vaccination activities result in different types of waste: glass vials, syringes and needles, and safety boxes. The unit weight of each of these was estimated using information available online and multiplied by the total quantity (Table A3).

TABLE A3 — **Weights of vaccine waste**

Type of vaccine waste	Total number	Unit weight (kg)	Total weight (tonnes)
Glass vials	6 364 021 792	0.011[a]	70
Safety boxes	63 640 218[b]	0.1[c]	6.4
Syringes + needles	6 364 021 792	0.006[d]	38
Total			114.6

[a] https://www.apg-pharma.com/5-ml-injection-vial-clear-type-1-moulded-glass-apg-art-no-1017867

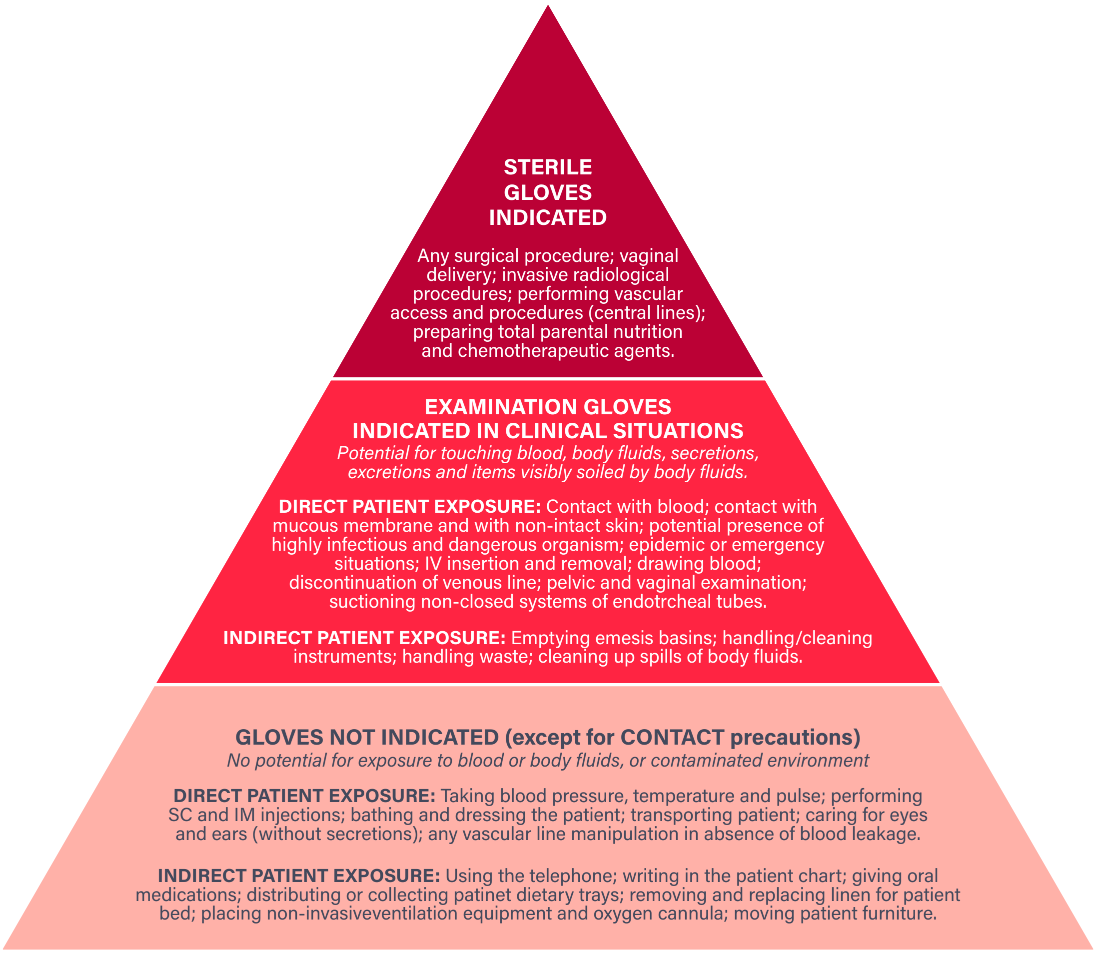
[b] For every 100 syringes and needles, one safety box is required.

[c] https://truscare.en.made-in-china.com/product/AXsJOqnKlyYC/China-Medical-Hospital-Biohazard-Cardboard-Paper-Safety-Box-Sharp-Container-for-Syringe-and-Needle.html

[d] http://www.ssaapp.com/product/injection-and-venipuncture-1.php

(c) WHO/ Oliver Asselin

ANNEX 2
PYRAMID OF GLOVE USE



Source: WHO *(16).*

ANNEX 3
GLOBAL INDICATORS OF WASTE SEGREGATION AND TREATMENT

Core health care waste management questions

Waste produced from health care activities, from contaminated needles to radioactive isotopes, can cause infection and injury, and inadequate management is likely to have serious public health consequences and deleterious effects on the environment. Safe health care waste management involves multiple steps from segregation to transport, treatment and final disposal. Questions G-WM1, G-WM2 and G-WM3 seek to distil this process into a small number of measurable elements.

G-WM1. Is waste correctly segregated into at least three labelled bins in the consultation area?	
Yes, waste is segregated into three labelled bins	
No, bins are present but do not meet all requirements or waste is not correctly segregated	
No, bins are not present	
Note: For facilities with multiple consultation rooms, select one at random and observe whether sharps waste, infectious waste and non-infectious general waste are segregated into three different bins. The bins should be colour-coded and/or clearly labelled, no more than three quarters (75%) full, and each bin should not contain waste other than that corresponding to its label. Bins should be appropriate to the type of waste they are to contain; sharps containers should be puncture-proof and others should be leak-proof. Bins for sharps waste and infectious waste should have lids.	

G-WM2. How does this facility usually treat/dispose of infectious waste?	
Autoclaved	
Incinerated (two chamber, 850-1000 °C incinerator)	
Incinerated (other)	
Burning in a protected pit	
Not treated, but buried in lined, protected pit	
Not treated, but collected for medical waste disposal off-site	
Open dumping without treatment	
Open burning	
Not treated and added to general waste	
Other (specify)	
Note: If more than one applies, select the method used most often. Methods considered to meet the basic service level include autoclaving; incineration; burning in a protected pit; burial in a lined, protected pit; and collection for medical waste disposal off-site.	

G-WM3. How does this facility usually treat/dispose of sharps waste?	
Autoclaved	
Incinerated (two chamber, 850-1000 °C incinerator)	
Incinerated (other)	
Burning in a protected pit	
Not treated, but buried in lined, protected pit	
Not treated, but collected for medical waste disposal off-site	
Open dumping without treatment	
Open burning	
Not treated and added to general waste	
Other (specify)	
Note: If more than one applies, select the method used most often. Methods considered to meet the basic service level include autoclaving; incineration; burning in a protected pit; burial in a lined, protected pit; and collection for medical waste disposal off-site.	

Source: WHO, UNICEF *(54)*.

ANNEX 4
CASE STUDIES OF IMPLEMENTING HEALTHCARE WASTE RECOMMENDATIONS

This annex details 11 diverse case studies that illustrate solutions to more safely and sustainably managing COVID-19 waste, and healthcare waste more broadly, in the spirit of “building back better”. They provide an opportunity to build and strengthen sustainable healthcare waste systems.

SUMMARY OF KEY THEMES ILLUSTRATED BY CASE STUDIES

Countr(ies)	Monitoring	Standards and training	Waste reduction, recycling and reuse	Centralized and non-burn treatment technologies
Colombia	✓	✓		
England	✓		✓	
Ghana	✓	✓	✓	✓
India	✓	✓	✓	
Lao People’s Democratic Republic		✓		✓
Liberia	✓	✓		
Madagascar		✓		✓
Malawi				✓
Nepal			✓	✓
Philippines	✓	✓		
Western Europe		✓	✓	

COLOMBIA
Facility-led initiatives and recommendations to combat the increase in COVID-19 waste

Fundación Clínica Infantil Club Noel, a medium-sized tertiary hospital located in south-west Colombia, undertook a number of activities to strengthen its waste management in response to COVID-19. First, the facility undertook training to raise awareness among staff on biosafety, management of PPE, patient care, cleaning and disinfection, and laundry and waste management in COVID-19 care areas. Protocols for managing COVID-19 waste were reviewed. It was agreed that COVID-19 waste should be managed in the same way as “normal” infectious waste, through decontamination and deactivation of the microbiological load by shredding and microwave technology. Sharps and pathological waste were incinerated according to Colombian regulations.

Although the use of disposable PPE was reduced in favour of reusable PPE, there was no reduction in the overall volume of waste. In fact, waste increased by 30% between 2019 and 2020: in 2019, an average of 5818 kg of hazardous waste (including infectious waste) was generated per month, compared with 7585 kg in 2020. Infectious waste increased by 27% in 2020 in comparison to 2019 (Fig. A1).

Major challenges faced by the facility include inadequate separation of waste at the source; increased reliance on plastic supplies, which cannot be recycled, by the health sector; and the added burden of an increased patient load and thus quantity of waste. Recommendations to tackle these include the following.

- Implement sustainable purchasing that takes into account the economic and socio-environmental impact of consumables; takes into account the cost, benefit and quality of items; limits the use of plastic-containing items because of their environmental impact; and favours purchase of PPE that can be decontaminated or reprocessed for reuse.

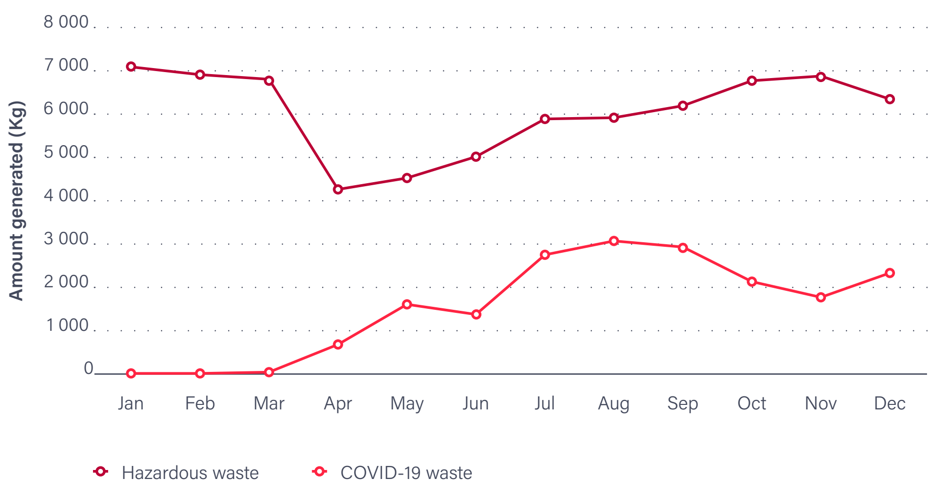
- Continue to treat infectious waste using available microwave (or autoclave) technologies that are environmentally friendly.

- Strengthen education within the facility (including through visual reminders, training and incentives) to generate awareness about safe waste management and proper use of PPE.

- Develop policies to regulate the quantity and use of plastic packaging for medical devices.

- Review national guidelines to include more environmentally sustainable products and practices for cleaning and disinfection (e.g. use of low-volatile-organic-compound glass cleaners, effective cleaning, and appropriate targeting and application of disinfectants).

FIG. A1 — **Hazardous and COVID-19 waste generation in Colombia, 2020**



ENGLAND

Overuse of gloves in health care associated with cost and carbon emissions

In the first 6 months of the COVID-19 pandemic in England, use of PPE alone added an additional 1% carbon burden, compared with pre-COVID-19 (*42*). Between February and August 2020, 3 billion items of PPE were used, resulting in 591 tonnes of waste per day. The greatest contribution came from gloves. Much of this PPE use was unnecessary.[19] Modelling showed that it was possible to reduce this environmental cost by 75% through a combination of strategies, including rational glove use, domestic manufacturing, using reusables where possible, and optimizing waste management by decontamination of contaminated PPE before recycling or waste-to-energy incineration (*42*).

Efforts in 2019 in England to reduce unnecessary glove use through a campaign titled "Gloves off: safer in our hands" demonstrate that change is possible; it requires investment in training, improvement support and monitoring. After 1 year, glove orders fell by 3.7 million, creating savings of £90 000 (*55*) and reducing the amount of waste by 18 tonnes over 6 months. This strategy could have a greater impact if it is sustained long term and adapted to outbreak situations. Further evaluation is needed of its potential effectiveness in other settings and countries.

GHANA

Multi-stakeholder efforts to respond to COVID-19

Effective waste management practices, particularly in response to a pandemic, require efforts from multiple stakeholders. In Ghana, two technical briefs were developed and shared with the National COVID-19 Management Team, outlining why it is important to ensure effective healthcare waste management in the response to COVID-19 and providing a detailed explanation of the processes (and related standard operating procedures – SOPs) that need to be followed to effectively manage infectious waste for infection prevention *(56)*. One thousand posters, illustrating waste management SOPs, have been distributed throughout the country. The Waste Recovery Platform met to discuss the impact of COVID-19 in the waste management sector, agree on actions to address these challenges and mobilize stakeholders to support their implementation.

The Health Facilities Regulatory Authority carried out monitoring visits to 800 healthcare facilities in the Greater Accra and Ashanti regions to verify compliance with infection prevention and control protocols. Furthermore, three 3-day training sessions on infection prevention and control, including healthcare waste management (HCWM) and advocacy of the National HCWM Policy and Guideline have been conducted in 2020 and 2021 with the support of the United States Centers for Disease Control and Prevention.

Experts from the Accra School of Hygiene provided on-the-spot training for 12 000 healthcare personnel on effective healthcare waste management, based on gaps identified during previous monitoring exercises. To institutionalize the training, the Accra School of Hygiene inserted a semester course on HCWM in different diploma programmes (Environmental Health, Occupational Health and Safety, and Occupational Therapy). A short course for all allied health professionals in Ghana is planned in November 2021. The Ministry of Health trained staff from 20 hotels being used as quarantine and isolation centres in the Greater

19 Gloves in the healthcare setting are not required for most interactions, including checking vital signs, administering intravenous drugs and vaccinations. They should only be used when the healthcare provider is likely to touch blood, other body fluids or mucous membranes.

Accra Region on how to effectively manage their waste to prevent infections. The National Tourism Authority ensured that these guidelines were part of health and safety requirements for tourist facilities across the country.

A private company has been contracted to collect the infectious waste from all vaccination centres in Ghana and treat it using a centralised autoclave. Together with tutors and students from the Accra School of Hygiene, the safe handling of waste in the vaccination centres is supervised.

UNDP partnered with the Korle Bu Teaching Hospital to produce hand sanitizers locally and donated 11 150 litres of alcohol-based hand sanitizer to the Ministry of Health to support 21 facilities playing leading roles in the testing and management of COVID-19 cases across the country (Fig. A2) *(57)*. UNDP also procured consumables (bins, waste bags and sharps containers) and PPE for the Ministry of Health to promote effective management of medical waste in the selected healthcare facilities.

Scale-up of training and sensitization to, and enforcement of, waste management guidelines are still needed. Financing for waste management is still inadequate. More investment and budgetary allocation is needed to respond to the increased volume of waste being generated. Educational curriculums should be reviewed to strengthen healthcare waste components, including best available technologies and best environmental practices. This will help healthcare workers respond to future outbreaks.

FIG. A2 — **Grace Kankam, Supply Manager at the Central Medical Store of the Ministry of Health, Ghana, receiving alcohol-based hand sanitizers at the store for onward distribution to selected health facilities**

INDIA

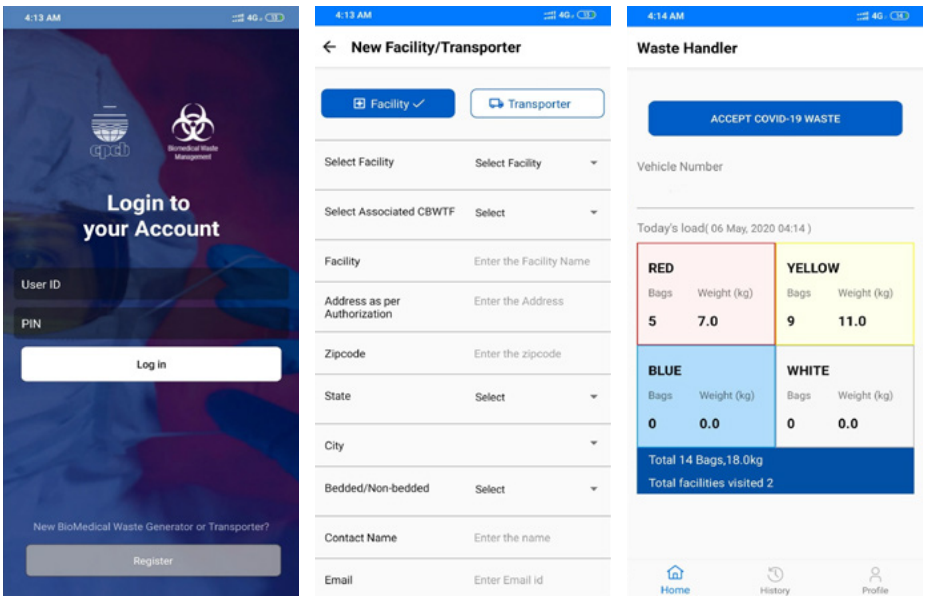
Improving waste segregation to reduce the quantity of waste incinerated and other innovations to increase recycling of waste

India generated approximately 101 tonnes of COVID-19-related healthcare waste per day during the first wave of the pandemic *(58)*, in addition to the 609 tonnes of waste generated daily from routine health services (a total of 710 tonnes). Accordingly, the generated medical waste increased by 17% in that time. The total available capacity for incineration of COVID-19 waste in the country is 840 tonnes. New Delhi accounts for 11% of India's daily COVID-19 waste generation but has only two incinerators. During the first wave, 70% of this capacity was being used, and measures were needed to ensure that capacity was not exceeded. In a few cities with particularly high incidence of COVID-19, where regular waste facilities could not handle the increased volumes, waste was sent to industrial incinerators and centralized waste treatment centres.

To tackle the increase in waste generated, the Central Pollution Control Board, under the Ministry of Environment, produced a set of waste guidelines in 2020 that emphasized the importance of waste segregation. The ministry regularly amended the guidelines in an effort to further reduce the amount of waste incinerated and placed a greater focus on non-burn and environmentally sustainable technologies and practices, such as autoclaving, microwaving and recycling by state-approved facilities. Training in local languages on COVID-19-appropriate waste disposal and hygiene practices was conducted, and mass media communication was used to educate the general public on management of COVID-19 waste generated at home.

In tandem, the ministry launched a COVID-19 medical waste mobile application (Fig. A3) to track generated waste amounts, as well as transport and reception at the treatment centres. This includes tracking of waste vehicles to prevent theft of waste and unauthorized recycling of waste.

FIG. A3 — **Screenshots of the India COVID-19 medical waste tracking application**



Source: Central Pollution Control Board *(59)*.

Since August 2020, data on the generated medical waste in each state have been published on a dedicated website each month *(60)*. As of June 2021, based on 198 biomedical waste treatment centres using the mobile app, approximately 13 000 generators of COVID-19 waste were registered. Data are submitted daily, and dedicated monitoring and control agencies can visualize the data submitted from different stakeholders.

A number of innovations have also been trialled during the pandemic; these include conversion of COVID-19 waste into clean energy (hydrogen fuel) using sunlight, and conversion of PPE waste into eco-friendly construction materials, including construction bricks, bituminous road surfaces and partial replacement of cement in concrete. Further evaluation of their impact is needed.

Waste management has proved particularly challenging in remote, rural areas where there are limited waste treatment and disposal facilities. In these areas, exceptions were made to allow waste disposal in landfills and deep burial (elsewhere, this is not permitted). There is an urgent need to increase the number of authorized, trained waste recyclers to respond to the increase in waste generated. Overall, the emphasis on waste segregation by the Central Pollution Control Board resulted in less waste being incinerated, reducing the environmental impact.

Implementing a waste tracking system allows waste generators and authorities to identify the current waste streams and determine how much waste is generated, and what waste can be recycled or reused to reduce the environmental footprint. This information helps with planning adequate infrastructure such as storage, and required waste treatment capacities. Furthermore, it can support healthcare facilities to monitor adequate segregation and evaluate performance of the waste management system.

LAO PEOPLE'S DEMOCRATIC REPUBLIC

Catalysing COVID-19 funding to finance environmentally sustainable healthcare facilities, including low-cost autoclaves in primary healthcare centres

Since 2017, the Government of Lao People's Democratic Republic has worked to implement a national vision, a coordination mechanism, policies and regulations to improve the resilience and sustainability of WASH and energy services in healthcare facilities that are prone to climate risks, particularly floods and droughts. New national standards for environmentally sustainable healthcare facilities were launched along, with the Climate Change and Health Adaptation Strategy, in 2018. Accountability for implementing these standards was strengthened by a call to build resilience in health systems after massive flooding in 2018 and the passing of the World Health Assembly resolution on WASH in healthcare facilities in 2019 *(61)*. A package of interventions for making hospitals "safe, clean, green and climate resilient" was introduced, and WASH and energy indicators were integrated into regular health systems monitoring. This allows rapid identification of gaps, and for the health sector and healthcare facility managers to be held accountable for maintaining adequate WASH and energy services.

These efforts provided a strong foundation for capitalizing on opportunities presented by COVID-19 to expose weaknesses in health systems and direct additional funding to address them. With leadership from the Ministry of Health, since 2020, more than US$ 2 million has been mobilized from a number of donors (the Global Environment Facility; WHO; the Pandemic Emergency Financing Facility of the World Bank; and the governments of Germany, Luxembourg, Australia and Japan) to scale up existing efforts on climate-resilient healthcare facilities, and to strengthen capacity for pandemic preparedness and response. More than 200 healthcare facilities nationwide have benefited. One important element was the installation of 70 low-cost autoclaves, which do not emit harmful pollutants (dioxins and furans). These low-cost autoclaves use as little as 3 L of water to treat 100–120 kg of waste. The green waste treatment technology was coupled with equipment for safe segregation and storage (e.g. bins, PPE for waste handlers), as well as training, supportive supervision and ongoing monitoring to help ensure long-term sustainability.

The effort in Lao People's Democratic Republic demonstrates how long-term systems strengthening can address basic infrastructure gaps, improve services to meet both health and climate standards, and use emergency funding and the pandemic to accelerate longer-term and environmentally sustainable improvements.

LIBERIA

A comparison of waste management during the Ebola and COVID-19 health emergencies

Proper healthcare waste management has been a challenge for Liberia for a long time. It was not prioritized until the outbreak of Ebola virus disease in 2013, when it became obvious that there were limitations in the number of staff, resources and guidelines to deal with healthcare waste.

Efforts were made to ensure that the country was better prepared for health emergencies. First, there was widescale training of more than 700 healthcare workers across the 15 counties of Liberia from 2013 to 2016 using "Safe Quality Services" training. This covered waste management, WASH, relevant national health policies and quality improvement within healthcare facilities.

Second, locally produced De Montfort incinerators were constructed in more than 600 primary and secondary healthcare facilities (Fig. A4). National guidelines for the safe management of healthcare waste, SOPs and job aids were developed and operationalized, and approximately 1500 copies were disseminated across the country. Waste management infrastructure is now part of the remit of the Ministry of Health's infrastructure unit and is standardized for use across the health system.

As a result, Liberia was better prepared at the onset of the COVID-19 pandemic by having more healthcare personnel with specialized training – more than 95 master trainers were trained to implement the guidelines and SOPs in line with COVID-19 and other routine service protocols. In addition, waste segregation has improved, as evidenced by the availability of a three-bin system in most healthcare facilities. Infectious waste is also properly handled by specialized staff (waste managers and incineration technicians) from healthcare facilities. Moreover, monitoring and supervision using WASH FIT are regularly conducted, and data are generated to inform decision-making across Liberia.

One of the main shortcomings has been the inability to quantify the waste generated from routine services and during health emergencies. Other challenges include an overdependence on donor funding, which is unsustainable; lack of regular maintenance of waste infrastructure, particularly incinerators; and lack of motivation of staff who handle waste. More training and supportive supervision are needed, particularly for operation and maintenance of existing infrastructure.

FIG. A4 — **Inspecting an incinerator in Liberia**

(c) WHO/Quincy T D'Goll.

MADAGASCAR

Strategic provision of medical waste management during the COVID-19 pandemic

During the COVID-19 pandemic, a large amount of additional waste was produced in COVID-19 treatment facilities in Madagascar, including university hospitals, district reference hospitals, basic health centres, hospitals and COVID-19 treatment centres (CTCs). Following a second wave of COVID-19 in March 2021, the number of COVID-19 patients exceeded the capacity of hospitals, requiring a massive recruitment of doctors, paramedics and support staff.

There are five CTCs in Antananarivo, the capital of Madagascar, which on average each generated 1 tonne of infectious waste every 3 days between March and June 2021. To ensure the management of COVID-19 waste, materials (waste garbage cans, waste bags, disinfectants, PPE, cleaning materials) and human resources were made available to each facility. Faced with the health emergency and the opening of CTCs, which are non-hospital centres that do not have the specific personnel or resources required, the Health and Environment Service was mandated by the Ministry of Public Health to ensure the implementation of infection prevention and control measures (IPC/WASH) in the CTCs of Antananarivo. In addition to mobilizing resources for IPC/WASH activities throughout Madagascar, the Health and Environment Service was responsible for training hygiene workers in cleaning, disinfection and waste management. Because of the large amount of infectious waste generated by the pandemic, waste was sent to a centralized disposal unit with the required capacity (Fig. A5).

FIG. A5 — **Transport of waste from Ankorondrano CTC (left) and waste storage at Village Voara CTC (right)**

© Ministry of Health Madagascar

To help cope with the excess waste generated in Antananarivo, a partnership was established between one of the CTCs and a nearby airport with a high-performance incinerator. The incinerator was repurposed to treat infectious waste generated by the CTC by order of the Ministry of Health. For the other four CTCs, waste was sent to waste disposal units in nearby hospitals that had incinerators and/or autoclaves. After 3 months, material that had not been sufficiently burnt in incinerators (approximately 10 tonnes) was transported and disposed of in a large pit at Manakavaly Hospital, a hospital with land available for this purpose.

Additional human, material and financial resources were required to respond to COVID-19. Much of this need was met by development partners who provided supplies (e.g. waste bins and bags) for CTCs and quarantine facilities, and transported waste for centralized treatment. There were further challenges relating to the availability of water and handwashing facilities for waste workers; PPE for support staff; vehicles for transporting waste; and disposal units for the huge amount of infectious waste generated in healthcare facilities, in non-hospital centres and at the household level (from home treatment of asymptomatic positive cases). The high volume of people using sanitation facilities in quarantine facilities also resulted in large volumes of faecal sludge that needed treating.

MALAWI

Use of reverse logistics to deal with increased waste from COVID-19 and HIV testing

Although policies for waste management exist in Malawi, implementation is hindered by the lack of resources, infrastructure, dedicated attention and policing. Diagnostics used in HIV programmes and COVID-19 testing have resulted in additional waste volumes and new waste challenges; these include increased levels of hazardous chemicals such as guanidinium thiocyanate (GTC) from PCR cartridges for SARS-CoV-2 testing, which require special treatment for safe disposal. Riders For Health (R4H) Malawi, a local nongovernmental organization, supports waste management in 44 healthcare facilities across the country. In addition to providing supplies and technical support, R4H conducts reverse logistics to transport GTC, using motorbikes, for treatment at a centralized high-spec, high-temperature pharmaceutical incinerator. The reverse logistics system in this example is a combination of delivering goods to the healthcare facilities and taking back waste using the same transport vehicle and personnel to save resources. It is based on a “hub and spoke” model (see Fig. A6) to connect the 44 facilities with the least possible travel across a developed transport network; the longest distance from a facility to the incinerator is 690 km. From 2019 to 2021, 3800 kg of GTC-contaminated waste was transported for incineration, enabling all testing facilities to comply with the national Good Clinical Laboratory Practice and minimize their environmental impact. Although the lack of resources available impedes day-to-day implementation, this model helps to lessen the burden on smaller, more remote facilities that do not have the necessary infrastructure to treat and safely dispose of waste.

NEPAL

Use of alternative waste treatment technologies and recycling of vaccination waste

Remote, rural facilities, including those in Nepal, often struggle with safe management and treatment of vaccine waste. Facilities from the periphery of Kathmandu Valley regularly request help to manage safety boxes, which frequently pile up around vaccination sites and health posts. Open burning of safety boxes is still the main treatment option in many places, posing health and environmental risks. Data on the quantity of waste generated are rarely collected, which makes planning for waste management more difficult. A partner organization, Terre des hommes, has piloted a method for measuring waste in three rural healthcare facilities. Waste produced from the delivery room, from the outpatient department and by facility staff was segregated and collected in plastic bags. Waste generated over a 24-hour period was transferred for digital weighing, and a new plastic bag was replaced at the point of collection to collect the waste for the next 24 hours. The number of people who produced the waste each day was also recorded. This continued for 7 consecutive days. This tracking effort allowed facilities to identify where segregation could be improved, thereby reducing the amount of waste that needs to be treated.

To address poor vaccine waste management in Kathmandu Valley, the Ministry of Health asked WHO Nepal to support safe management and treatment of vaccine waste. The waste management strategy involved the safe collection, storage, treatment and disposal of safety containers, as well as use of two non-burn technologies: microwaving and autoclaving. The estimated cost for the packaging, collection, safe storage and treatment of 1500 sharps boxes included in the effort was about US$ 15 000 (about US$ 10 per sharps box). Of the 1500 safety boxes collected,[20] 613 were taken to a nearby hospital and treated using a microwave with an inbuilt shredder (Fig. A6). Decontamination and shredding rendered the waste unrecognizable, allowing it to be sent directly to the landfill site as normal nonhazardous waste. This option had fast treatment cycles and was easy to implement, but the waste could not be recycled. The remaining boxes were sent to a local maternity and women's hospital, and treated in a 227-litre pre-vacuum autoclave (Fig. A6). This method had longer treatment cycles and slightly higher operational costs, but had the benefit of producing decontaminated plastic waste that could be recycled – syringes were cut with needle cutters, leaving the plastic part for recycling (about 95% of the decontaminated waste).

FIG. A6 — **(a) Collection of safety boxes in drums. b) Shredded waste after microwaving. c) Loading of the autoclave.**

(c) HECAF 360/ Prerana Dangol

a

(c) HECAF 360

b

(c) WHO/ Sudan Raj Panthi

c

20 One safety box contains approximately 100 used syringes and corresponding empty vials.

A number of challenges were faced: ideally, needles should be cut at the place of generation to prevent unnecessary risk to waste workers using autoclaves. However, at the time of implementation, this system had not been fully set up, and needle cutters were not available at the points of vaccination. Some vaccines were delivered in prefilled glass syringes; since needle cutters cannot be used for glass, these syringes could not be recycled. Plastic from the syringes can be sold for recycling, generating some revenue and saving environmental costs of disposal. However, revenue is not sufficient to cover the entire operational costs of autoclaving, and thus additional financing is needed. Finally, financial and human resources were insufficient. Safe waste management requires investment by the government and a national waste plan, including specific guidance for COVID-19 vaccines *(62)*.

The safe vaccine waste management effort in Nepal demonstrates that organizations providing vaccines should plan for and provide financing for the additional costs of waste management, plan for and support needle cutters from the outset of the system, and procure products that can be recycled.

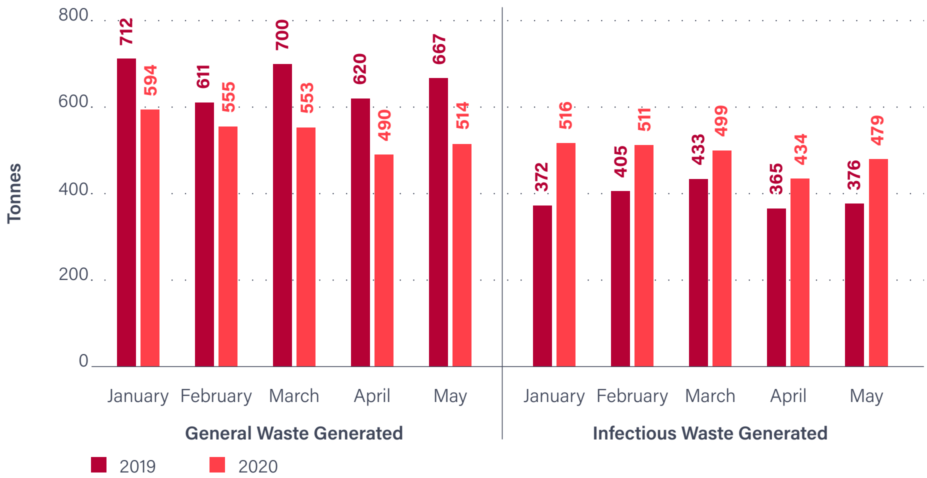
PHILIPPINES

Public hospitals addressing healthcare waste in environmentally sustainable ways

The Philippines' Department of Health (DOH) updated its Health Care Waste Management Manual (2020) and issued the Green and Safe Health Facility Manual (2021). The two manuals offer a guide for healthcare facilities to reduce their environmental footprint through climate-friendly technology and initiatives. They were published along with new guidelines on infection prevention and control measures (including waste) for healthcare facilities that are designated COVID-19 referral or accepting hospitals, and temporary treatment and monitoring facilities. The manuals call for environmentally sustainable procurement, including waste prevention and reduction at source, and the use of WASH FIT (see box in **section 4.2.2**) to help facilities make improvements *(48)*.

A study of compliance with waste management performance standards during the COVID-19 pandemic, conducted in 51 DOH hospitals, showed an increase in waste generated in hospitals between 2019 and 2020 (see Fig. A7).

FIG. A7 — **General and infectious waste generated in Philippine hospitals, 2019 and 2020**



Source: Ruiz et al. *(62)*.

The survey found a 25% increase in infectious waste and a 13% decrease in general waste in 2020, compared with 2019. Overall, an additional 70 tonnes of waste was generated during that time by the 51 hospitals (an average of 1.4 tonnes per hospital – an increase of 12%). Data on waste generated during COVID-19 were also collected at five facilities in Metro Manila from emergency rooms, intensive care units and medical wards. Across all hospitals, 50% of waste was infectious (an increase of 10–20% during the pandemic), while 18% of the total waste was PPE, of which 51% were gloves.

The healthcare facilities facing an increased amount of infectious waste responded in a variety of ways. Some hospitals amended their annual contracts with service providers to collect larger volumes of waste, whereas others began to disinfect infectious waste at the point of generation using sodium hypochlorite (*64*). Waste disinfected with chemicals should not be incinerated or autoclaved because acidic fumes generated pose a risk for the operator and can damage the equipment. In some cases, local governments help with collection and disposal of general waste. The DOH subsequently issued interim guidelines on the management of healthcare waste in healthcare facilities and on waste generated during COVID-19 vaccination (*65*, *66*). The national government has supported facilities in retrieving empty and expired COVID-19 vaccine vials as part of a reverse logistics strategy.

WESTERN EUROPE

COVID-19 lockdown measures disrupting waste recycling and straining waste management capacity in world’s wealthiest countries

In western Europe, most countries classify all waste generated during the treatment of COVID-19 patients as infectious. The prevalent technology for the treatment of hazardous waste (including infectious waste) is centralized, advanced incineration. Environmentally sustainable treatment technologies such as autoclaving are used in several countries, including Germany, France and Sweden. Waste from households with patients in quarantine or confirmed COVID-19 cases is classified as normal household waste and should be treated by incineration (thermal recovery). Household waste is collected and managed by professional private or municipal waste services where workers, generally, have adequate PPE and equipment.

In the first few months of the COVID-19 pandemic, countries across Europe faced challenges with collection and sorting services, such as staff shortages; temporary disruptions to, or reduced frequencies of, collection of certain waste streams; physical access limitations to waste recycling centres; and the need for safe handling of waste from households with COVID-19 cases. In response, many countries suspended occupational health requirements, allowing longer working times, transport using normal waste bins and trucks, and treatment of infectious waste at municipal waste sites.

The European recycling industry claimed that the lockdown measures undermined the circular economy.[21] Less segregation of waste occurred, and recycling centres where domestic recyclables can be dropped off were closed to the public, leading to fewer recyclable materials and therefore fewer materials produced from recyclables.

21 A circular economy aims to maintain the value of products, materials and resources for as long as possible by returning them into the product cycle at the end of their use, while minimizing the generation of waste (**https://ec.europa.eu/eurostat/web/circular-economy**).

The lesson was that countries with an integrated circular economy need to invest in and develop contingency plans for the continuous operation of the recycling industry to ensure that sufficient recycled materials are available for the production of new goods – even in times of crisis. Reliable collection of municipal waste is also essential to sustain waste disposal and hygienic environments to prevent the spread of infectious pathogens. The waste management sector should be considered an essential service or “systemically relevant infrastructure” during future outbreaks or crises.

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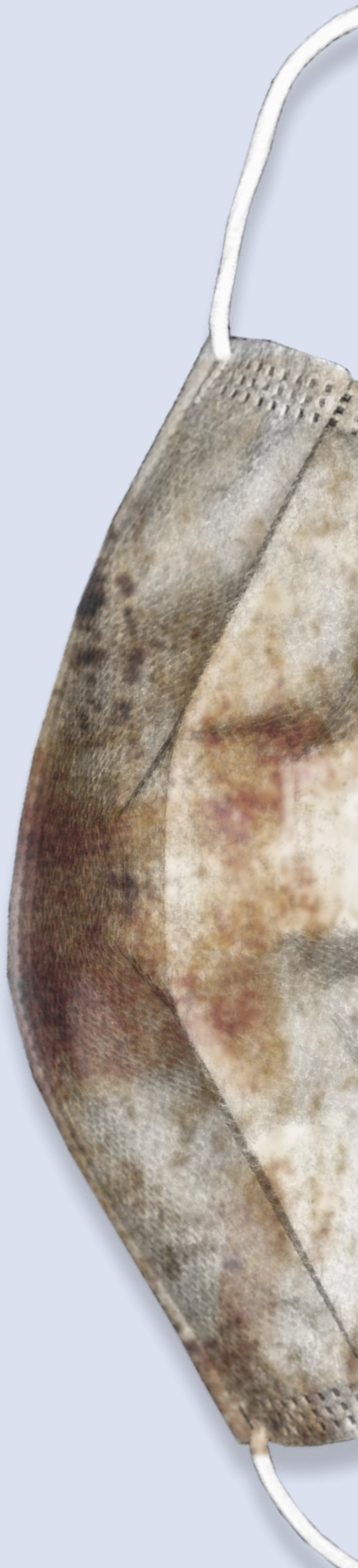

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