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Scientific Paper

INNOVATION IN MANUFACTURING PERSONAL PROTECTIVE EQUIPMENT

Toward Sustainability and Circularity

SterilSmart™
—Innovation for Billions—

FORSTA™
MEDTECH

Other Scientific Papers

WM&R - Klaus Zimmermann Report Sagepub

The main benefit of microwave energy is the direct delivery of energy to microwave-absorbing materials, which allows the volumetric heating of samples. Issues such as long heating periods, thermal gradients, and energy loss to the environment can be minimized. https://journals.sagepub.com/doi/10.1177/0734242X16684385

Sterilization of Linen Matrices in Microwave:

Hospital linen which are soiled discharged of infectious patients, including those with HIV, hepatitis B, C, and other infectious agents. At least 8 log disinfection efficacy of representative bacteria, fungi, and spores were achieved via SterilSmart™ treatment at 70°C with a hold time of 10 min.

http://nopr.niscair.res.in/handle/123456789/51177

https://europepmc.org/article/pat/de10110952?client=bot

8 Application Cycles

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Acronyms

AAMI	Association for the Advancement of Medical Instrumentation
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
FDA	Food and Drug Administration
IS	Indian Standards
ISO	International Organization for Standardization
NABL	National Accreditation Board for Testing and Calibration Laboratories
NIOSH	National Institute for Occupational Safety and Health
OECD	Organisation for Economic Co-operation and Development
OSR M1	Open Standard Respirator Model 1
PAPS	Powered air protection system
PET	Polyethylene terephthalate
PLA	Polylactic acid
PPE	Personal protective equipment
UK	United Kingdom
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
US	United States
WHO	World Health Organization

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Foreword

Personal protective equipment, or PPE, has been a critical health-care supply for managing the COVID-19 crisis, but it has also proven to exacerbate the global waste challenge. As the use of disposable PPE such as masks and gloves grows, so too does plastic waste, ending up in landfills, rivers, and oceans.

Most PPE is inexpensive and single use by design and can contain a range of different plastics, from polypropylene and polyethylene in face masks and gowns, to nitrile, vinyl, and latex in gloves. Rising awareness of the negative impact that disposable PPE has on the environment is leading companies to embrace innovative approaches to reduce this waste. A growing number of manufacturers are trying to make reusable PPE that is appropriate for consumers, such as face masks, but also for medical professionals, such as gowns and coveralls. The approaches include using more environmentally friendly and reusable materials to produce PPE, ensuring materials are properly recycled, and minimizing waste and pollution.

To support the production of PPE in developing countries, IFC recently developed a global advisory program[1] on PPE manufacturing, in partnership with the UK government. This report forms part of this program and builds on an IFC webinar from November 24, 2020,[2] which first highlighted how the global waste challenge has been exacerbated by the growing use of PPE in response to the COVID-19 pandemic.

This report showcases how select manufacturers are exploring circular economy opportunities. With a growing world population and the potential of future pandemics, the demand for PPE will likely continue to rise. While many of the innovations profiled in this report are in the early stages of adoption and have not yet been scaled, we hope that by shining a spotlight on what is possible, manufacturers will find inspiration to develop new products and services. However, manufacturers cannot sustainably meet global PPE demand alone. By using their purchasing power to choose goods and services with reduced environmental impact, governments and health sector players can make an important contribution to shifting away from single use, plastic-based PPE.

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1 https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/manufacturing/priorities/ppe+production.

2 https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/manufacturing/events/webinar_how+to+start+ppe+production.

Executive summary

Adopting circular economy approaches is becoming an increasingly important part of policy makers' agendas in the fight against climate change. These approaches include reducing material inputs, using more environmentally friendly and reusable materials when producing goods, ensuring materials are properly recycled, and minimizing waste and pollution. They have become even more important in the wake of the COVID-19 pandemic, with personal protective equipment (PPE) becoming an inseparable part of daily life. Manufacturers across the globe had to increase PPE production, which inevitably created a surge in plastic waste because polypropylene is still the main material used to manufacture PPE for health-care workers.

A recent research study estimates that, since the outbreak, the amount of plastic waste generated globally is 1.6 million tons per day. Furthermore, an estimated 3.4 billion single-use face masks and shields are being discarded every day.[3] This unpredicted increase in plastic waste is happening at a time when countries are reluctant to recycle products because of the lack of complementary decontamination steps and coordination in waste management.

Some manufacturers took this opportunity of increased PPE production to adopt circular economy approaches that can be replicated by others. Decentralized production and material sourcing became more important as supply chains were severely disrupted by the pandemic. This has accelerated the ongoing changes in conventional production methods, with businesses embracing a cradle-to-cradle manufacturing model—that is, rethinking the design of their products from the starting point at the sourcing stage through to the end of the product's life.

This is not without its challenges. For example, when replacing plastics with alternative materials, manufacturers need to ensure that these materials meet quality standards set by standards institutions and enforced by governments.

However, PPE manufacturers cannot shoulder the responsibility of the global plastic waste challenge alone. This publication calls on a broad range of stakeholders along the PPE value chain to work together to shift toward a more sustainable and circular PPE ecosystem (Table 1.0).

This report takes stock of approaches that PPE manufacturers are taking to make their production more sustainable and achieve a true circular economy, while responding to COVID-19 PPE shortages. It does not provide a life-cycle assessment of each PPE product, which is needed to evaluate the environmental effects associated with each product against the benefits created. The approaches highlighted in this report can be grouped into four main categories[4]:

- **Circular inputs**: The use of renewable, bio-based, or completely recyclable materials as input.
- **Resource recovery**: Ensuring that useful resources and energy are recovered from disposed products by collecting and reprocessing products at the end of their life.
- **Product use extension**: Prolonging the lifespan of PPE products by choosing a design that allows the product to be repaired or by choosing durable materials as inputs for the main PPE parts.
- **Product as service**: The product-as-service model allows the consumer to use a product that is retained by the producer to increase resource productivity (for example, leasing PPE). This model allows PPE manufacturers to move from selling products to selling services.

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3 Benson, N.U., et al. 2021. "COVID Pollution: Impact of COVID-19 Pandemic on Global Plastic Waste Footprint." *Heliyon 7* (2).

4 These four circularity approaches are based on Accenture's circular economy business model grouping. Accenture Strategy. 2014. *Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth.*

3 | Companies with innovative circular economy approaches in PPE manufacturing

Globally, several multinational enterprises and start-ups are adopting innovative solutions using biodegradable, compostable, or recycled materials in PPE, while still ensuring that the materials meet the stringent performance standards and durability targets at affordable prices. Other business models are emerging where selling products is being replaced by a merchandizing service (performance-based model); and waste is being converted into new (and even superior) products such as construction materials or new PPE items.

This chapter profiles the innovations of 11 multinational and national PPE manufacturers. Annex A provides a more exhaustive overview of relevant companies, categorized by the four circularity approaches. The examples in this chapter provide multiple entry points to rethink circularity principles in PPE manufacturing.

FORSTA MEDTECH

Resource recovery | Product use extension

COVID-19 PPE products offered

Forsta Medtech is an Indian biotechnology company that makes microwave-based sterilizers. It provides innovative proprietary microwave-based infection and epidemic control solutions for patient safety and for preventing hospital-acquired secondary infections.

Forsta Medtech's SterilSmart is based on the innovative "microwave-assisted cold 70°C sterilization" (MACS) technique, which uses microwaves to treat and disinfect different types of PPE at the point of generation so that they can be reused.

Product technical features in terms of circularity

SterilSmart offers a dry process, enabling sterilization of moisture-sensitive products. Key features of SterilSmart include its low-temperature sterilization, between 60°C and 80°C, without affecting material qualities; quick throughput of 7–30 minutes depending on the type of PPE; and low consumption of energy (3 kilowatts vs. 18 kilowatts for autoclaves) and water (8 liters vs. 900 liters per day). SterilSmart also has a higher sterilization efficacy (in terms of kill rate) than autoclaves (Log^{10} compared with Log^{6}).

The system is available in three models. Based on the number of health-care facility beds, it can cater to 75, 250, and 500 beds with a capacity volume of 150, 400, and 500 liters, respectively. A 500-liter system can disinfect over 60 PPE kits per cycle. On average, this accounts for a load-handling capacity of 80–380 kilograms per day.

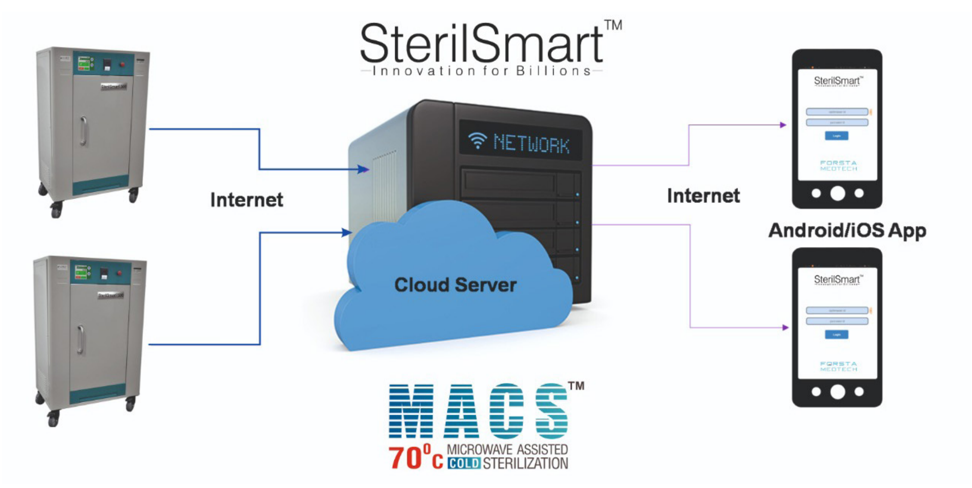
Each model has an easy-to-install plug-and-play unit with nine programmable applications. The models are also Internet-of-Things-enabled with hub connectivity. This allows the user to control the disinfection process through an app, which provides reports and alerts throughout the process.

SterilSmart meets several requirements of the Indian government, along with worldwide quality accreditations from the European Union, ISO 13485, Good Manufacturing Practice, Department of Scientific and Industrial Research, WHO-GMP, OHSAS 18001:2007, and NABL. In addition, it meets several international regulatory guidelines, including the Basel and Stockholm international conventions on managing medical waste.

Circularity mapping

Forsta Medtech's SterilSmart is an innovative decontamination technology that can be used for large-scale sterilization of PPE, at a high throughput, to make them reusable.

FIGURE 3.5: STERILSMART IS INTERNET-OF-THINGS-ENABLED



Source: Adapted from Forsta Medtech's website material.

TABLE 3.3: CIRCULAR DESIGN PRINCIPLES ADOPTED BY FORSTA MEDTECH

CIRCULAR PRINCIPLES	FEATURES	IMPLEMENTATION
Resource recovery and product use extension: SterilSmart makes PPE products reusable by sterilizing them	Decontamination technology	PPE kits and N95 masks can be sterilized and disinfected in bulk within a cycle time of 7–30 minutes

Other companies with innovative circular economy approaches in PPE manufacturing

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APPLICATIONS

INNOVATIVE MOBILE TOTAL INFECTION CONTROL SYSTEM

- Microbiology Labs
- Isolation Wards
- CHC / PHC
- OPDs / OTs
- Clinics

- District Hospitals
- Medical Colleges
- Tertiary Centres
- Private Hospitals
- Blood Banks
- Dialysis Centres

- CBWTFs
- Medical Colleges
- Multi OT Hospitals
- Tertiary Centres
- Pharma Companies
- 500 +Modular Usage

Advantages of Integrated ONLINE Shredder:

- Versatile
- Solar Power Connectivity
- Total Infection Control
- Ease of Storage
- Low Down time
- Low Power Consumption
- Low Maintenance
- Easy to Clean

Capacity	10/20/30 Kg/hr	Rotor Diameter	150
Blades	Stainless Steel 316	Throat Size	250 X 280
Number of Blades	10	Sieve Hole Size	12 mm
Feed Width	250 X 280 mm	Control Panel	YES
Blade Length	250 mm	Speed of Rotor	<100 RPM
Number of Motors	ONE	Automation	Semi-Automatic

CONSUMABLES

Contagious Waste Disinfection | Medical Waste Disinfection | O.T. Linen Disinfection | Dialyzer Sterilization & Reuse | O.T. Instrument Sterilization | Catheters, tubings Sterilization & Reuse | Veterinary Waste Disinfection

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