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A Review On The Environmental Impact Due To Face Mask Disposal And To Explore Methods To Recycle And Reuse Them.

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ABSTRACT: Face mask have been used as a PPE (Personal protective equipment) against the COVID-19 pandemic. Use of face masks delays the transmission of viruses. A variety of shapes, forms, and materials are being used for facemask[6]. However, many researchers have found evidence that these facemasks are being dumped into lakes, rivers, and open garbage dumps and have found their way to soil matrices and inland water bodies, and ultimately, to the sea. [14].Most of these masks contain plastics or other derivatives of plastics. Therefore, this extensive usage of face masks generates million tons of plastic wastes to the environments in a short span of time. This study aims to investigate the environmental impact induced by face mask wastes and sustainable solution to reduce this waste[4].

Chinese and American engineers are devising new procedures for decontaminating and reusing masks that hospitals already have on hand[3].Five fast ways to kill a virus are to irradiate it, fumigate it, heat it in hot water, steam it, or bake it. Each of these approaches seems to be effective, but that is not the only criterion for a successful decontamination. It is also important for masks to come out of the decontamination process as good as new[2]. In this review i have investigated five promising disinfection methods that may be applied to the recycling and reuse of facial masks: vaporised hydrogen peroxide, hot air, UV light, steam and hot water.

KEY WORDS: Face mask, Decontamination, Environmental pollution, Filtration efficiency.

I. INTRODUCTION

The COVID-19 pandemic caused by the virus SARS-COV-2, which first emerged in Wuhan, China, in December 2019, is posing a huge global health threat. This pandemic situation induced uncertain environments for every human, business, education, job, and economy of each country. There is no viable meditation to prevent the spread of this deadly coronavirus disease[17]. The use of personal protective equipment (PPE), social distance, travel restrictions and lockdown were currently employed to reduce this spreading level of coronavirus[18].Face masks are essential to protect from viruses. This on- going pandemic situation created that wearing mask is must for every human life. There are various types of masks such as surgical, N95, and commercial fabric/cloth masks used to tackle the on-going pandemic situation [4](FIG:1).

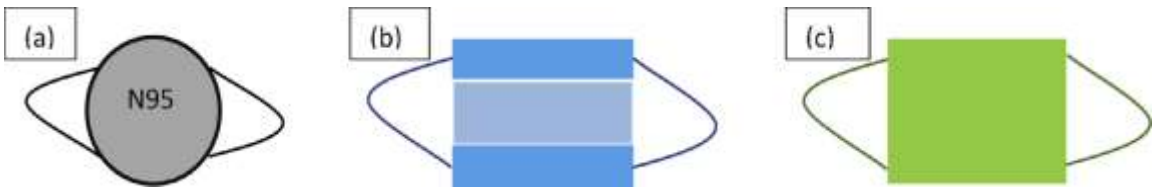

FIG. 1EXAMPLE OF DIFFERENT TYPE OF MASKS: (A) N95 MASK; (B) SURGICAL MASK; AND (C) CLOTH MASK.[4]

As of February 2020, China has raised its daily production of medical masks to 14.8 million. The Japanese ministry of finance, trade, and industry recorded that more than 600 million face masks required per month of April 2020[17].Increasing use of mask significantly increases the production of mask and it consumes higher amount of energy. A study by Klemeš et al.,2020a[20]shows that mask production consumes about 10-30 Wh energy and releases 59 g CO 2 -eq greenhouse gas to the environment. Further, ever increasing uses of face mask also increase the

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landfill and medical waste. Most of these face mask wastes contains either polypropylene and/or polyethylene, polyurethane, polystyrene, polycarbonate, poly- acrylonitrile, which add plastic or micro-plasticpollution to the environment [19].Apart from that most of the facemasks are not been disposed properly, masks are dumped in open spaces and facemasks have found their way to soil matrices, inland water bodies, and to the sea (FIG:2,3).

FIG.2THREAT TO BIRDS DUE TO USAGE OF MASK[21].

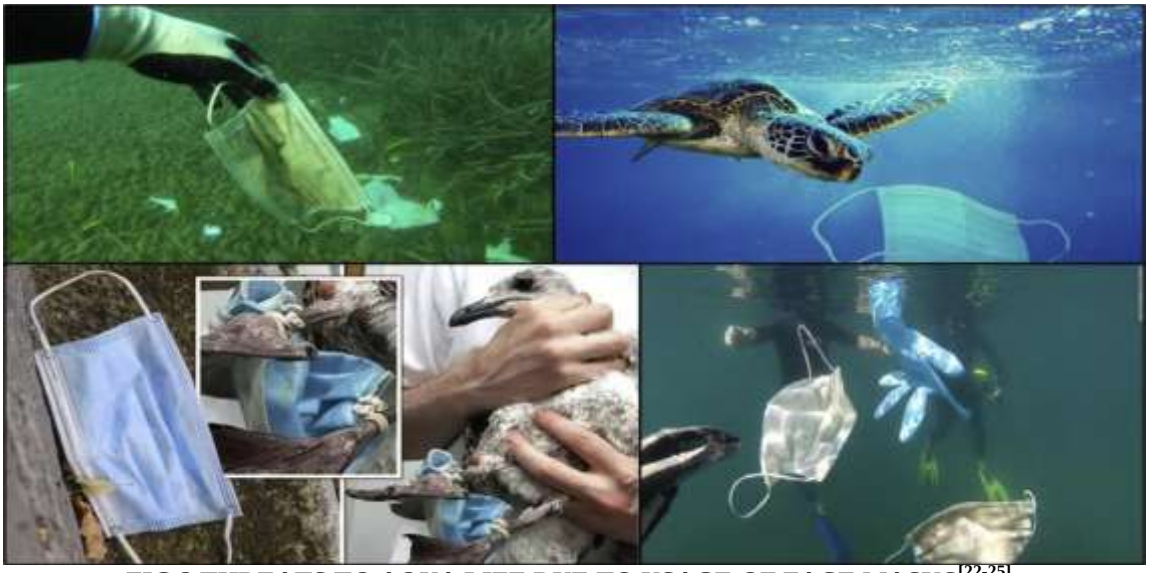

FIG.3 THREATS TO AQUA LIFE DUE TO USAGE OF FACE MASKS[22-25].

Current ongoingpandemic increases the environmental pollution and negative impact to human and animal health. Therefore, sustainable solutions need to reduce the environmental impacts, while meeting the mask demand. Governments and publics have already begun to explore the alternative solutions including the reuse, reprocessing and disinfection of approved disposable masks, and producing biodegradable masks and homemade or non-certified masks[18]. Sterilization is the procedure of destroying all microorganisms in or on a given environment to prevent the spread of infection.Physical and chemical sterilisation techniques are used. Chemical methods include vapour hydrogen peroxide, chlorine dioxide, ethylene oxide, bleach, alcohol, soap solution, ethylene oxide and ozone decontamination. Physical methods include dry/steam heat treatment,microwave oven, hot water, UV light sterilization, electron beam and ionizing radiation[26-28]. These sterilization methods

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have advantages and disadvantages compared to each other [TAB:1].

Technique	Protocol	Duration	Advantage	Disadvantage	Effect on filtration	Evidence
Time decontamination	Doff used N95 respirator into clean paper bag, store in designated space until reuse	At least 72 h, longer if possible (5-7 d ideal	Simple, low-cost, easiest to implement	Unproven, requires daily extended use, requires adequate supply for rotation	Minimal,secondary to reuse.	Not validated but based onstudies by van Doremalenet al,29 2020; Kampfet al,34 2020; Chin et al,33 2020; Otter et al,36 2015;endorsed by CDC19
Chemical decontamination						
Bleach	Submerge N95 respirator mask in 0.6% bleachsolution, rinse with deionized water, dry overnight	Treat 30 min then dry 16-h	Toxic to coronaviruses, readily available, low cost	Residual toxic, unpleasant odour	Aerosol penetration met NIOSH certification criteria	Peer-reviewed: Viscusi et al,23 2009; Kampf et al,34 2020
Alcohols	Submerge N95 respirator in solution of 70% isopropyl alcohol, dry	Soak 20 min, then dry 72 h	Toxic to coronaviruses, readily available, low cost	Rendered respirator filter ineffective	Filtration efficiency significantly degraded	Peer reviewed: Viscusi et al,38 2007; Kampf et al,34 2020
Soap and water	Soak N95 respirator in Ivory bar soap, 1 g/L,shaved from bar anddiluted in tap water, dry.	Soak 20 min, then dry 72 h	Readily available, low cost	Rendered respirator filter ineffective	Filtration efficiency significantly degraded	Peer reviewed: Viscusi et al,38 2007
Vaporized hydrogen peroxide	STERRAD 100S: H2O2 gas plasma sterilizer, single 55-min standard cycle	55 min	Commercially available, fast turnaround	Cellulose-based product (ie, cotton in certain brands) may interfere with sterilization	Aerosol penetration met NIOSH certification criteria	Peer-reviewed: Viscusi et al,23 2009; Not peer reviewed: Dukeprotocol,432020; Fischeret al,402020
Ethylene oxide	Steri-Vac 5XL: singlewarm cycle (55 °C) and 100% ethylene oxide gas,followed by aeration	Ethylene oxide 1 h, then 4-h aeration	Commercially available	Lengthy protocol may limit overall capacity; residual chemicals present	Aerosol penetration met NIOSH certification criteria	Peer-reviewed: Viscusi et al,23 2009; Salter et al,41 2010
Heat decontamination						

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Microwave steam	1100-1250 W–Microwave; individualN95 respirator placed onbox filled with 50 mLwater, or commercially available steam bag(Medela) with 60 mLwater	Microwave 1.5-2 min at full power, then drying time (60 min)	Fast turnaround, materials commerciall y available	Requires individual mask sterilization; may be difficult to scale up	Filtration efficiency remains >95%	Peer reviewed: Fisher et al,21 2011; Lore et al,20 2012
Microwave oven heat.	1100-W microwave at full power; individualN95 respirator placed on a paper towel overrevolving glass plate	2 min total (1 min per side of mask)	Commercial ly available, fast turnaround	Mask material melted after treatment	Unable to test filtration owing to melted components	Peer reviewed: Viscusi et al,23 2009
Dry oven heat	Heat N95 respirator at 70-160 °C in oven for 30min	30-min treatment	>99% effective against Escherichia coli, relatively fast	Temperature s >100C may cause mask to melt	Filtration efficiency remains >95% at 70C, degraded at 160C	Peer reviewed: Viscusiet al, 382007; Non–peerreviewed: Price and Chu,42 2020; Fischer et al,40 2020
Hot water vapour/moist heat	Treat N95 respirator with hot water vapour fromboiling water, or moist heat at 65 °C	10-20 min treatment	>99% effective against E coli, fast treatment, low cost	Protocol not well described, not proven against viruses	Filtration efficiency remains high	Peer reviewed: Lore et al,202012 Non–peer reviewed:Price and Chu,422020
UV light decontamination						
UVGI	Protocols vary; UV light applied to 1 or both sides of N95respirator; UVGIstudied at exposuresranging from 2 to 950J/cm2	1- to 30-min exposure	Multiple studies suggesting effectiveness; protocol for clinical use already pioneered	Variability in protocols mask contour affects UVdose; parts of mask(straps) may take longer to treat; high dose UV may degrade mask	Aerosol penetration met NIOSH certification criteria	Peer reviewed: Mills et al,142018; Lindsley et al,39 2015, Viscusi et al,23 2009Non–peer reviewed:Nebraska protocol,43 2020; Fischer et al,402020

TAB:1. SUMMARY OF DECONTAMINATION METHODS FOR N95 RESPIRATORS[16].(Abbreviations: NIOSH, National Institute for Occupational Safety and Health; UVGI, UV germicidal irradiation.)

Five fast ways to kill a virus are UV irradiation, Vaporized Hydrogen peroxide, treat in hot water, steam it, Dry oven heat. Each of these approaches seems tobe effective, but that is not the only criterion for a successful decontamination. There are four criteriaa good decontamination

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method should satisfy: It should①be effective against the target organism, such as the severe acuterespiratory syndrome coronavirus 2 (SARS-CoV-2) virus thatcauses coronavirus disease 2019 (COVID-19); ②not damage therespirator's filtration;③not affect the respirator's fit; and ④besafe for the person wearing it [29]. Some obvious methods fail these tests. Microwaving, for example,can partially melt the masks [30]. Alcohol and bleach destroy the static charge within the mask, which is vital to its proper function [30,31]. The active layer of an N95 mask is 90% empty space, sothe fibres need help to trap 95% of the particles that pass through they get that help from static electricity [31,32].

II. METHODS

Five effective ways to kill virus without losing filtration efficiency of face mask are UV irradiation, Vaporized Hydrogen peroxide, treat in hot water,steam it, Dry oven heat.Some methods fail these tests. Microwaving can partially melt the masks. Alcohol and bleach can destroy the static charge within the mask, which is vital to its proper function. So here we are discussing some relevant methods without losing its filtration efficiency for decontamination of mask.

N95 Masks Can be Rotated, 1 Mask Every 3–4 Days

Use 3–4 masks, numbered on the outside as 1–4, for each day. They can be used each day in numerical order. All SARS-CoV-2 viruses on the mask will be dead in 3 days. Masks should be kept at room temperature (21–23_C [70–73_F]) and 40% humidity. There is no change in the mask's properties [33].

Hot air (75 °C)

Take 15 pieces of facemask. Preheat the oven (FIG:3**)** to 75 °C. Put the facemasks into the oven. After 30 minutes of heating, take out all the samples and cool at room temperature for 10 minutes. Repeatfor a total of 20 total cycles. After every 5 cycles, pick 3 samples to test filtration efficiency and pressure drop.

FIG:3 HEATING VACUUM OVEN[7].

UV irradiation (254 nm wavelength, 8 W UV light bulb).

Place facemasks into a UV sterilizer (FIG:4). Irradiate under UV light for 30 minutes. Take out the facemasks and let it for 10 minutes. Repeat for 10 cycles.Test the filtration efficiency and pressure drop.

FIG:4STERILIZER CABINET WITH UV[7].

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Steam sterilisation

Prepare a beaker with clean water and heat on a hot plate to a boil. Place the 3 face masks on the beaker and heat them via boiling water vapour for 10 minutes (FIG:5) . Take the samples off and cool at room temperature, making sure the samples are dry. Test the filtration efficiency and pressure drop.

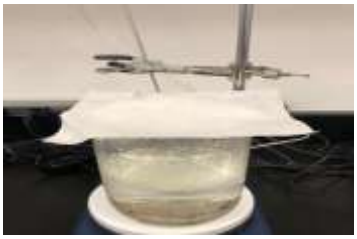

FIG:5 HOT WATER STEAM DISINFECTION[7].

Vaporized Hydrogen peroxide

A 48 minutes steam sterilization process of single use face masks with 15 min holding time at a 121 ℃ was developed, validated and implemented in 19 different hospitals, Steam and H2O2 plasma sterilized as well as new, imported masks are tested in a custom-made, nonstandard EN-149, test set-up that measures Particle Filtration Efficiency (PFE) and pressure.

FIG:6 USING A BIOQUELL (HORSHAM, PA, USA) HYDROGEN PEROXIDE VAPOR GENERATOR, DUKE UNIVERSITY HOSPITALS STAFF CAN DISINFECT, FOR REUSE, 1250 MASKS PER CYCLE, AND 2500 PER 12 H SHIFT

III. DISCUSSION

The above methods are evaluating by filtration efficiency and pressure drop tests.

Air filtration efficiency measurement

Standard filter testing TSI8130A to measure the air filtration efficiency and pressure drop under the flow rate of 32 L/min. The experimental apparatus is show in FIG:6

FIG:6TSI 8130A FOR FILTRATION EFFICIENCY AND PRESSURE DROP MEASUREMENT[7].

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Three types of facemasks viz. certified N-95, non-woven fabric and self-made double layer fabric/textile masks have been evaluated for particulate FE and pressure drop. The macro and microscopic evaluation of facemask fibre/fabric has been carried to characterize whether the decontamination processes caused any significant damage to the mask. The efficiency of facemask from five samples is in the range of 95.77 to 99.02% with an average at 97.44%. The air pressure drop is from 8-11 Pa, with the average at 8.8 Pa(TAB:2**)**.

	Original	
#	Efficiency(%)	PressureDrop(Pa)
1	97.38	8
2	98.67	9
3	99.02	11
4	96.37	7
5	95.77	9
Average	97.44±1.41	8.8±1.5

TAB:2INITIALFACEMASK WITHOUTANYDISINFECTIONTREATMENT[7]

Hot air (75 °C)

Filtration efficiency after 15 cycles of hot airtreatment shows no change (97.51%). After 20 cycles with nearly nochange (95.96%). Compared to the initial 97.44% filtration efficiency, pressure drop is also nearly constant. This data shows that 75 °C hot airdoes not cause the static charge three-dimensional structure offilter(TAB:3).

Cycle	Efficiency(%)	PressureDrop(Pa)
5	96.86	7
	96.02	6
	96.21	7
Average	96.36±0.44	6.7±0.6
10	96.85	7
	97.48	8
	97.41	9
Average		HotAir(30min,75°C)
15	97.47	8
	97.94	11
	97.12	8
Average	97.51±0.41	9.0±1.7
20	95.74	8
	95.7	8
	96.44	9
Average	95.96±0.42	8.3±0.6

TAB:3 .HOTAIR(75 °C)DISINFECTION[7].

UV irradiation (254 nm wavelength, 8 W UV light bulb)

After 10 cycles of UV treatment, the filtration efficiency and pressure drop of facemask remainedconstant. 254 nm UV light can break the chemical bonds of polypropylene, theUV

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dosagehere does notcause any noticeabledamage to the facemask (TAB:4).

Cycle	UVlight(30min)	
10	96.01	10
	96.73	7
	97.60	10
Average	96.78±0.80	9.0±1.7

TAB:4 UVDISINFECTION[7].

Steam sterilisation

After the first 3 cycles, the steam does not seem to change the filtration efficiency. However,after 5 cycles, the filtration efficiency sees an appreciable drop from ~97% to ~85%. After 10cycles, the efficiency significantly degrades ~80%. The air pressure drop does not significantlychange, suggesting that the three-dimensional structure does not change and degrading thestatic chargeofthefiber (TAB:5).

Cycle	Steam(10min)	
1	97.49	10
	98.19	10
	98.23	10
Average	97.97±0.41	10.0±0.0
3	95.19	9
	96.91	8
	97.14	10
Average	96.41±1.07	9.0±1.0
5	83.94	8
	85.14	6
	86.03	8
Average	85.04±1.05	7.3±1.2
10	80.47	7
	77.77	9

TAB:5 STEAMDISINFECTION

Vaporized Hydrogen peroxide

FE of the facemasks remains same after the H2O2 sterilization,but the ink marks present in the outer surface is faded. Masks will retain 92.4% FE [1].

IV. CONCLUSION

Environmental pollution and threats due to facemask can be reduced by recycling and reuse by decontaminating using different sterilisation techniques. The recycling the mask by the appropriate processes is one of the alternatives used to reduce the plastic pollution generated by mask waste. Broadly, there are two ways forrecycling such as primary recycling and secondary/chemical recycling. Primary recycling is the reusing of the product in their original structure. In the secondary recycling, the mask consisting of thermoplastic can be recycle[34].

From the above, there are three disinfection methods which do not reduce the filtration efficiency of the facemask after an appreciable number of treatment cycles.

Method 1: **75 °C Hot air** (30 min) for 20 cycles (Regarding treatment with steam, we advise caution. For 3 treatment cycles or less, we found the filtration efficiency can be maintained at >95%. However, after 5 cycles the efficiency drops to ~85%, and 10 cycles will drop the efficiency to ~80%.

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Method 2: **UV** (254 nm, 8 W, 30 min) for 10 cycles.96.78 filtration efficiency.

Hot air method and UV sterilization methods are the most effective ways for sterilization of masks. UV sterilization is one of the most effective way UV sterilization bag, UV sterilization box, UV sterilization cabinets etc. are available and these makes UV sterilization much more easier .

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