Hasan *et al. Water Emerg Contam Nanoplastics* 2023;2:18
DOI: 10.20517/wecn.2023.31

Water Emerging Contaminants & Nanoplastics

Research Article

Open Access

Check for updates

Release of microfibers from surgical face masks: an undesirable contributor to aquatic pollution

Jabed Hasan[#], Sheik Istiak Md Shahriar[#], Md Shahjahan

Laboratory of Fish Ecophysiology, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
[#]Authors contributed equally.

Correspondence to: Prof. Md Shahjahan, Department of Fisheries Management, Bangladesh Agricultural University, BAU Main Road, Mymensingh 2202, Bangladesh. E-mail: mdshahjahan@bau.edu.bd

How to cite this article: Hasan J, Shahriar SIM, Shahjahan M. Release of microfibers from surgical face masks: an undesirable contributor to aquatic pollution. *Water Emerg Contam Nanoplastics* 2023;2:18. https://dx.doi.org/10.20517/wecn.2023.31

Received: 25 May 2023 **First Decision:** 25 Jul 2023 **Revised:** 30 Aug 2023 **Accepted:** 4 Sep 2023 **Published:** 7 Sep 2023

Academic Editor: Antoni Ginebreda **Copy Editor:** Dong-Li Li **Production Editor:** Dong-Li Li

Abstract

The worldwide usage of surgical face masks (SFM) has increased rapidly during the COVID-19 pandemic. Its degradation possibly produces billions of microplastics (MPs) in the environment. To quantify the release of microfibers (MFs), unused SFM were treated with eight different aqueous solutions, each with five replications in two categories, i.e., freshwater (FW) treatments [800 mL FW, 40 mL of 95% alcohol + 800 mL FW, 40 mL of 30% H_2O_2 + 800 mL FW, and 4 g sodium dodecyl sulfate (SDS) + 800 mL FW], and saltwater (SW) treatments (800 mL SW, 40 mL of 95% alcohol + 800 mL SW, 40 mL of 30% H_2O_2 + 800 mL SW, and 4 g SDS + 800 mL SW) at 25 °C for 60 days. The predominant MFs disposed from SFM were transparent and sized between 1.0 to < 0.5 mm. The mean highest amount of MFs observed was 4,911.3 (1-day) and 6,180.24 (30-day) in sodium dodecyl sulfate (SDS) mixed with SW, and 7,269.7 (60-day) in SDS with FW. The greatest number of MFs released per day was 275 (SDS in SW), followed by 193 (SDS in FW). The results indicated that if different kinds of water are mixed with detergent (SDS), it could accelerate the disposal of MP, whereas SW has considerably higher ability to release more MFs in a shorter time period compared to FW. Furthermore, this study implied that the inappropriate dumping of SFM could unfortunately escalate the preexisting MP pollution in the aquatic environment, which could negatively affect the aquatic living beings.

Keywords: Microplastics, face mask fibers, alcohol, hydrogen peroxide, sodium dodecyl sulfate, aquatic environment

INTRODUCTION

Microplastics (MPs) are complex heterogeneous plastic particles ranging from < 5 mm to 100 nm, with different chemical compositions, molecular weights, sizes, colors, and shapes. MPs can either be categorized as primary or secondary based on their origin. Primary MPs are deliberately manufactured in a desired size of < 5 mm[1], while secondary MPs are produced from the degradation of larger plastic polymers. Various physical, chemical and biological processes such as abrasion, eroding, aging, weathering, photo-oxidation process, and microbial activity accelerate its degradation in the environment[2,3]. Different shapes of MPs can be identified based on their morphology. Beads, pellets, and granules are primary MPs, while fibers (lines and filaments), foam, fragments, and film are the common form of secondary MPs[4]. MP pollutants are ubiquitous contaminants due to their persistent and low biodegradation characteristics in nature. Owing to smaller particle size (< 5 mm), MPs have the potency of bio-accumulation and bio-magnification across food webs for both freshwater and marine environments. This emergent MP contaminant is responsible for environmental pollution and threatens aquatic life, which is widely recognized as a matter of global concern[5-8].

Surgical face masks (SFM) are currently perceived as the most used personal protective equipment (PPE) to curb the worldwide transmission of the COVID-19 virus[9-12]. The use of this single-use or disposable face mask has been advocated by World Health Organization (WHO) and researchers as an effective means against the spread of this virus[13]. In general, disposable surgical masks are purposed for doctors, nurses, and other healthcare practitioners. The usage of and demand for SFM have surged worldwide in response to the COVID-19 pandemic; their application has expanded from healthcare professionals to individuals, with the primary aim of limiting the transmission of this fatal contagious disease[14]. The annual face mask usage during this pandemic reported for Asian countries is 289.63 billion and 32.12 million daily in Bangladesh[15], leading to a significant increase in the demand for and the production of SFM worldwide. Surgical masks are produced from high-density polymeric materials. Synthetic non-(bio)-degradable polymers such as polypropylene (PP) and polyethylene (PE) are the main manufacturing components of disposable face masks[5]. Besides that, other polymers such as polyester (PET), polycarbonate (PC), polyacrylonitrile (PAN), and polystyrene (PS) are used as well[6,16]. Disposable face masks are available in various colors such as dark blue, green, and yellow[17] and consist of three layers: a nonwoven fabric inner layer, a melt-blown filter middle layer, and a nonwoven colored outer layer (water resistant), and feature ear bands made of fiber[18]. The nonwoven layers are produced together with short and long fibers through electrospinning. Upon degradation, they likely release these micro and nanofibers to the environment, addressed as a secondary source of MP pollutants[5,7,10,16].

Unfortunately, the mismanagement and improper disposal of surgical masks polluting public places such as streets, parks, roads, and beaches have led to the rise of environmental plastic and MP pollution in both terrestrial and aquatic environments, especially during the COVID pandemic[12]. People with limited knowledge about the proper disposal of face masks often discard them haphazardly, leading to an accumulation of these masks in terrestrial landfills. Subsequently, these masks can be transported into freshwater aquatic systems through wind and rainfall. Drains, canals, lakes, streams, and rivers ultimately lead to their accumulation in the marine environment. Consequently, the enhanced face mask usage that proved useful against the COVID-19 pandemic would have been responsible for the burgeoning microplastic waste in the environment[10,11] posing a serious threat to aquatic organisms. Since SFM degrade slowly in aquatic environments, releasing microfibers that contribute to environmental pollution and pose a significant threat to aquatic organisms[5]. Additionally, face masks take a longer time to release microfibers in natural environments due to photo-oxidation[19] and UV radiation[20]. Various studies regarding microfibers released from SFM have been carried out, such as face masks as a potential source of MP[5,6,13],

estimation of microfibers (MFs) from surgical masks[15,17,18], microfiber generation and environmental repercussion of MFs[8,12,14,16], and microfibers release from the simulated environment, and probable removal approach from water[19-21]. However, previous record has not been established on whether the salinity of water itself or along with alcohol, detergent or reducing agents has any differences in terms of MPs' disposal from SFM; therefore, this study was aimed to delineate the qualitative and quantitative release of MP from unused surgical masks in both freshwater and saltwater media accompanying with different chemicals under laboratory condition. This study has also reviewed the MFs pathway to aquatic environments, the potential adverse impact of microfibers in aquatic ecology, and the management or safe disposal of SFM.

EXPERIMENTAL

Chemicals

The SFM samples considered in this experiment were new (unused), had three layers (inner, middle and outer) with melt-blown properties, and contained no glass fibers. Chemicals like 95% alcohol, sodium dodecyl sulfate (SDS, molar mass 288.38 g/mol; density: 1.05 g/cm^3), 30% hydrogen peroxide (H_2O_2, molar mass 34.0147 g/mol; density 1.11 g/cm^3), salt (molar mass 58.44 g/mol; density: 2.16 cm^3), and cellulose nitrate filter (0.45 and 0.2 μm) membrane were collected from the available chemical and scientific equipment stores.

Experimental design

New unused SFM were exposed at room temperature for a 60-day trial period with eight different treatments. Each treatment had five replications in two categories, i.e., freshwater (FW) treatments (800 mL FW, 40 mL of 95% alcohol + 800 mL FW, 40 mL of 30% H_2O_2+ 800 mL FW, and 4 g SDS + 800 mL FW), and saltwater (SW) treatments (800 mL SW, 40 mL of 95% alcohol + 800 mL SW, 40 mL of 30% H_2O_2 + 800 mL SW, and 4 g SDS + 800 mL SW) shown in Figure 1. The ultimate destination of unaware discarded face masks is the aquatic environment, both in fresh and marine water[8]. The H_2O_2, SDS and alcohol have potential toxic effects on aquatic life and frequently accumulate in the aquatic environment[22,23], hence used in this study. Saltwater salinity was maintained at 25 ppt with regular checking using ATC portable Refractometer throughout the experimental period. Submersed face masks (without treatments and two groups) were stirred daily at 1,500 rpm for five min at room temperature.

Microfiber extraction

For the first sampling (24-h interval), the mask was taken from the beaker and kept in a cleaned metal tray using a pre-cleaned sterile scissor. The solution remaining in the beaker was filtered through a 0.45 μm cellulose nitrate filter (Sartorius, Germany) by a glass filtration unit (Duran, Germany) attached to a vacuum pump (Rocker 300), and the filter paper was immediately covered with clean glass petri dish. Afterward, the solution and the mask were replaced carefully in the same beaker, and to prevent cross contamination, the opening of the beaker was covered with aluminum foil. In addition to that, the petri dishes were marked according to their treatment group in order to avoid counting errors. For the second and third sampling, the isolation procedure (30-day and 60-day, respectively) followed was the same as the first sampling. Hereafter, all the filter paper was stored carefully for further analysis.

Visualization

After each sampling, the filter paper was placed under a Daffodil MCX100 microscope (Micros Austria) with multiple zoom levels (40-100X) for clear visual identification and quantification of MFs[5,23]. MFs were quantified and, at the same time, categorized according to their color and size group. For size categories, randomly selected 200 MFs from each treatment group were measured and categorized as < 0.5 mm, 0.5-1 mm, and 1-5 mm. Each filter paper was photographed by AmScope camera coupled with the microscope with IS-capture software facilities.

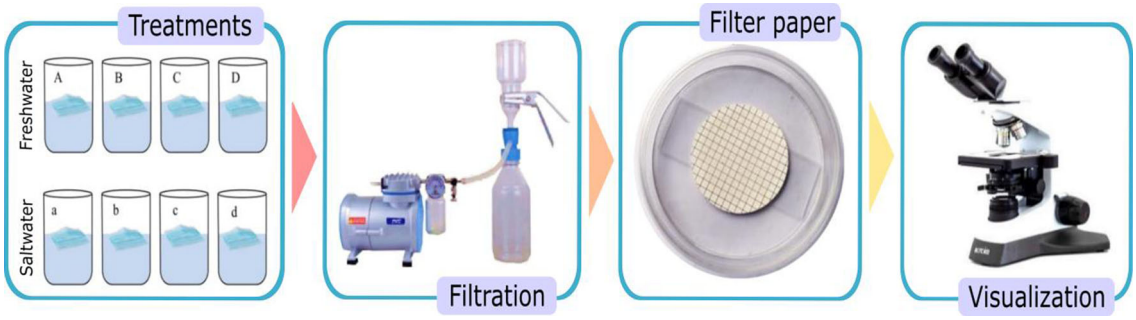

Figure 1. The treatments, filtration and visualization process for microfiber extraction.

Contamination control

The experiment was carried out in a non-ventilated, low-traffic clean room. All solutions were filtered through 0.2 μm filter paper prior to use. The opening of the beaker was covered with aluminum foil. The filter was kept in a cleaned glass petri dish. The filtration unit, beakers, and other equipment were cleaned with distilled water before each sampling. Glassware and metal tools were used for the whole experimental period.

Statistical analysis

All the recorded data were compiled in an Excel sheet and analyzed in SPSS software (IBM SPSS statistics, version 22). The differences in the mean abundance of isolated microfibers were analyzed by one-way ANOVA followed by Tukey's HSD test. Image J software with calibrated slide (Japan) was used for size measurement analysis.

RESULTS

Quantitative analysis of microfibers

The amount of MFs was counted from the samples taken from 1 day, 30 days, and 60 days, respectively. The quantification of MFs in different treatment groups at various sampling days is illustrated in Table 1. After 24 h of soaking, the highest average number of microfibers discharged from SFM was recorded at 4,911.3 ± 247.0 in SDS with SW followed by 586.1 ± 5.0 and 377.3 ± 95.2 in normal SW and 95% alcohol in SW, accordingly. In 30-day sampling, again, the highest mean amount of microfibers (6,180.24 ± 251.7) was released in SDS with SW accompanied by 95% alcohol in SW with average MFs of 4,660.06 ± 123.0. At the end of the trial, the largest average amount of microfibers was counted with SDS in FW (7,269.7 ± 283.1), followed by SDS with SW (5,430.29 ± 213.9). The lowest average number of MFs was released by freshwater treatment, which was 112.04 ± 20.3, 2,707.1 ± 71.5, and 3,320 ± 124.0, accordingly, in three consecutive samplings [Table 1]. The MFs from the sampling days were averaged to get the possible MFs per day. The greatest number of MFs per day discarded from SFM was 275 (SDS in SW) and 193 (SDS in FW), and the least amount of MFs (102) was estimated from normal freshwater samples. One-way ANOVA was constructed in order to compare the number of released MFs from SFM among three different sampling days and between the water types at a 95% confidence interval. The data showed that there were significant differences ($P < 0.05$) in the released MFs number between 1-day sample and 30-day samples, whereas in most cases, there are no significant differences ($P < 0.05$) between 30-day and 60-day samples. Apart from this, the treatments varied significantly ($P < 0.05$) between freshwater and saltwater.

Qualitative analysis of microfibers

The MFs released from the face masks were identified, categorized, and estimated based on their morphology, color, and size. The morphology of isolated microfibers on different treatment groups of

Table 1. Quantity of MFs in different treatment groups at various sampling days

Treatment	Water	MF number in sampling days			MFs/day
		1	30	60	
Normal	FW	$112.04 \pm 20.23^{a,1}$	$2,707.10 \pm 71.56^{b,1}$	$3,320.12 \pm 124.01^{b,1}$	102
	SW	$586.110 \pm 5.00^{a,2}$	$4,021.00 \pm 111.66^{b,2}$	$4,779.03 \pm 154.11^{b,2}$	156
95% Alcohol	FW	$131.02 \pm 33.21^{a,1}$	$2,943.09 \pm 119.02^{b,1}$	$3,578.11 \pm 116.31^{b,1}$	111
	SW	$377.30 \pm 95.22^{a,2}$	$4,660.06 \pm 123.03^{b,2}$	$3,792.00 \pm 138.77^{b,2}$	147
30% H_2O_2	FW	$246.22 \pm 49.06^{a,2}$	$3,191.09 \pm 139.04^{b,1}$	$4,259.27 \pm 205.10^{b,1}$	128
	SW	$119.21 \pm 14.30^{a,1}$	$4,256.07 \pm 133.05^{b,2}$	$5,122.02 \pm 182.01^{b,2}$	158
SDS	FW	$377.10 \pm 29.30^{a,1}$	$3,940.55 \pm 234.06^{b,1}$	$7,269.70 \pm 283.11^{c,2}$	193
	SW	$4,911.33 \pm 247.02^{a,2}$	$6,180.24 \pm 251.71^{b,2}$	$5,430.29 \pm 213.91^{ab,1}$	275

Different alphabetic and numeric superscript indicates (a, b: significance among columns; and 1, 2: significance among rows) the significant difference ($P < 0.01$) among the sampling days and between the water types, respectively. All the data except MF per day are expressed as mean ± SD. FW: Freshwater; MFs: microfibers; SDS: sodium dodecyl sulfate; SW: saltwater.

freshwater and saltwater is shown in Figure 2. The percentage ratio of MFs released per day from SFM based on their colors is depicted in Figure 3. Transparent and blue were the dominant colors of the microplastic fibers discharged from the SFM in this experiment. The highest percentages of transparent (colorless) microfibers were released from face masks treated with SDS (84%), whereas normal saltwater treatment produced the lowest percentage of 41%. The discharge of blue microfibers was recorded as dominant (59.0%) in normal saltwater treatment.

The size distribution of released microfibers from unused SFM was categorized under three different sizes: 1-5 mm (large), 0.5-1.0 mm (medium), and less than 0.5 mm (small). The percentage of MFs size group is shown in Figure 4. The highest percentage of microfibers was small (46.25%) when treated with freshwater and medium-sized (0.5 to 1 mm) microfibers were prominent (39.25%) in saltwater treatments. SDS and 30% H_2O_2 mixed with freshwater produced a greater number of small microfibers, whereas seawater with 95% alcohol released the greatest percentages of medium-sized particles.

DISCUSSION

The release of MP had been witnessed in the present study after unused SFM were put into different treatments. Various literatures addressed that SFM contributed to the release of MP in the forms of MFs and fragments in the environment. MFs discharged from fabrics are the most common form of MP to be found in terrestrial and aquatic environments[24,25]. Aqueous solution is a comparatively more appropriate medium to observe the release potentiality of MP from SFM[26,27]. In this experiment, SFM were submerged in eight different solutions, and the morphology and release capability of MFs were quantified. The face masks submerged in solutions were observed to degrade and a substantial amount of microfibers were released in both freshwater and saltwater media. A previous study reported a higher number of microfibers (360 items per mask) released from static water compared to the present study[18]. However, studies conducted laboratory assessments for the release kinetics of MPs from surgical face masks and gloves aligned with the present study[28,29]. The color of released microfiber from SFM is dependent on its use, the color of the mask, and the polymers and processes used to manufacture it[5,16]. Transparent microfibers could be high in number if face masks are made of PP or PET[25]. Airborne MPs are colorful and ubiquitous in the environment[30]; as a result, there is a chance of finding more colorful microfibers in used SFM. However, from this study, it was perceived that freshwater, when mixed with detergent (SDS), alcohol and hydrogen peroxide, becomes more active in degrading SFM in order to release the greatest percentages of small- to medium-sized microfibers.

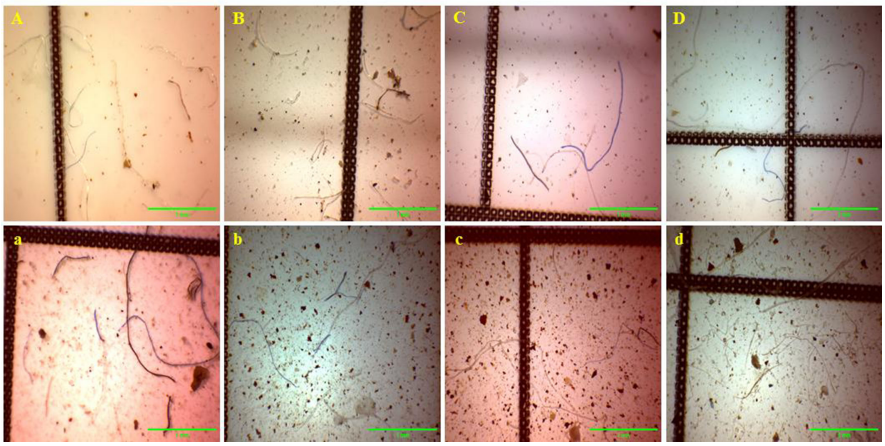

Figure 2. Microscopic images of isolated microfibers from different treatment groups of freshwater [(A) 400 ml FW; (B) 40 mL 95% alcohol + 800 mL FW; (C) 40 mL 30% H_2O_2 + 800 mL FW; and (D) 4 g SDS + 800 mL FW] and saltwater [(a) 800 mL SW; (b) 40 mL 95% alcohol + 800 mL SW; (c) 40 mL 30% H_2O_2 + 800 mL SW; and (d) 4 g SDS + 800 mL SW]. Scale bar: 1 mm; and zoom: 4X.

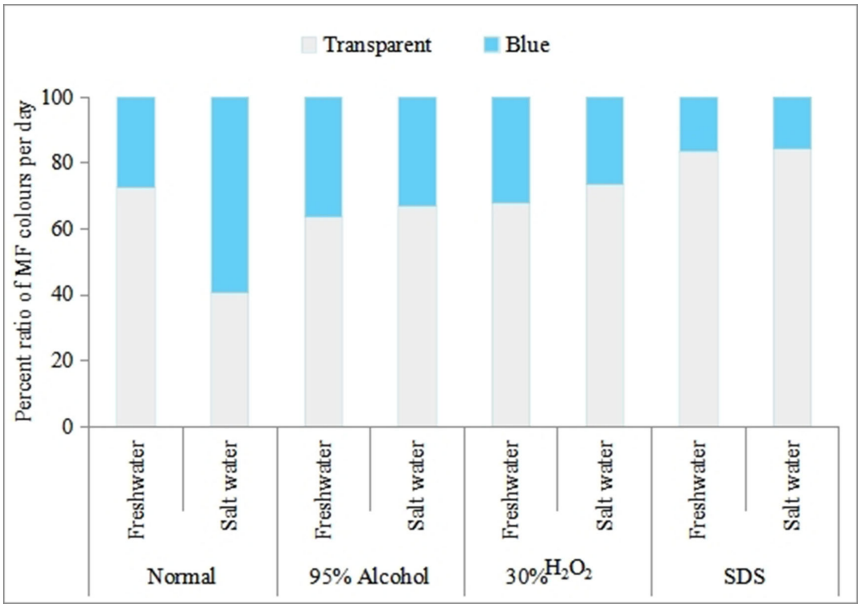

Figure 3. The percentage ratio of isolated microfibers from the different treatments per day by colors. SDS: Sodium dodecyl sulfate.

However, Chen *et al.* (2021) observed the release ability of MPs through soaking used and unused SFM in deionized water[28]. They recorded that the release potentiality of MPs from used face masks (average 1,246.6 ± 403.5 particles/piece) was higher than the unused ones (average 183.0 ± 78.4 particles/piece) in 24 h. Another 24-h experiment exhibited that SFM released 3,600, 5,400, and 4,400 items in first use, whereas this amount had risen to a total of 116,600, 168,800, and 147,000 items after second and third use under ultrapure water, detergent, and alcohol treatment, respectively[18]. Similarly, SDS discharged the greatest amount of MPs in the form of microfibers in this study [Table 1]. Detergent affects the surface charge of fabric tissue and disturbs the distribution of woven fabric by causing microfractures. It also reduces the binding force between nodes and facilitates the release of microfibers. In this study, the released MFs per day in SDS in SW were highest (275), whereas the total disposed microfibers from a single mask was reported to be 254 by Sun *et al.* (2021)[31].

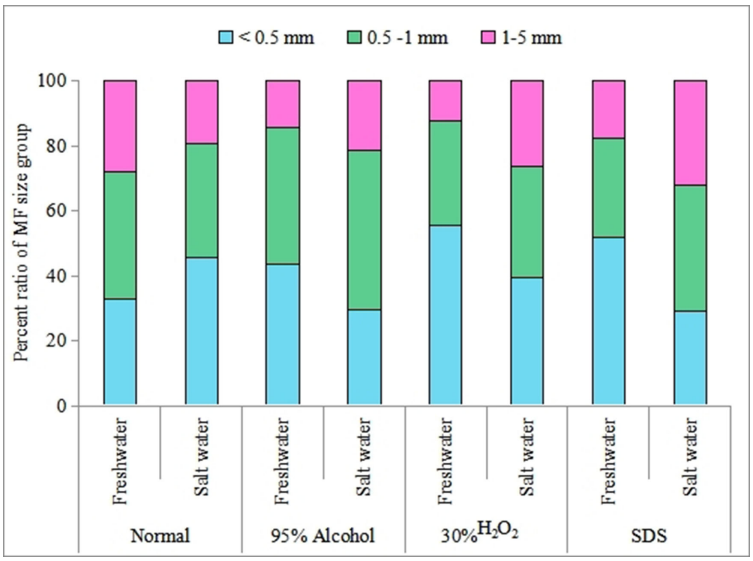

Figure 4. The percentage ratio of isolated microfibers from the different treatments per day by size. SDS: Sodium dodecyl sulfate.

The presence of discarded SFMs is reported to be everywhere, likely streets, parks, beaches, freshwater and marine environments[6,32]. The inappropriate disposal of SFM gives rise to solid waste on the land. The general pathway of SFM, along with its degradation process from land to water, follows when the initial decaying of face mask polymer commences on the terrestrial landfills under the interaction of roughness of land surface along with the high temperature (UV radiation)[33,34]. These factors make the face mask more delicate, brittle, and prone to be fragmented to release microfibers on land and air. Friction stress on rough road surfaces exceeds the limiting strength of the outer layer fabric (nonwoven) of the face mask, subsequently leading to the disruption of the face mask[35]. Discarded face masks could persist on land for several weeks before reaching the aquatic environment. These masks can reach inland or marine water bodies through various means, such as surface runoff, precipitation, drainage pipes, or direct disposal in landfills[36,37]. Upon entering the aquatic environment, face masks undergo discoloration, weakening, tearing, and fragmentation as a result of the fabric integrity being compromised by physical and mechanical stress[38,39]. Furthermore, waves are considered a major driving force for the release of fragmented microfibers from face masks in marine environments[40]. Additionally, various mechanical forces, including water turbulence, tides, water current on the river bed, and abrasion with bottom sand and rocks, coupled with microbial activity, contribute to the enhanced release of MFs from SFM in aquatic environments[41].

The aging or natural weathering process has a huge impact on the degradation of fabric, depending on the characteristics of the fabric and the media in which the aging occurs. The nonwoven part of the face mask (inner and outer layer) used in this experiment also became fragile due to natural weathering and tended to release microfibers. The release capacity of microfibers is augmented with the retention time of face masks in different aqueous media. Saliu *et al.* (2021) assumed that if the mass loss of a disposable face mask is 0.2% in the artificial weathering process, it will take about 2 years for complete degradation[26]. Here, it is observed that saltwater has the ability to degrade SFM more quickly than freshwater, but when water is mixed with detergent, alcohol or oxidizing agent, the decaying time can be less [Table 1]. According to Kenney *et al.*, (1985) seawater has the potential to decrease the strength of synthetic fabric by approximately 10%[42]. The degradation of face masks is also accelerated when other physical, chemical and mechanical forces are applied. The effect of high temperature (UV radiation), friction with the surface (abrasion), turbulence, wave action, storm, and microorganisms can easily degrade plastics into macroplastics (> 5 mm) and then

to MPs. Since the environment is exceptionally variable, it is almost impossible to perform a laboratory simulation that encompasses all the factors or their interactions responsible for the decomposition of surgical masks in the environment. The abrasion-induced degradation of plastic is a common phenomenon in marine environments that leads to the formation of MPs[43].

Environmental microplastic pollution is a serious concern of the scientific community[44-47]. MPs appear to be an emergent class of contaminants with long-term adverse consequences for aquatic ecosystems[12,48]. Owing to its smaller size, MPs are reported to be ingested by aquatic organisms of many different species[49]. This consumption process might be active, i.e., uptake as food material, or passive (ingested accidentally while grazing food). Larger aquatic organisms could easily ingest entire SFM or fragments released from them. A disposable face mask had been found in the stomach of a dead juvenile penguin (*Spheniscus magellanicus*) from Brazil, and it was suspected that the cause of its death was starvation through gut obstruction[50]. Additionally, entanglement with face masks is a common phenomenon that has been reported for several species of birds (*Larus* sp., *Falco peregrinus*, and *Turdus migratorius*), crabs (*Carcinus minus* and *Coenobita perlatus*), and fishes (*Sphoeroides testudineus*)[51]. This entanglement can alter its survivability through immobilization, strangulation, and starvation, making animals prone to predation, infection, or temporary irritation[11]. Moreover, microfibers released from SFM are also reported to be ingested and accumulated by marine zooplankton, directly affecting its reproductive potentiality by reducing fecundity[31]. Microfibers are believed to enter into the higher food chain level through bioaccumulation and biomagnification, imparting various adverse effects on the physiology of aquatic organisms[10,51]. Polyethylene, polypropylene, and polyester (as a form of microfibers) were traced from filter feeders such as bivalves, small crustaceans, crabs, and small fishes[52,53]. The adverse ecotoxicological effects include cessation of feeding, reduced body mass, hampered growth, reduced embryonic development, and mortality; in addition, disruption in metabolic activity, inflammation, and oxidative stress at the cellular level were reported[54,55]. The presence of MPs in aquatic environments is a threat to human existence because their major food supply is dependent on freshwater and marine food chains. Due to their smaller size, microfibers can easily affect the marine environment physically or biologically by entering into food webs[56]. Additionally, MPs can either leach toxic substances and/or absorb harmful chemicals, such as heavy metals[57]. Furthermore, MPs can serve as biofilm and are suspected of harboring disease-carrying pathogens[40].

The overall results of this experiment indicated that seawater mixed with chemicals released a larger amount of MFs in a shorter time period than that of freshwater treatments [Table 1], i.e., if water is contaminated with undesirable chemicals, it leads to a shorter release time for microfibers; consequently, the organisms inhabiting in water bodies near chemical discharge points are at a higher risk of exposure to microfibers. However, the present study was carried out in a photic place of the laboratory and stir was done daily at 1,500 rpm (except normal FW and SW). It could be deduced that the exposure of a beaker containing SFM to photic zone, along with daily stirring and its chemical characteristics, enhanced the release of microfibers. In addition, the overall aging process used in this study revealed that transparent MFs released by normal freshwater treatments generated comparatively more microfibers (72.25%) than saltwater treatments (66.25%). The release of transparent fibers was around 2.5 times and 2 times higher than blue microfibers in freshwater (FW) and saltwater (SW) treatments, respectively [Figure 3]. On the other hand, it has been observed that the degradation of face masks results in the release of a considerable amount of microfibers ranging between < 0.5 mm to 1 mm; particularly, when exposed to normal saltwater, noteworthy percentages of small microfiber (46%) are generated compared to exposure to regular freshwater treatments (33%). In contrast, freshwater itself, along with 95% alcohol, 30% H_2O_2, and SDS, had the capacity to release 82.0% of MFs with a size range of 1 mm - < 0.5 mm [Figure 4]. Therefore, it could be speculated that if the

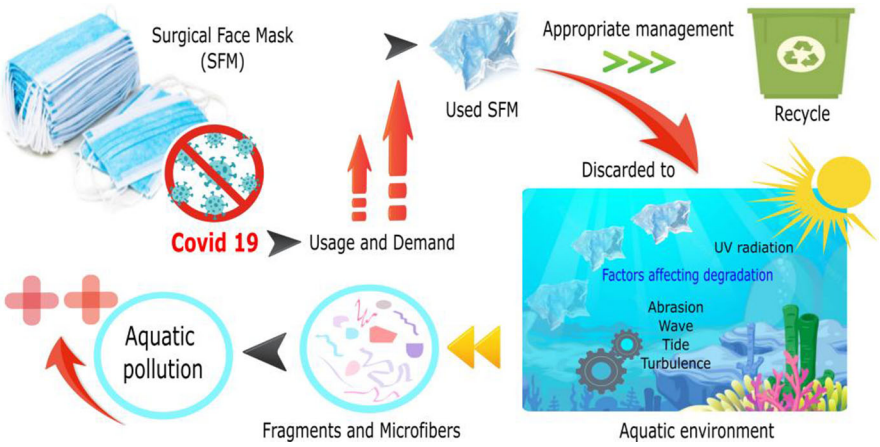

Figure 5. Schematic diagram of microfiber released from SFM to increase aquatic pollution. SFM: Surgical face masks.

degradation of SFM occurred in freshwater, it could produce more microfibers of relatively transparent and larger size. Due to its size and transparency, there could be huge chances that visual and/or filter feeder organisms such as fishes, crustaceans, mollusks, *etc*. in freshwater might mistakenly identify these plastic particles as food[58]. These indigestible particles have the capacity to obstruct the gut and negatively interfere with the digestion of daily food uptakes. In contrast, saltwater produces more micro-sized fibers; as a result, aquatic organisms in saltwater are exposed to smaller particles that can bio-accumulate, produce toxicity and alter the physiology of aquatic organisms when penetrating to the cellular level[59-61].

SFM are addressed as the leading COVID-related waste found in terrestrial and aquatic environments. SFM has been anticipated as a potential MP pollutant in freshwater, coastal and marine environments, allowing aquatic organisms to be exposed to relatively higher concentrations of MPs[62]. The release of microfiber and its pollution inducing schematic diagram is illustrated in Figure 5. Management of plastic waste is still challenging for many South Asian countries such as Bangladesh and this situation is worsening because SFM usage has significantly increased during the COVID and post-COVID period, imposing additional pressure on existing waste management practices. Improperly discarded face masks in the environment are causing pollution. To address this issue, proper management strategies should be implemented, which include raising public awareness, labeling masks with recycling marks, and ensuring that used or discarded masks are sealed in containers and subsequently incinerated. In addition, SFM could be manufactured using biodegradable materials, such as wood fibers or 3D filaments, instead of synthetic polymers. Furthermore, in addressing the chemical nature of MPs for removal from aquatic environments, a recent breakthrough has been achieved by a group of scientists who proposed the use of a froth flotation method to remove MPs from water, leveraging the hydrophobicity/hydrophilicity properties of MPs[63,64].

CONCLUSIONS

This study successfully addressed the ability of SFM to release microfibers in different aquatic environments, although the limitation of this study was yet to use micro-FTIR (Fourier Transform Infrared Spectroscopy) for the confirmation of microfiber composition. In addition, the probable threat to aquatic life has been assumed in this experiment, since detailed work of microfiber release and its adverse effect on fish physiology could be another scope of further research. In conclusion, it could be stated that SFM can produce MPs of different shapes and sizes in aquatic environments. The release potentiality varies between freshwater and seawater. The potency of discharge is also influenced by chemicals such as alcohol, reducing agents, detergent, and/or other various environmental factors. However, the usage of SFM has been

enhanced during COVID-19 worldwide, of which 1%-10% has finally landed in aquatic environments. The total mass that reached aquatic environments could produce billions of MPs, which could have adverse consequences for aquatic organisms. The authors believe that due to improper management of SFM, it has become an undesirable contributor to the preexisting plastic waste in the aquatic environment. The proper management, including both collection and disposal, of SFM is crucial in terrestrial environment, because once SFM enter aquatic environments, their persistence and harmful effects will be impossible to address.

DECLARATIONS

Acknowledgments

The Laboratory of Fish Ecophysiology, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh-2202, gratefully acknowledges the financial support of Ministry of Education, People's Republic of Bangladesh and Bangladesh Agricultural University Research System.

Authors' contributions

Performed the experiment, finalization of extraction protocol, extraction and analysis of microfibers, table and graph preparation, data analysis, and writing the first draft: Hasan J
Preparation of the graph and first draft of the manuscript: Shahriar SIM
Conceptualization, fund acquisition, visualization, supervision, editing the manuscript, and final approval: Shahjahan M

Availability of data and materials

Not applicable.

Financial support and sponsorship

This study was supported by grants from Ministry of Education, People's Republic of Bangladesh (Project No. 2021/10/MoE/LS20211662) and Bangladesh Agricultural University Research System (Project No. 2021/1482/BAU) to the corresponding author.

Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

REFERENCES

1. Eriksen M, Liboiron M, Kiessling T, et al. Microplastic sampling with the AVANI trawl compared to two neuston trawls in the Bay of Bengal and South Pacific. *Environ Pollut* 2018;232:430-9. DOI
2. Horton AA, Dixon SJ. Microplastics: an introduction to environmental transport processes. *WIREs Water* 2018;5:e1268. DOI
3. Paul-pont I, Tallec K, Gonzalez-fernandez C, et al. Constraints and priorities for conducting experimental exposures of marine organisms to microplastics. *Front Mar Sci* 2018;5:252. DOI
4. Karami A, Golieskardi A, Choo CK, Larat V, Karbalaei S, Salamatinia B. Microplastic and mesoplastic contamination in canned sardines and sprats. *Sci Total Environ* 2018;612:1380-6. DOI PubMed
5. Fadare OO, Okoffo ED. COVID-19 face masks: a potential source of microplastic fibers in the environment. *Sci Total Environ* 2020;737:140279. DOI PubMed PMC

6. Anastopoulos I, Pashalidis I. Single-use surgical face masks, as a potential source of microplastics: do they act as pollutant carriers? *J Mol Liq* 2021;326:115247. DOI PubMed PMC
7. Kumar M, Chen H, Sarsaiya S, et al. Current research trends on micro- and nano-plastics as an emerging threat to global environment: a review. *J Hazard Mater* 2021;409:124967. DOI
8. Hasan NA, Heal RD, Bashar A, Haque MM. Face masks: protecting the wearer but neglecting the aquatic environment? - A perspective from Bangladesh. *Environ Chall* 2021;4:100126. DOI PubMed PMC
9. Prata JC, Silva ALP, Walker TR, Duarte AC, Rocha-Santos T. COVID-19 pandemic repercussions on the use and management of plastics. *Environ Sci Technol* 2020;54:7760-5. DOI PubMed
10. De-la-Torre GE, Aragaw TA. What we need to know about PPE associated with the COVID-19 pandemic in the marine environment. *Mar Pollut Bull* 2021;163:111879. DOI PubMed PMC
11. Silva AL, Prata JC, Mouneyrac C, Barcelò D, Duarte AC, Rocha-Santos T. Risks of COVID-19 face masks to wildlife: present and future research needs. *Sci Total Environ* 2021;792:148505. DOI PubMed PMC
12. Torres FG, De-la-torre GE. Face mask waste generation and management during the COVID-19 pandemic: an overview and the Peruvian case. *Sci Total Environ* 2021;786:147628. DOI PMC
13. Worby CJ, Chang HH. Face mask use in the general population and optimal resource allocation during the COVID-19 pandemic. *Nat Commun* 2020;11:4049. DOI PubMed PMC
14. Prata JC, Silva ALP, Duarte AC, Rocha-santos T. Disposable over reusable face masks: public safety or environmental disaster? *Environments* 2021;8:31. DOI
15. Chowdhury H, Chowdhury T, Sait SM. Estimating marine plastic pollution from COVID-19 face masks in coastal regions. *Mar Pollut Bull* 2021;168:112419. DOI PubMed PMC
16. Aragaw TA. Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario. *Mar Pollut Bull* 2020;159:111517. DOI PubMed PMC
17. Chua MH, Cheng W, Goh SS, et al. Face masks in the new COVID-19 normal: materials, testing, and perspectives. *Research* 2020;2020:7286735. DOI PubMed PMC
18. Shen M, Zeng Z, Song B, et al. Neglected microplastics pollution in global COVID-19: disposable surgical masks. *Sci Total Environ* 2021;790:148130. DOI PubMed PMC
19. Liu Y, Yang X, Luo L, et al. Long-term release kinetic characteristics of microplastic from commonly used masks into water under simulated natural environments. *Sci Total Environ* 2023;876:162526. DOI
20. Liang H, Guo R, Liu D, et al. The behavior of microplastics and nanoplastics release from UV-aged masks in the water. *Sci Total Environ* 2023;891:164361. DOI PubMed
21. Jiang H, Su J, Zhang Y, et al. Insight into the microplastics release from disposable face mask: simulated environment and removal strategy. *Chemosphere* 2022;309:136748. DOI PubMed PMC
22. Sunday MO, Jadoon WA, Ayeni TT, et al. Heterogeneity and potential aquatic toxicity of hydrogen peroxide concentrations in selected rivers across Japan. *Sci Total Environ* 2020;733:139349. DOI PubMed
23. Asio JRG, Garcia JS, Antonatos C, Sevilla-nastor JB, Trinidad LC. Sodium lauryl sulfate and its potential impacts on organisms and the environment: a thematic analysis. *Emerg Contam* 2023;9:100205. DOI
24. Hernandez E, Nowack B, Mitrano DM. Polyester textiles as a source of microplastics from households: a mechanistic study to understand microfiber release during washing. *Environ Sci Technol* 2017;51:7036-46. DOI PubMed
25. Wang T, Li B, Zou X, et al. Emission of primary microplastics in mainland China: invisible but not negligible. *Water Res* 2019;162:214-24. DOI PubMed
26. Saliu F, Veronelli M, Raguso C, Barana D, Galli P, Lasagni M. The release process of microfibers: from surgical face masks into the marine environment. *Environ Adv* 2021;4:100042. DOI
27. Napper IE, Thompson RC. Release of synthetic microplastic plastic fibres from domestic washing machines: effects of fabric type and washing conditions. *Mar Pollut Bull* 2016;112:39-45. DOI PubMed
28. Chen X, Chen X, Liu Q, Zhao Q, Xiong X, Wu C. Used disposable face masks are significant sources of microplastics to environment. *Environ Pollut* 2021;285:117485. DOI PubMed PMC
29. Akhbarizadeh R, Dobaradaran S, Nabipour I, et al. Abandoned COVID-19 personal protective equipment along the Bushehr shores, the Persian Gulf: an emerging source of secondary microplastics in coastlines. *Mar Pollut Bull* 2021;168:112386. DOI PubMed PMC
30. Enyoh CE, Verla AW, Verla EN, Ibe FC, Amaobi CE. Airborne microplastics: a review study on method for analysis, occurrence, movement and risks. *Environ Monit Assess* 2019;191:668. DOI
31. Sun J, Yang S, Zhou GJ, et al. Release of microplastics from discarded surgical masks and their adverse impacts on the marine copepod *Tigriopus japonicus*. *Environ Sci Technol Lett* 2021;8:1065-70. DOI
32. Jiang H, Luo D, Wang L, Zhang Y, Wang H, Wang C. A review of disposable facemasks during the COVID-19 pandemic: a focus on microplastics release. *Chemosphere* 2023;312:137178. DOI PubMed PMC
33. Ardusso M, Forero-López AD, Buzzi NS, Spetter CV, Fernández-Severini MD. COVID-19 pandemic repercussions on plastic and antiviral polymeric textile causing pollution on beaches and coasts of South America. *Sci Total Environ* 2021;763:144365. DOI PubMed PMC
34. Song YK, Hong SH, Jang M, Han GM, Jung SW, Shim WJ. Combined effects of UV exposure duration and mechanical abrasion on microplastic fragmentation by polymer type. *Environ Sci Technol* 2017;51:4368-76. DOI PubMed

35. Zhang K, Hamidian AH, Tubić A, et al. Understanding plastic degradation and microplastic formation in the environment: a review. *Environ Pollut* 2021;274:116554. DOI
36. Castro-Jiménez J, González-Fernández D, Fornier M, Schmidt N, Sempéré R. Macro-litter in surface waters from the Rhone River: plastic pollution and loading to the NW Mediterranean Sea. *Mar Pollut Bull* 2019;146:60-6. DOI
37. Kane IA, Clare MA, Miramontes E, et al. Seafloor microplastic hotspots controlled by deep-sea circulation. *Science* 2020;368:1140-5. DOI PubMed
38. Torres-Agullo A, Karanasiou A, Moreno T, Lacorte S. Overview on the occurrence of microplastics in air and implications from the use of face masks during the COVID-19 pandemic. *Sci Total Environ* 2021;800:149555. DOI PubMed PMC
39. Cooper DA, Corcoran PL. Effects of mechanical and chemical processes on the degradation of plastic beach debris on the island of Kauai, Hawaii. *Mar Pollut Bull* 2010;60:650-4. DOI PubMed
40. Dharmaraj S, Ashokkumar V, Hariharan S, et al. The COVID-19 pandemic face mask waste: a blooming threat to the marine environment. *Chemosphere* 2021;272:129601. DOI PubMed PMC
41. Morgana S, Casentini B, Amalfitano S. Uncovering the release of micro/nanoplastics from disposable face masks at times of COVID-19. *J Hazard Mater* 2021;419:126507. DOI PubMed PMC
42. Kenney MC, Mandell JF, Mcgarry FJ. The effects of sea water and concentrated salt solutions on the fatigue of nylon 6,6 fibres. *J Mater Sci* 1985;20:2060-70. DOI
43. Efimova I, Bagaeva M, Bagaev A, Kileso A, Chubarenko IP. Secondary microplastics generation in the sea swash zone with coarse bottom sediments: laboratory experiments. *Front Mar Sci* 2018;5:313. DOI
44. Thompson RC, Olsen Y, Mitchell RP, et al. Lost at sea: where is all the plastic? *Science* 2004;304:838. DOI PubMed
45. Su L, Xue Y, Li L, et al. Microplastics in Taihu Lake, China. *Environ Pollut* 2016;216:711-9. DOI
46. Murphy F, Ewins C, Carbonnier F, Quinn B. Wastewater treatment works (WwTW) as a source of microplastics in the aquatic environment. *Environ Sci Technol* 2016;50:5800-8. DOI PubMed
47. Reid AJ, Carlson AK, Creed IF, et al. Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biol Rev Camb Philos Soc* 2019;94:849-73. DOI PubMed
48. Aragaw TA, Mekonnen BA. Distribution and impact of microplastics in the aquatic systems: a review of ecotoxicological effects on biota. In: Muthu SS, editor. Microplastic Pollution. Singapore: Springer; 2021. p. 65-104. DOI
49. Singh RP, Mishra S, Das AP. Synthetic microfibers: pollution toxicity and remediation. *Chemosphere* 2020;257:127199. DOI PubMed
50. Gallo Neto H, Gomes Bantel C, Browning J, et al. Mortality of a juvenile Magellanic penguin (*Spheniscus magellanicus*, Spheniscidae) associated with the ingestion of a PFF-2 protective mask during the COVID-19 pandemic. *Mar Pollut Bull* 2021;166:112232. DOI PubMed PMC
51. Hiemstra AF, Rambonnet L, Gravendeel B, Schilthuizen M. The effects of COVID-19 litter on animal life. *Animal Biol* 2021;71:215-31. Available from: https://www.remed-zero-plastique.org/upload/resource/619cd4bd87c84_[15707563%20-%20Animal%20Biology]%20The%20effects%20of%20COVID-19%20litter%20on%20animal%20life.pdf. [Last accessed on 5 Sep 2023]
52. Miller ME, Hamann M, Kroon FJ. Bioaccumulation and biomagnification of microplastics in marine organisms: a review and meta-analysis of current data. *PLoS One* 2020;15:e0240792. DOI PubMed PMC
53. Kutralam-Muniasamy G, Pérez-Guevara F, Elizalde-Martínez I, Shruti VC. An overview of recent advances in micro/nano beads and microfibers research: critical assessment and promoting the less known. *Sci Total Environ* 2020;740:139991. DOI PubMed
54. Santos D, Félix L, Luzio A, et al. Toxicological effects induced on early life stages of zebrafish (*Danio rerio*) after an acute exposure to microplastics alone or co-exposed with copper. *Chemosphere* 2020;261:127748. DOI PubMed
55. Zheng X, Zhang W, Yuan Y, et al. Growth inhibition, toxin production and oxidative stress caused by three microplastics in *Microcystis aeruginosa*. *Ecotoxicol Environ Saf* 2021;208:111575. DOI
56. Klemeš JJ, Fan YV, Tan RR, Jiang P. Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. *Renew Sustain Energy Rev* 2020;127:109883. DOI PubMed PMC
57. Wang Y, Wang X, Li Y, et al. Effects of exposure of polyethylene microplastics to air, water and soil on their adsorption behaviors for copper and tetracycline. *Chem Eng J* 2021;404:126412. DOI
58. Alnajar N, Jha AN, Turner A. Impacts of microplastic fibres on the marine mussel, *Mytilus galloprovinciallis*. *Chemosphere* 2021;262:128290. DOI PubMed
59. Hamed M, Soliman HAM, Osman AGM, Sayed AEH. Assessment the effect of exposure to microplastics in Nile Tilapia (*Oreochromis niloticus*) early juvenile: I. blood biomarkers. *Chemosphere* 2019;228:345-50. DOI PubMed
60. Espinosa C, Cuesta A, Esteban MÁ. Effects of dietary polyvinylchloride microparticles on general health, immune status and expression of several genes related to stress in gilthead seabream (*Sparus aurata L.*). *Fish Shellfish Immunol* 2017;68:251-9. DOI PubMed
61. Meier P, Zabara M, Hirsch C, et al. Evaluation of fiber and debris release from protective COVID-19 mask textiles and *in vitro* acute cytotoxicity effects. *Environ Int* 2022;167:107364. DOI PubMed PMC
62. Soo XYD, Wang S, Yeo CCJ, et al. Polylactic acid face masks: are these the sustainable solutions in times of COVID-19 pandemic? *Sci Total Environ* 2022;807:151084. DOI PubMed PMC
63. Jiang H, Bu J, Bian K, et al. Surface change of microplastics in aquatic environment and the removal by froth flotation assisted with cationic and anionic surfactants. *Water Res* 2023;233:119794. DOI
64. Bian K, Hu B, Jiang H, Zhang Y, Wang H, Wang C. Is the presence of Cu(II) and p-benzoquinone a challenge for the removal of microplastics from landfill leachate? *Sci Total Environ* 2022;851:158395. DOI