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The Release Potential of Microplastics from Face Masks into the Aquatic Environment

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Abstract: Since the COVID-19 pandemic, a huge number of face masks have been used to prevent the spread of the coronavirus on a global scale. Unfortunately, several studies have reported the presence of used face masks in marine litter in different countries around the world. Face masks produced from synthetic polymers can increase the environmental burden and contradict sustainability. This study aimed to investigate the environmental behavior of face masks when exposed to natural environmental conditions following improper disposal. New and naturally aged surgical and FFP2 masks were exposed to deionized water (DI) and sea water conditions to understand the environmental behavior of face masks when exposed to different environmental conditions. Following natural aging and DI and sea water exposure, face masks were characterized with Fourier transform infrared (FTIR) spectroscopy and scanning electron microscopy (SEM), and compared with new masks. According to the results, the middle layers of both mask types were exposed to more severe degradation. Aging resulted in higher microplastic (MP) release than new masks in DI and seawater for both types of face masks. Compared to new ones, aging and seawater exposure caused 11 to 13 and 14 to 22 times higher MP release from surgical and FFP2 face masks, respectively. Following seawater exposure, aged FFP2 mask released higher amounts of MP ($4.36–6.20 \times 10^6$) than aged surgical masks ($4.03–5.45 \times 10^6$). According to the results, a significant portion of the released MPs were <10 μm for both types of masks. However, when aged FFP2 masks were exposed to seawater, a remarkable increase was found in the fraction of 10–50 μm and 50–100 μm, suggesting that aged FFP2 masks also became fragmented in seawater conditions. FTIR and SEM analyses confirmed the transformation in the structure and chemical composition of the materials. A significant change was observed in chemical and physical structure of the masks after being exposed to weathering conditions in a relatively short period of time (one month).

Keywords: microplastic; face mask; natural weathering; aquatic environment; seawater

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1. Introduction

Plastics have been used in a wide range of materials since they were invented. Although some plastic products are recycled at the end of their useful life, a significant amount of plastics become waste. The Great Pacific Garbage Patch, which is predicted to contain 79,000 tons of floating plastics, is a visible sign of the extent of plastic pollution in the marine environment [1]. Recently, microplastics (MPs) have been increasingly encountered in various aquatic and terrestrial environments at a global scale. The presence of MPs was reported in a wide variety of environments, including the ocean [2], surface and groundwater [3–5], soil [6,7], and indoor and outdoor air [8–10]. There is increasing evidence of MP presence in aquatic organisms [11–13], as well as the potential harmful effects of MPs on aquatic organisms [12,14]. It was found that 35% of MPs in the oceans are fiber-type [2]. Moreover, fibers were found as the primary source of MPs in marine organisms [11]. In addition to the intake of MPs into the human body through inhalation or the food chain, it was determined that MPs can reach different parts of the human body. MPs have been found in the placenta [15], lung tissue [16], intestine tissue [17], etc. Although

evidence for the extent of the impact of MPs on health is limited, the number of recent studies has increased dramatically. These studies have revealed a variety of biological effects, including DNA and cellular damage, cytokines secretion, allergy, inflammation, fibrosis, etc. [18–21]. Another point to be noted is that MPs can adsorb harmful pollutants on their surfaces [22–24].

Since the COVID-19 pandemic, a huge amount of face masks have been used to prevent the spread of the coronavirus on a global scale. Unfortunately, several studies have already reported the presence of used face masks in marine litter in different countries around the world [25–27]. As a consequence of the extensive use of these types of plastic equipment, MP pollution will unavoidably increase due to improper disposal. According to the World Health Organization (WHO), the estimated global need for surgical masks was 89 million per month in 2020 [28]. The annual usage of face masks was estimated to be 289.63 billion in Asian countries alone [29]. Single-use personal protective equipment (face masks, gloves, wipes, etc.) contain plastic and should be disposed of via a proper waste management strategy. A huge amount of used face masks end up on open dumps or landfills in developing countries. Even if just 1% of face masks are disposed of improperly on global scale, dozens of tons of face masks correspond to several million masks released into the environment. Face masks are generally made of polypropylene, and they contain mostly fiber-type MPs. Although the degradation rate depends on various factors, when face masks are exposed to environmental conditions, such as sunlight or salt water, they may be completely converted into MPs within a shorter period of time than other hard plastic materials. Moreover, these personal protective materials contain a certain amount of non-recyclable plastic. In a recent article, it was estimated that 0.15–0.39 million tons of plastic waste from used face masks could end up in oceans [29]. During the COVID-19 pandemic, several governments announced their decision to require masks in indoor public settings. Some governments announced the measures that people must be wear N95 or FFP2 masks with a higher protection against the coronavirus rather than other basic types face masks. Unfortunately, it seems that the huge amount of used masks and other personal protective materials have become a threat to the aquatic and terrestrial environment. Therefore, it has become important to evaluate the environmental behavior of face masks when they are exposed to different environmental conditions, to record information about what precautions should be taken for the plastic disposable face masks in a possible future pandemic and to develop a strategy for how to dispose of used masks. Research has shown that face masks are the source of micro/nanoplastics [25,30–33]. However, most of the research evaluating the MP release from masks has been conducted with different brands of new surgical masks. Some studies have investigated the MP release from artificially aged (UV-weathered) masks [31,32], and one particular study investigated the effect of natural aging under sunlight on MP release from face masks [33]. However, the above-mentioned study was conducted with just surgical masks. Only one previous study investigated MP release from N95 masks, but the experiments were performed using DI water [30]. There is only one particular study carried out in sea water conditions [32]. Saliu et al. (2021) evaluated the MP release from artificially aged surgical masks under UV light in laboratory conditions. However, the aforementioned study did not include N95 masks. Considering the plastic content of a single N95 mask is approximately 3-fold more than a surgical mask [29], the MP release potential of N95 (or FFP2) is not negligible. This study aimed to evaluate the effect of aging and exposure of different environmental conditions on disposable surgical and FFP2 (equivalent to N95) face masks. New and naturally aged disposable face masks were characterized and compared to evaluate the effect of the aging process and water exposure. Thus, a comprehensive evaluation of new and naturally aged surgical and FFP2 masks was performed.

2. Materials and Methods

2.1. Materials

Masks used in the experiments were four widely available surgical (S1–S4) masks and three FFP2 (F1–F3) face masks purchased from a pharmacy during the pandemic. Both types of face mask consist of three layers. Table 1 shows the specifications of the face masks used in the study according to the information on the package. New and naturally aged face masks were used to evaluate the impact of different conditions on MP release. All face mask samples were unused. Some of the face mask samples were kept under direct sunlight on the flat roof of the laboratory over one month to obtain naturally aged face mask samples exposed to natural UV weathering. Following one month of natural UV weathering, aged face masks were carefully transferred to pre-cleaned glass containers, which were then covered with aluminum foil. The weather was clear and sunny during the weathering experiments. The minimum and maximum temperatures are shown in Figure 1. The solar UV index was between 8 and 10 during the period when the experiments were being conducted (August 2022).

Table 1. Face mask specifications used in experiments.

Face Masks	Specifications
S1	Surgical face mask, Type IIR, TS EN 14683, polypropylene, latex-free, nylon-free, non-sterile, three-ply with ear loop, CE certification, meltblown in three layers.
S2	Surgical face mask, Type IIR, EN 14683, polypropylene, non-sterile, three-ply wit ear loop, CE certification, spunbound (inner and outer layer), meltblown (middle layer)
S3	Surgical face mask, TS EN 14683-AC, Polypropylene, non-sterile, latex-free, glass-fiber-free, three-ply wit ear loop, CE certification
S4	Surgical face mask, Type IIR, TS EN 14683, polypropylene, fiberglass-free, three-ply with ear loop, CE certification, spunbound (inner and outer layer), meltblown (middle layer)
F1	FFP2 face mask, EN 149:2001+A1:2009, latex-free, EU 2016/425, CE certificate
F2	FFP2 face mask, EN 149:2001+A1:2009, latex-free, EU 2016/425, CE certificate
F3	FFP2 face mask, EN 149:2001+A1:2009, latex-free, EU 2016/425, CE certificate

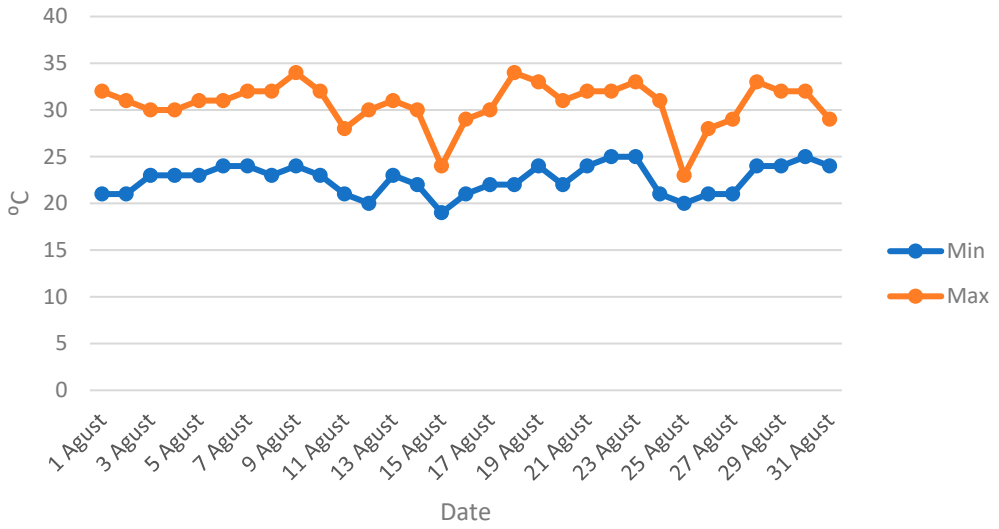

Figure 1. Minimum and maximum temperatures during the weathering experiments.

2.2. Experimental Setup

To evaluate the effect of water exposure following natural aging, new and naturally aged face masks in whole form were put into a 500 mL Erlenmeyer and soaked in either 250 mL of DI or seawater, separately. The flasks were then placed in an orbital shaker with a rotation speed of 200 rpm for 24 h to simulate mechanical forces (e.g., wave, turbulence). The procedure was performed with three samples of each mask. Artificial seawater was

prepared according to ASTM D1141-98 [34]. Control samples without a mask were prepared with DI or artificial seawater to detect for any contamination. Following 24 h of shaking, face masks were removed from the Erlenmeyer flasks using tweezers and rinsed with 250 mL of deionized water to collect the remaining MPs on the surface of the masks. Then, each of the solutions obtained with the same procedure were immediately filtered through an Isolab 0.2 µm nitrocellulose membrane (Ø = 4.7 cm). The filter was placed into an aluminum foil-coated Petri dish and air-dried for 24 h. The volume of the solution was varied between 100 to 500 mL to avoid the overlapping of fibers on the filters to obtain 100 to 200 MPs per filter. All laboratory equipment were cleaned with ethanol and rinsed with ultrapure water several times, and then they were exposed to 400 °C before use to avoid organic impurities. Data obtained from the different environmental exposure experiments were analyzed statistically using one-way ANOVA (SPSS version 18) and *t*-tests ($p < 0.05$). The data were given as MPs per face mask ± standard deviation.

2.3. Instrumental Analysis

2.3.1. Physicochemical Changes of the Face Masks

After natural aging under direct sunlight, all layers of the face masks were detached from the mask, and each layer of the mask samples was characterized using ATR–FTIR (Vertex 70, Bruker, USA). New masks and masks exposed to seawater or deionized water were also characterized using ATR–FTIR to compare and reveal the physicochemical changes of the masks exposed to different weathering conditions. FTIR spectra were recorded in the wavenumber range of 4000–400 cm^{-1} with a 4 cm^{-1} resolution across 32 scans. The background spectrum was recorded against air. The FTIR spectra were compared to reference data for spectral matching. The outer, inner and middle layers of the obtained face mask samples, following natural aging under direct sunlight, were also scanned using scanning electron microscope (SEM). SEM micrographs were obtained to examine the structural changes using SEM/QUANTA FEG-250 in the low-vacuum mode (PH_2O = 90 pa). Small pieces of the samples (5 mm × 5 mm) were placed on aluminum stubs using an adhesive carbon band and analyzed at an electron-accelerating voltage of 5 kV. The samples were photographed under various magnifications between 100× and 5000× to observe and physicochemical changes in the masks.

2.3.2. MP Count

After the MP release experiments, each solution obtained was filtered through a 0.2 µm nitrocellulose membrane. The dried filter was first examined using a Tinyscope mobile microscope (20×–400×) mounted on a smart phone with an optical resolution of 2 µm to control the homogeneous distribution of MPs. Then, SEM micrographs of the filters were obtained. Magnifications of the SEM micrographs were between 100× and 10,000×. The amount and size of the MPs on the filter were determined using SEM micrographs with the help of ImageJ [35]. MPs were grouped into five categories (<10 µm, 10–50 µm, 50–100 µm, 100–500 µm, 500–1000 µm). MPs were gently taken from the surface of the filter with the help of tweezers, and the polymer origin was verified by ATR–FTIR. Verification was made for each filtration experiment according to Saliu et al. (2021) [32].

3. Results and Discussion

3.1. The Effect of Natural Weathering on the Physicochemical Structure of the Face Masks

Figure 2 shows the SEM micrographs of the surgical and FFP2 face masks before and after natural weathering. As shown in Figure 2, fibers on all layers of the new face masks (a1, a3, a5, a7, b1, b3, b5 and b7) were intact with a conserved structure. It can be clearly seen from the micrographs of the weathered face mask samples that the fibers became fragile and damaged after natural weathering (a2, a4, a6, a8, b2, b4, b6, and b8).

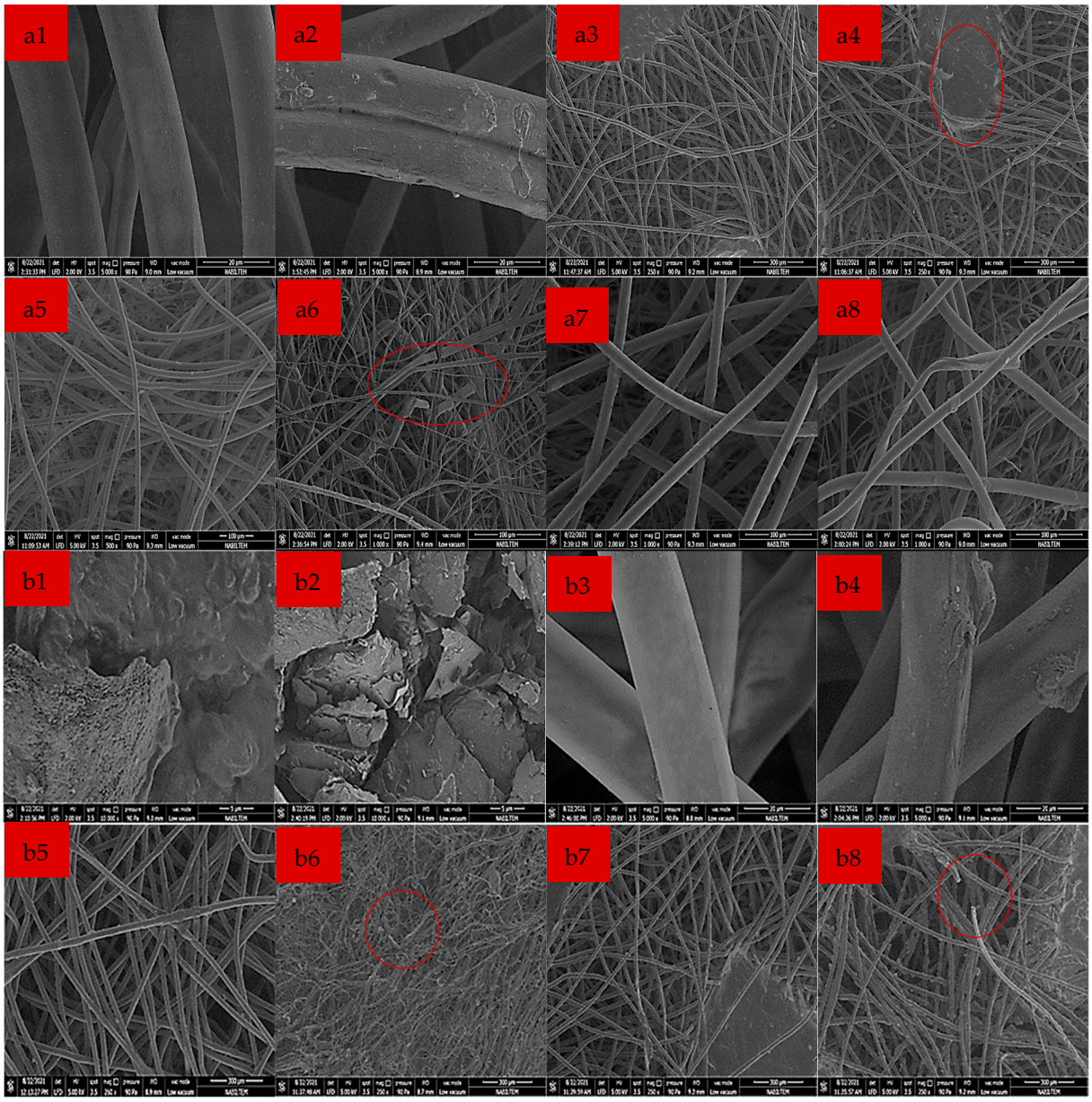

Figure 2. SEM micrographs of the surgical and FFP2 face masks before and after natural aging: (**a1**,**a2**) ear loop, (**a3**,**a4**) outer layer, (**a5**,**a6**) middle layer and (**a7**,**a8**) inner layer of the surgical face mask; (**b1**,**b2**) ear loop, (**b3**,**b4**) outer layer, (**b5**,**b6**) middle layer and (**b7**,**b8**) inner layer of the FFP2 mask.

All layers of the mask were affected by aging, and the mask structure was significantly destroyed. The middle layers of both mask types were exposed to more severe degradation, and showed signs of shrinkage after natural weathering. Cracked fibers in the outer and middle layers of the surgical face masks are marked with circles. Unlike the surgical face mask, fibers in the inner layer of the FFP2 masks were also cracked.

Face masks exposed to sunlight for 30 days were analyzed by FTIR spectroscopy to observe changes in the chemical compositions. Figures 3 and 4 show the FTIR spectra of each layer of the new and weathered face masks. When the infrared spectra of the face masks were examined, it could be clearly seen that all layers of both masks were made of polypropylene, corresponding to the characteristic adsorption bands at 2950, 2916, 2870, 2837, 1456, 1375, 1166, 996, 973, 840 and 808 cm^{-1} [36,37]. Four broad peaks in the wavenumber ranging from 2800 to 3000 cm^{-1} were evident, corresponding to CH_2 and CH_3 vibrations. More specifically, the peaks at 2916 and 2837 cm^{-1} corresponded

to the asymmetric and symmetric –C–CH_2–C– stretching vibrations, while the peaks at 2950 and 2870 cm^{-1} were due to –C–CH_3 stretching vibrations [37,38]. The peaks at 1456 and 1375 cm^{-1} were attributed to –CH_3, –CH_2– bending vibrations, while the peaks at 1166 cm^{-1} were due to –(CH_2)n– bending vibrations [37]. Lastly, small peaks in the spectrum are characteristic of polypropylene, including C-C stretching and CH_3 asymmetric rocking at 996 cm^{-1} and 973 cm^{-1}, C-H rocking at 840 cm^{-1} and C-C stretching at 808 cm^{-1} [36].

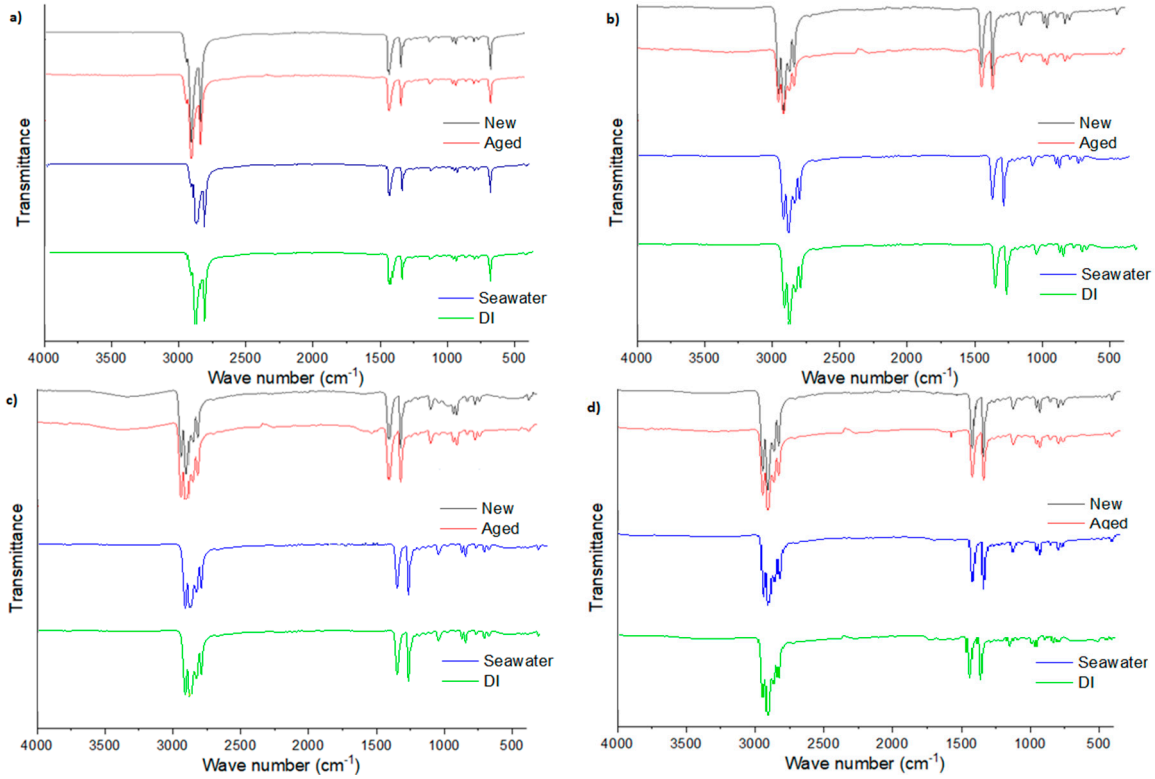

Figure 3. FTIR spectra of surgical face masks before and after natural aging, and seawater and DI water exposure. (**a**) Ear loop, (**b**) outer layer, (**c**) middle layer and (**d**) inner layer of the surgical face mask.

When the infrared spectra of naturally weathered face masks were examined (Figures 3 and 4), it was shown that multiple new small peaks appeared between 1600 and 1900 cm^{-1} after 30 days of natural weathering under direct sunlight. The peaks between 1600 and 1900 cm^{-1} can be attributed to the carbonyl group (C=O). In addition, a reduction in the intensity of peaks was also observed between 2950 and 2850 cm^{-1}, corresponding to ultraviolet radiation. This reduction was observed in all layers of the aged, seawater-exposed or DI water-exposed surgical face masks, indicating that C–C and C–H bonds were broken due to photo-oxidation. On the other hand, the same reduction was observed, especially in the ear loop and middle layer of the seawater-exposed N95 masks. Polypropylene is known for its low stability to photo-oxidative stress. Direct sunlight exposure of polypropylene leads to photo-oxidation, and this is extended when oxygen is present in the environment. According to the FTIR spectra, chemical evidence of oxidation was evident in almost all layers of the masks. Carbonyl peaks determined in FTIR spectra confirm the alteration in tensile strength of the material. Deterioration of the face mask material can be clearly seen from the SEM micrographs. It is worth noting that the middle layer was the most affected layer in both types of face mask. In summary, exposure to weathering led to a change in structure and chemical composition of the mask material. In a real marine environment, the degradation of plastics under UV radiation (photo-oxidation) is the dominant degradation pathway [39]. Other mechanisms

that contribute to the degradation, such as temperature, microbial exposure, etc., occur much slower. However, mechanical degradation is the second-most important mechanism, related to abrasion by mechanical forces (e.g., turbulence, waves). Mechanical degradation following photo-oxidation contributes to the fragmentation of plastics [40]. Therefore, mechanical forces and UV exposure were simulated in this study.

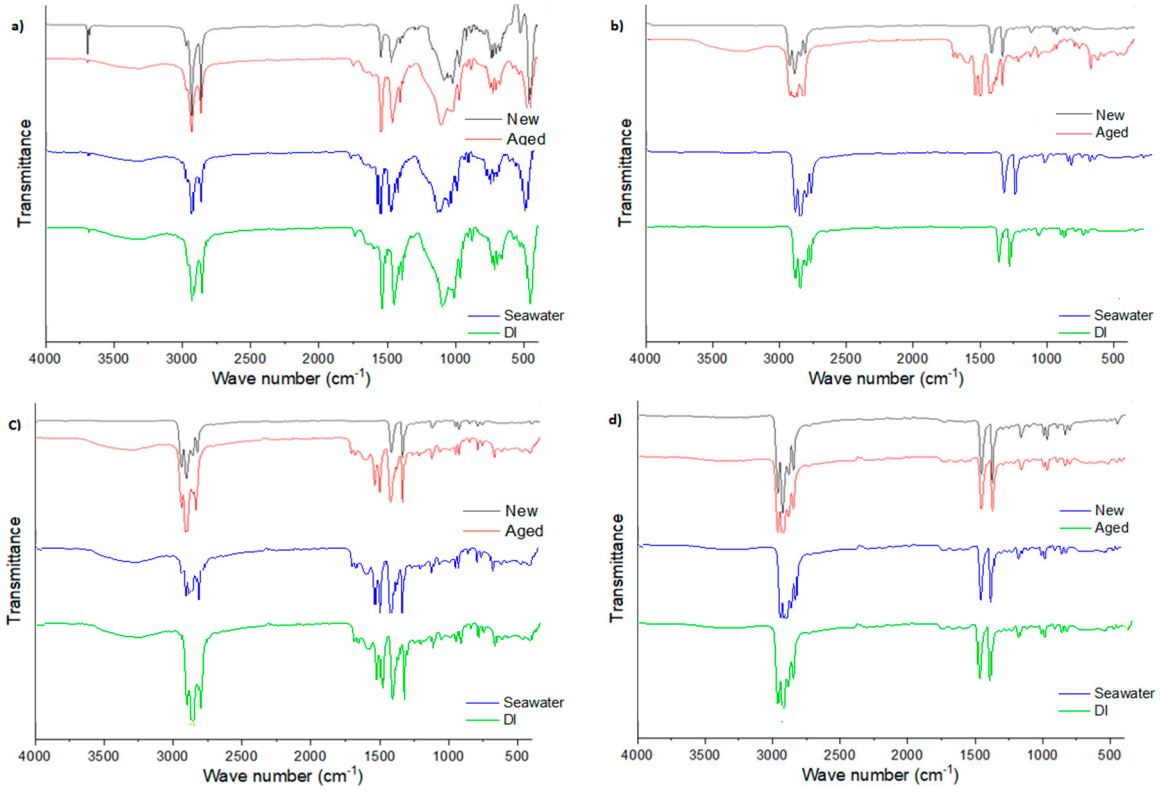

Figure 4. FTIR spectra of FFP2 face masks before and after natural aging, and seawater and DI water exposure. (**a**) Ear loop of FFP2 face mask, (**b**) outer layer, (**c**) middle layer, (**d**) inner layer of the FFP2 face mask.

3.2. The Effect of Natural Weathering on MP Release

Released MPs from new and naturally aged face masks after DI or seawater exposure were counted using SEM micrographs (Figures 5 and S1).

It can be clearly seen from the SEM micrographs that the amount of MPs released from the new masks was low and small in size. MP releases from the face masks after DI water exposure are shown in Figure 6. According to the results, aging resulted in 72 to 96 and 77 to 85 times higher MP release after DI water exposure than the new ones, for surgical and FFP2 masks, respectively. It is worth noting that a significant portion of the released MPs were <10 µm (Figure 7).

The amount of released MPs following seawater exposure is shown in Figure 8. As shown in Figure 8, following seawater exposure, the new surgical masks released higher amounts of MPs (3.29×10^5–4.56×10^5) than new FFP2 masks (2.81×10^5–3.44×10^5) ($p < 0.05$). However, aging resulted in a greater MP release, in addition to a small increase in the size of the particles for both types of masks. MP release from the aged FFP2 masks (4.36×10^6–6.20×10^6) was higher compared to the aged surgical masks (4.03×10^6–5.45×10^6) ($p < 0.05$). Surprisingly, following weathering, seawater-exposed F1 masks gave the highest MP release, although the MP release from the new F1 masks was the lowest among the FFP2 masks. On the other hand, the new FFP2 masks preserved their structural integrity to some degree when exposed to salt water. This phenomenon suggests that, although the material of the new F1 mask qualified for certification, the mask structure was strongly affected by sunlight and thus destroyed. Considering the MP count,

SEM micrographs and FTIR results, it can be said that both face masks were affected by UV exposure (sunlight), mask structure was significantly destroyed, and a considerable amount of MPs were released. Considering the highest MP release was from the FFP2 mask, it is particularly noteworthy that it can be the most significant source of MPs if disposed of improperly.

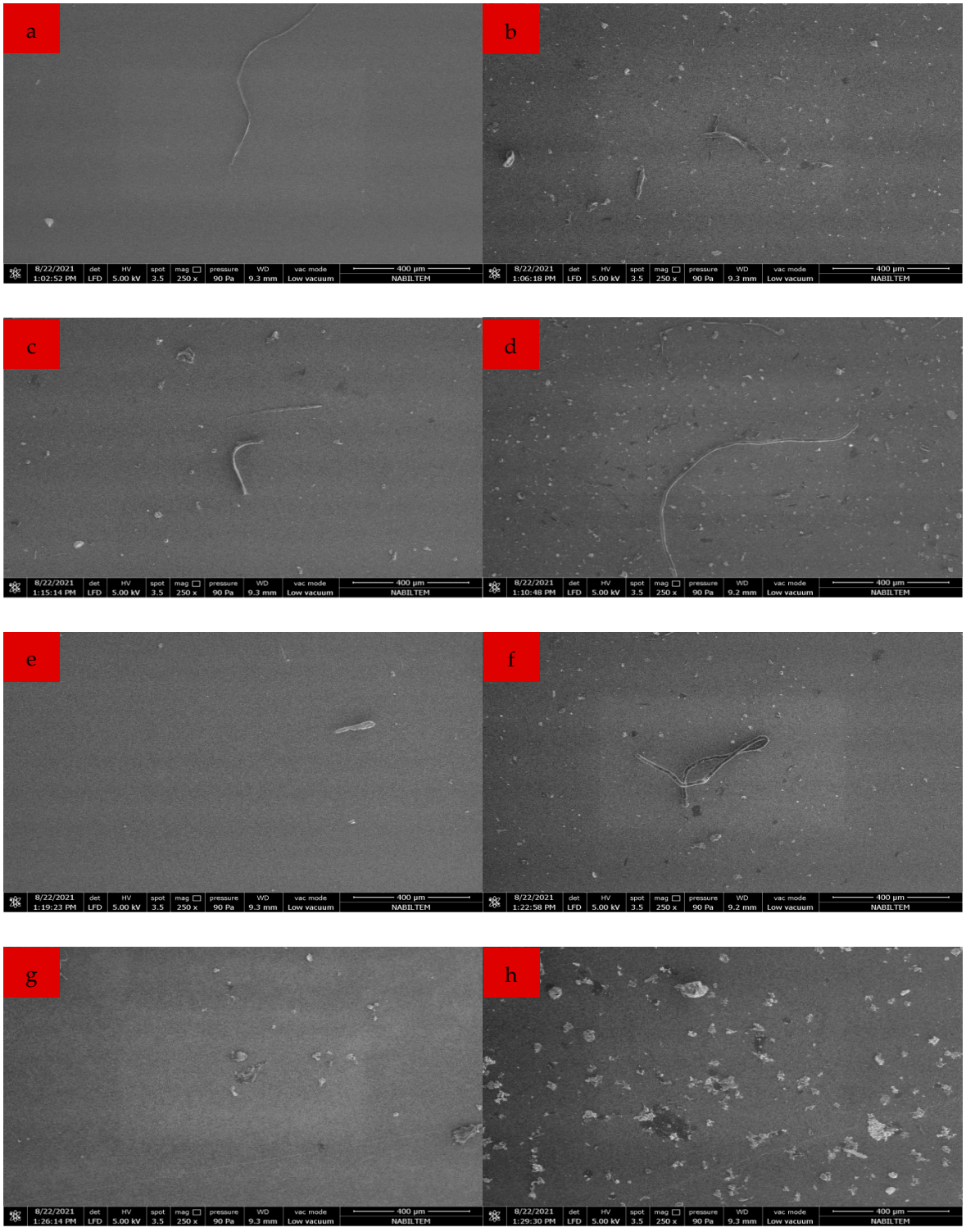

Figure 5. MP release from (**a**,**b**) new and aged surgical masks after DI water exposure; (**c**,**d**) new and aged surgical masks after sea water exposure; (**e**,**f**) new and aged FFP2 masks after DI water exposure; and (**g**,**h**) new and aged FFP2 masks after sea water.

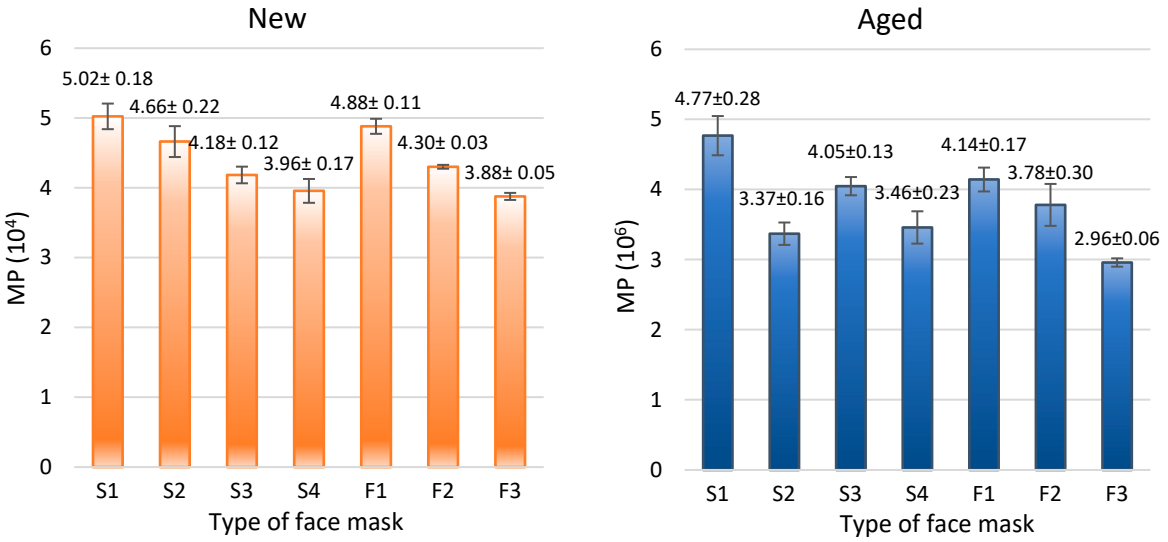

Figure 6. MP release from face masks after DI water exposure (n = 3).

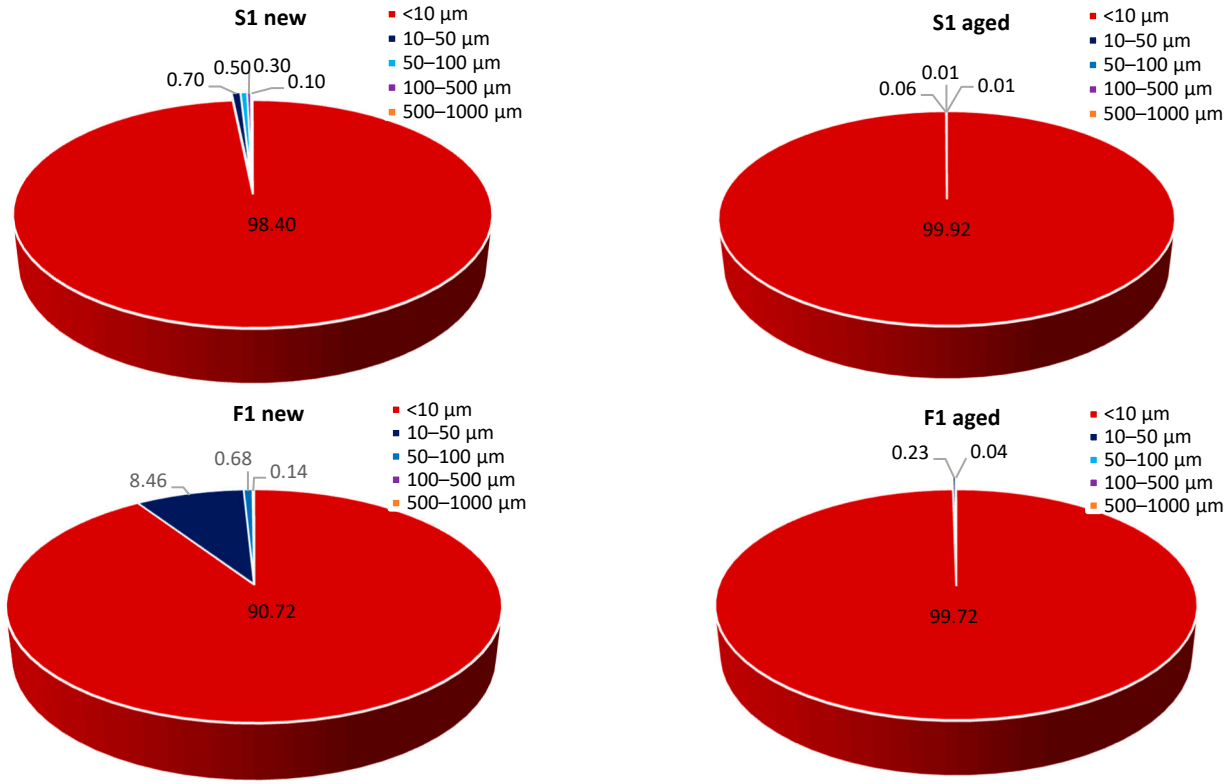

Figure 7. Size distribution of the S1 and F1 masks (DI).

The face masks are generally made of polypropylene. In this specific case, the face masks were made from polypropylene, as confirmed by FTIR. Polypropylene is known for its low stability to photo-oxidative stress. Exposure of polypropylene to direct sunlight leads to photo-oxidation, and this is extended with a prolonged exposure time. Polypropylene-containing face masks were easily converted into macro-, micro- and nanoplastics after weathering. When exposed to sunlight and/or salt water, they can be completely converted into MPs depending on the exposure period. The size distribution of the released MPs from the masks exposed to salt water are shown in Figure 9. As shown in Figure 9, most of the MPs were <10 µm in size. Regarding the surgical mask, 97.71 and 95.8% of the MPs were <10 µm for the new and aged masks, respectively. On the other hand, 88.2 and

77.4% of MPs were <10 µm for the new and aged FFP2 masks, respectively. It is worth nothing that a remarkable increase in MPs released from the FFP2 mask in the fraction of 10–50 µm and 50–100 µm was observed after aging and salt water exposure. Sunlight exposure was performed over one month in this study to simulate natural aging. It seems that both face masks are a source of plastic pollution, either as macro or especially small MPs. Degradation of the plastics takes a long time; however, regarding face masks, they readily degraded into small MPs, as shown here and in previous studies [30–33].

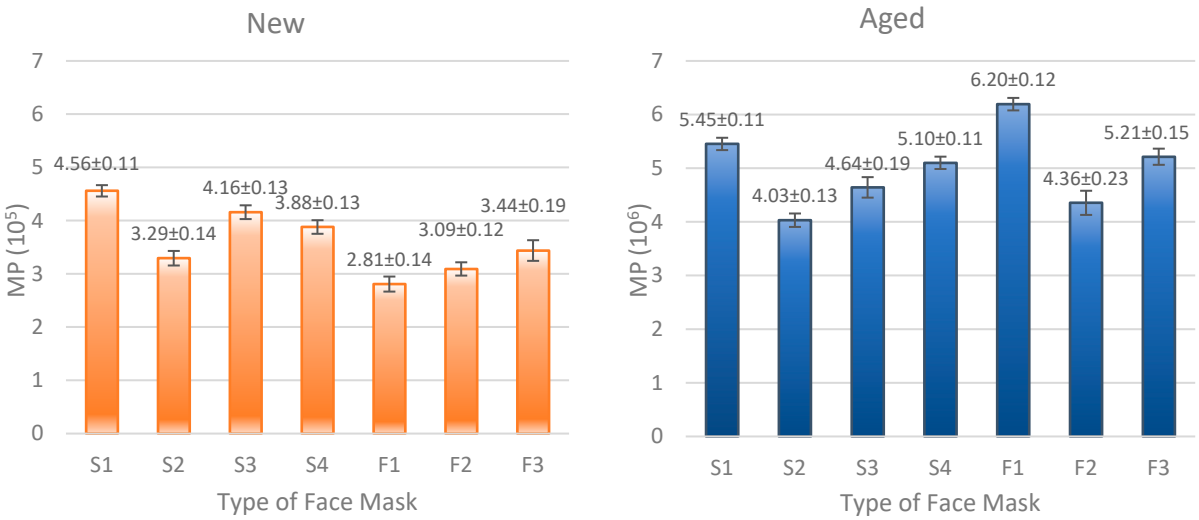

Figure 8. MP release from the face masks after sea water exposure (n = 3).

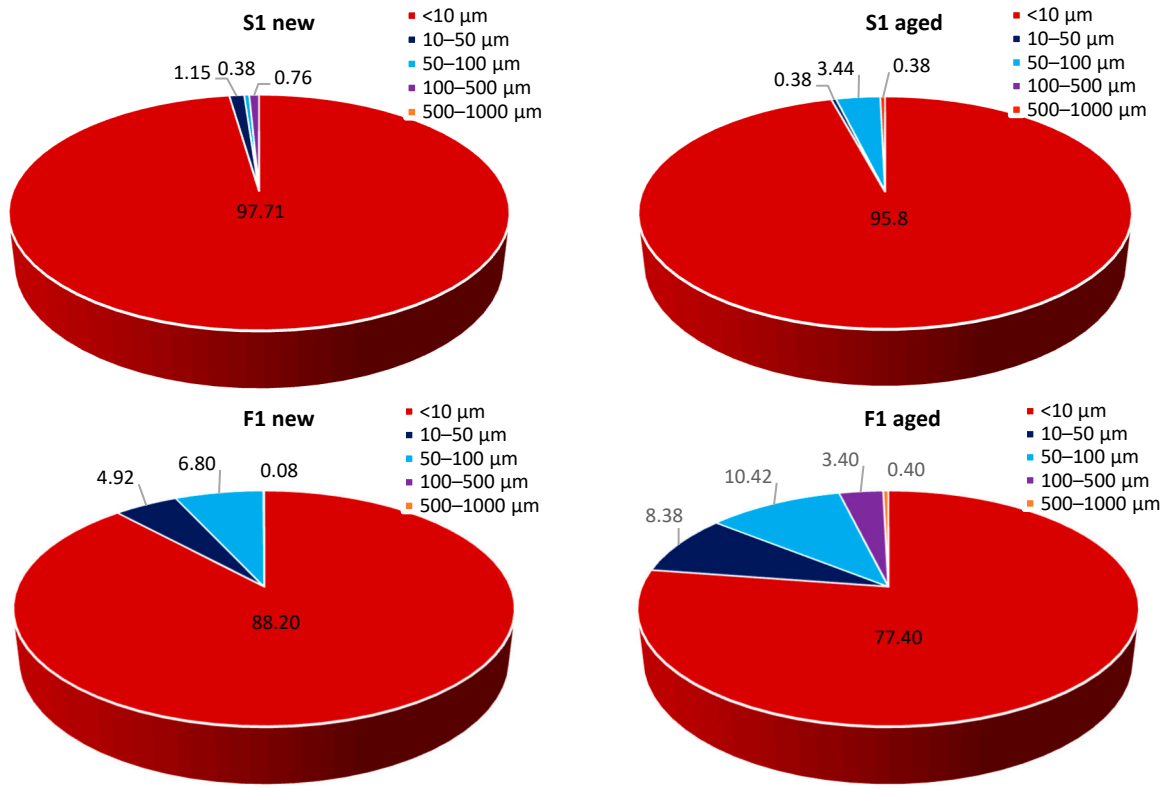

Figure 9. Size distribution (%) of the S1 and F1 masks (seawater).

A high MP release was determined in some studies conducted with DI water for aged masks; this is possibly due to the prolonged exposure time—as long as two months [39]. Wang et al. (2021) [31] evaluated the effect of UV irradiation (254 nm) on the MP release

from surgical face masks. They found in their study that 4.84×10^5 MPs were released from new masks, while 1.66×10^6 MPs were released from UV-weathered masks. Our results from the DI water experiments conducted with aged surgical face masks are in accordance with the data reported by Wang et al. (2021). Ma et al. (2021) [30] did not perform aging experiments, but stated that most of the MPs released from surgical ($1.6–3.8 \times 10^9$) and N95 masks ($3.1–3.3 \times 10^9$) were below 1 µm. The results of our experiments conducted with DI water are in line with the studies mentioned above, showing that most of the MPs found were <10 µm for the new and aged face masks. When aged FFP2 masks were exposed to seawater, a remarkable increase in the fraction of 10–50 µm and 50–100 µm was found, suggesting that the aged FFP2 mask was also fragmented in seawater conditions. Although seawater exposure increased the fragmented plastics of the aged FFP2 mask, it was found in our study that 95.8% and 77.40% of the MPs were still <10 µm for the surgical and FFP2 masks, respectively. On the other hand, the amounts of released MPs increased when the aged FFP2 masks were exposed to seawater. There is only one specific study carried out using sea water conditions [32]. Saliu et al. (2021) evaluated the MP release from artificially aged surgical masks under UV light in laboratory conditions over 180 h, reporting that an average of 1.35×10^5 MPs were released from the surgical face masks. The amount of MPs released was found to be higher in our present study than that reported by Saliu et al. (2021). This is possibly due to the UV light/direct sunlight and duration period difference because the aged face masks obtained in our study were exposed to direct sunlight for one month. It is expected that the MP release of face masks exposed to seawater is higher than that of DI or river water due to the high density and salinity of seawater [41]. However, the experiments can be extended to the river or fresh water environment. Polymer type, temperature, salinity, pH and other conditions can affect the release behavior and toxicity of micro and nanoplastics [42,43]. Micro- and nanoplastics below 10 µm have more harmful effects on aquatic organisms [44]. This is because MPs < 10 µm can be more easily ingested by aquatic organisms, reaching various organs to cause a biological effect on their health. In addition, oxidation of functional groups and the breaking of the polymer bonds can result in an increase in the absorption of various pollutants [42].

On the other hand, following different weathering conditions, the tensile strength experiments confirmed an alteration in the tensile strength of both face masks. The tensile strength experiments were conducted with one surgical (S1) and one FFP2 (F1) face mask due to their high MP release results. It is worth noting that these masks were the cheapest masks in the surgical and FFP2 mask category. It can be clearly seen from Figure 10 that considerable variations in tensile strength occurred in both face masks following weathering.

The tensile strength of the face masks can be listed in decreasing order as follows: new masks > naturally aged masks > DI water-exposed masks > salt water-exposed masks. The elongation percentage of the face masks can be listed in same order. The results of the tensile strength experiments indicate that the brittleness of the face masks increased following weathering. These results are consistent with the MP release experiments, SEM micrographs and FTIR results.

According to the results, it was observed that face masks can be readily degraded into high quantities of small MPs. Therefore, they have significant potential to increase plastic pollution in aqueous environment if they are disposed of improperly. In this study, it was determined that up to 6.20×10^6 MPs were released from FFP2 following one month of natural weathering and subsequent sea water exposure. The MP release potential of FFP2 is not negligible. Similarly, stormwater exposure following sun exposure will cause the release of huge amounts of MPs, as was shown from the results of the experiments performed with DI water. Although salinity has an important role in the degradation of the plastics, face masks will be completely converted to MPs after prolonged exposure in any aqueous environment. These particles will inevitably reach various aquatic environments, such as lakes, rivers and oceans [45]. This means that small particles can be released into the aquatic environment if used face masks are disposed of improperly. Micro- and

nanoplastics below 10 µm have more harmful effects on aquatic organisms. It is clear that special measures should be taken for disposing of used face masks. Although MPs released from face masks have been investigated in this research, including FFP2, which has not been thoroughly investigated in the literature, some limitations need to be addressed. Further studies evaluating alternative disposal and recycling methods are needed. On the other hand, a number of research studies have recently been conducted on the recycling or upcycling of face masks [46,47]. Detailed research studies investigating the effects, waste management and disposal alternatives of face masks are crucial to help formulate suitable measures and mitigate the environmental burden and negative impacts of MPs.

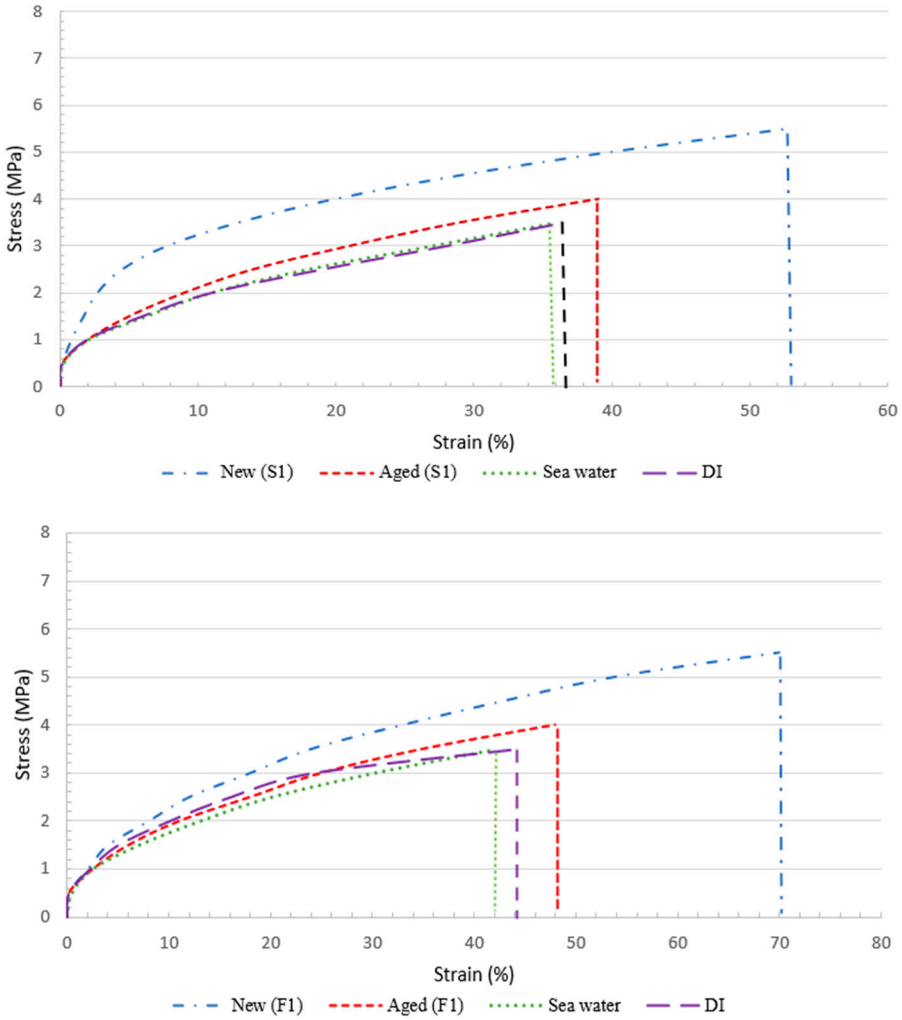

Figure 10. Stress–strain curves of the S1 and F1 masks exposed to different environmental conditions (n = 3).

4. Conclusions

As a consequence of the use of enormous amounts of disposable plastic personal protective equipment to limit the spread of the coronavirus and protect against COVID-19, they have become a potential threat to the environment. The present study has shown that the chemical and physical structure of the masks change after being exposed to weathering conditions. It was observed that surgical and FFP2 masks were readily degraded into high quantities of small MPs in a short time. Face masks are made from plastic fibers. Considering this, approximately 10 g and 15 g of polypropylene can be released from unvalved and valved FFP2 masks. It is particularly noteworthy that the middle layer of both types of mask was most affected from the weathering conditions. The effect of sea water on MP release was higher than that of DI water. According to the results, FFP2

masks are a non-negligible source of MPs. MPs that have been released into the aquatic environment can be ingested by aquatic organisms. Although the impact mechanisms of MPs on health are unclear, MPs are known to pose a threat to marine organisms. It has been determined in various studies that MPs reach different parts of the human body. Governments should consider the release of MPs from face masks, and precautions must be taken to maintain their safe disposal to be ready for a future pandemic. Further studies must be conducted to produce face masks using biodegradable materials and to evaluate the recycling possibilities for these kinds of wastes to maintain sustainability. On the other hand, it should also be taken into account that face masks may contain various additives, which may pose another threat to the environment. As the studies on this subject increase, the influencing factors will be better understood, and precautions can be taken by authorities to overcome the environmental burden of the improper disposal of face masks. Such studies will also be convincing for more environmentally friendly and sustainable mask production, and additional precautions should be taken for mask production.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su151914293/s1, Figure S1: MP release after salt water exposure.

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