Environ Res Tec, Vol. 6, Issue. 4, pp. 279–287, December 2023

Environmental Research and Technology
https://ert.yildiz.edu.tr - https://dergipark.org.tr/tr/pub/ert
DOI: https://doi.org/10.35208/ert.1249400

Research Article

The evaluation of fibrous disposable facemask for oil sorption and efficient oil/water separation

Soner KIZIL[*1,2]

[1]*Üsküdar University, Faculty of Engineering and Natural Sciences, İstanbul, Türkiye*
[2]*Institute of Addiction and Forensic Sciences, Üsküdar University, Faculty of Engineering and Natural Sciences, İstanbul, Türkiye*

ARTICLE INFO

Article history
Received: 09 February 2023
Revised: 11 August 2023
Accepted: 05 September 2023

Key words:
Absorbent; Disposable facemask; Oil/water separation

ABSTRACT

During the pandemic period, people have used various personal protective equipment including gloves, facemask and face shields. Among them, disposable facemask plays a critical role to control the spread of COVID-19, that situation lead to occurring huge amount waste materials. Hence, there is urgent need to evaluate and suspend such waste materials from environment. Herein, we have investigated the potential use of disposable facemask as oil sorbent material for efficient oil/water separation due to their hydrophobic/oleophilic character of PP based disposable facemask. Some structural characterization techniques are employed to examine the facemask. A number of tests including absorbency, oil/water separation stability in oils and waters, selective removal of oils in different water medium have been systematically investigated. The outcomes show that waste facemask have great potential in the field of oil-water separation that achieve selectively separate the oil from oily wastewater.

Cite this article as: Soner Kızıl. The evaluation of fibrous disposable facemask for oil sorption and efficient oil/water separation. Environ Res Tec 2023;6(4)279–287.

INTRODUCTION

The COVID-19 virus emerged towards the end of 2019 and has spread all over the world in a very short time. Since the major cause for the transmission of the virus between people was reported as respiratory droplets [1], people all around the world have used different personal protective equipment such as facemasks, face shield, gloves, gown, etc. Among them, Facemasks have been especially introduced as a countermeasure to decelerate the spread of the virus since it can repel the air droplets caused by cough, sneeze, breathe, and can prevent human-to-human transmission of the virus. Subsequently, there were difficulties in the supplement of masks globally for a short period [2]. Fortunately, there is no longer a shortage of facemasks after significant efforts made in the production and supply of masks on a global scale. Not surprisingly, the use of facemasks has increased with the increasing number of COVID-19 cases [3]. Throughout pandemic, facemasks are required in places such as public transport, indoor and crowded environments in most countries and this led to facemasks have become an essential item of everyday life and exploded the numbers of facemasks used. Disposable facemask can be manufactured from different polymer materials such as polyethylene, polypropylene, polyester, polyurethane, polyamide [4]. Therefore, amount of generated waste allied with the use of this personal protective equipment also increased unwittingly and mishandling of this waste led to environmental contamination [5]. Although recommendations on the management of pandemic derived wastes including waste facemasks have been developed and implemented by most administrations, proper management and final destination of this waste is

***Corresponding author.**
*E-mail address: soner.kizil@uskudar.edu.tr

Published by Yıldız Technical University Press, İstanbul, Türkiye

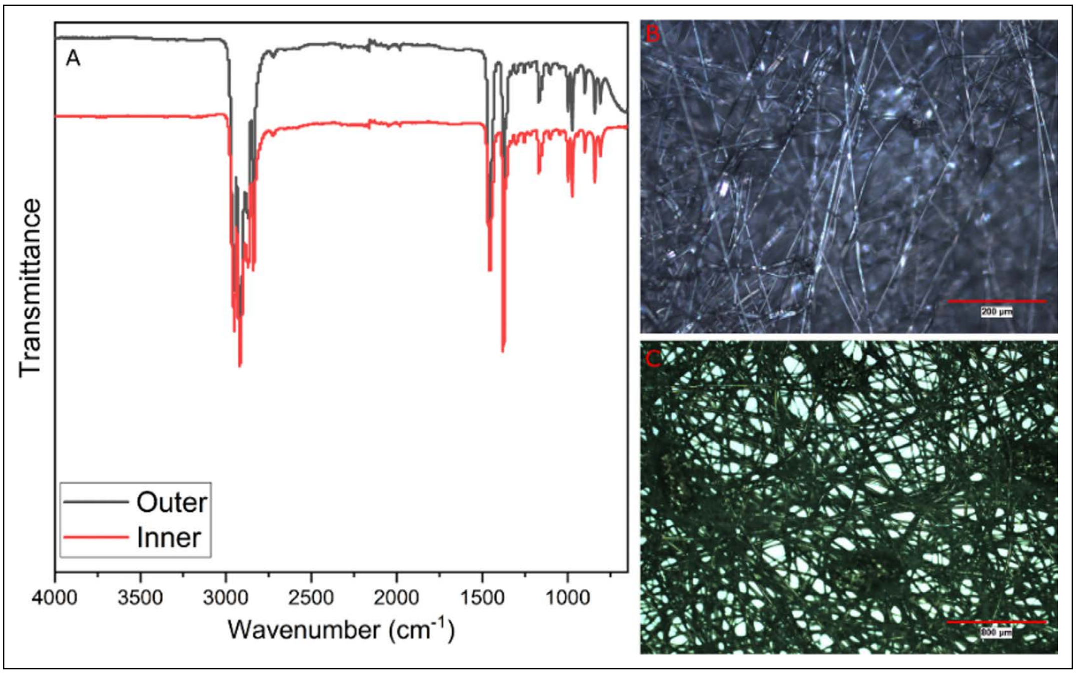

Figure 1. **(a)** FTIR spectra of inner and outer layer of facemask **(b)** Optical microscope image of inner layer **(c)** Optical microscope image of outer layer.

highly dependent on the citizen's awareness and commitment [6]. A mask waste that has not been disposed of properly and has entered the environment has potential threats to the nature. Main concerns arising from these threats are plastic pollution [7], organophosphate esters [8], microplastic release from masks to the aquatic environment [9–11] and leaching of chemicals and nanoparticles [12, 13].

One of the important things that will determine the future of facemask waste is how long the pandemic will last. The effectiveness of existing vaccines against new variants of the virus remains unclear for now, which also extends the estimated time for us to achieve herd immunity [14]. So, as the pandemic continues, it will not be possible to reduce these facemask wastes because it is a necessity. Then, recycling or reuse for different purposes comes into prominence. So far, many studies have been carried out on how to recycle and reuse waste facemasks in order to reduce the waste caused by the pandemic. In one of the studies, the use of waste facemasks in sound insulation has been tried and compared with commercial sound absorbers that currently used in building sector. Acoustic efficiency of waste facemasks was found better than actually used fibrous sound absorbers and it was recommended that it can be used for sound insulation purposes after proper disinfection [15]. The fibril structure of masks is also of interest in the field of construction to increase mechanical strength. It has been revealed that the addition of disposable masks up to 0.2% into the initial mixture increased the strength and quality of the concrete [16]. In another study, it was demonstrated that shredded masks can also be used successfully in road and pavement applications [17]. Rehman and Khalid used shredded facemasks successfully as a fibrous reinforcement additive to increase the mechanical strength of fat clay [18]. Purnomo et. al. reviewed thermochemical conversion technologies for COVID-19 derived medical wastes (CMW) including incineration, carbonization, pyrolysis and gasification. Incineration was found suitable for all types of CMW including waste facemasks but also found most potential harmful to the nature since it releases CO2 and other gases coming from burning process. Moreover, gasification and pyrolysis were evaluated as towardly with regards to environmental impact and efficiency [19]. In another study, pyrolysis of single use facemask was examined to benefit from this waste as an energy source. Fuel range chemicals as 14.7 wt% gasoline-, 18.4 wt% jet fuel-, 34.1 wt% diesel-, and 18.1 wt% motor oil-range hydrocarbons were yielded in this study [20].

As can be seen from the previous paragraph, various recycling and reuse strategies have been developed by utilizing the fibrous structure and carbon-containing nature of waste facemasks. This fibrous structure and hydrophobic nature of the facemasks can also be utilized for the separation of oils, which is an important pollutant for nature. Oil spill is a major threat for all living organism due to its negative effects such as inhibits the penetration of sunlight, make water source undrinkable etc. Water can be polluted because of tanker accidents, natural events, war, and personnel mistakes and so on. To minimize the catastrophic effects of oil spill, effective removal of such pollutions should be paid close attention. So far, a wide range of clean-up methods such as chemical, biological and physical was operated for effective removal of oil from wastewater. Among them, use of absorbents is most promising approach due to its easy to operate, cheap and high selectivity properties [21]. Plenty of absorbents have been utilized for rapid oil spill conditions, mainly categorized as inorganic mineral sor-

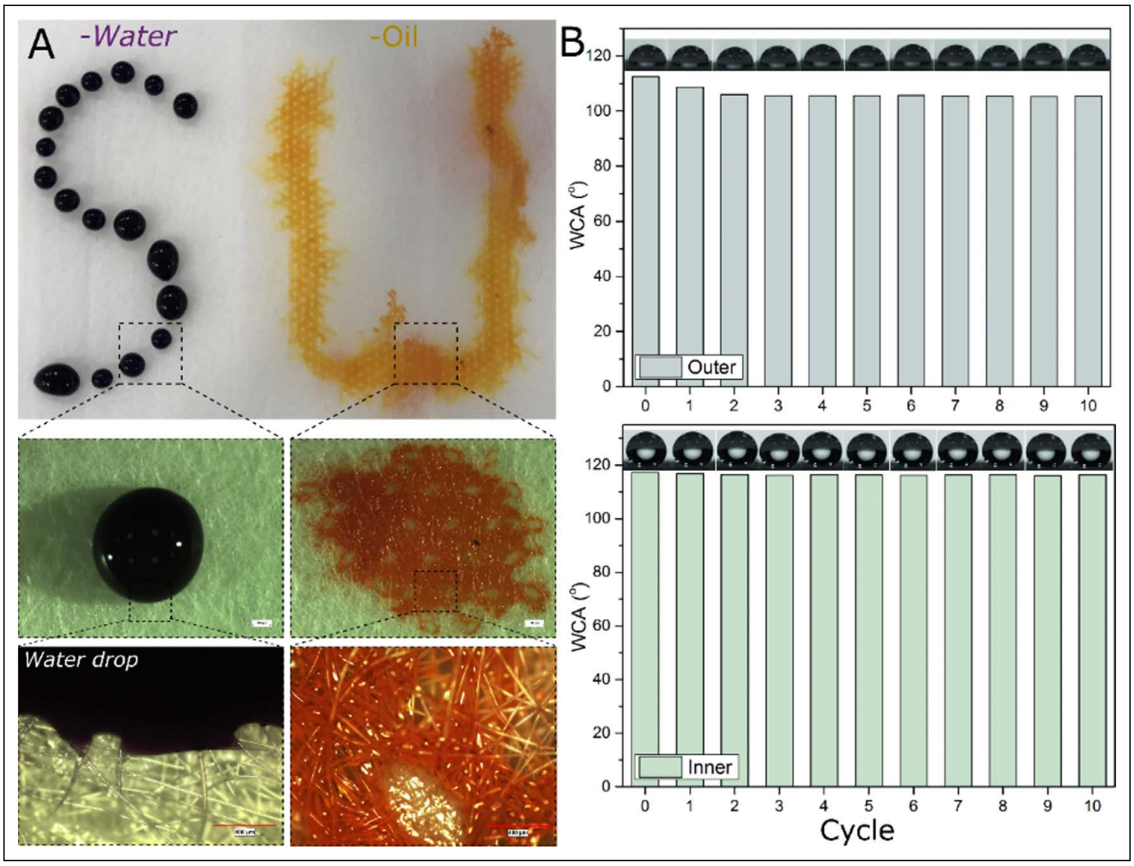

Figure 2. **(a)** The photos of facemask contacted with oil and water **(b)** WCA of inner/outer layer of facemask.

bents such as perlite, clay; organic vegetable sorbents such as straw, kenaf, rice husk, bark; and synthetic sorbents such as polyalkoxysilanes, alkyl acrylates, foams, electrospun fibers, and polypropylene [22–24]. It was well known that ideal sorbent should have some characteristics including high and quick oil absorbency, hydrophobicity, high oil/water selectivity, buoyancy before and after sorption [25]. Among them, use of polypropylene stand out for oil/water separation applications due to their attractive features such as high hydrophobicity and oleophilicity, low water interest, easy to use and low cost [26].

In this study, the use of facemask wastes in oil removal from water was investigated in order to benefit from its polypropylene material and fibrous structure. Since it is not certain when the epidemic will end and thus these wastes will continue to be created, it is very important for sustainability to investigate the potential benefits that can be obtained from these wastes. To the best of our knowledge, there has not been any research for the use of waste facemask as oil sorbent materials. The oil absorbency and oil absorption kinetics are investigated by dipping into different oils and organic liquids and different oil/water medium is explored. Detailed characterizations of the masks were carried out with FTIR, contact angle, microscopic analysis. The outcomes show that waste nonwoven polypropylene facemask have high hydrophobicity, thus have high oil and organic liquids interest and low water absorbency. What's more, they can selectively absorb the oil from different water medium including simulated and subzero water with an almost same performance in organic liquids medium. We think that this study reveals a significant benefit potential in waste facemasks.

MATERIALS AND METHODS

Materials and Chemicals

The oils used in swelling experiments including toluene, hexane and chloroform were purchased from Sigma-Aldrich. Euro diesel was purchased from British Petroleum (BP) and motor oil was obtained from Mobil. Disposable, three-layer surgical single use facemasks providing European Standard EN 14683:2019 were purchased from a local store. It consists of a polypropylene melt-blown non-woven fabric layer sandwiched between two spunbonded fabric layers. Disperse red and Crystal violet, which were used for visualization of oil and water are purchased from Fluka. To get a reliable swelling result, some units of facemask such as ear strap, metallic nose wire are removed. In this study, a clean facemask was used to eliminate the risk of COVID-19 spread and transmission in the laboratory. However, there are many studies in the literature on disinfecting masks describing the methods like ethyl alcohol treatment, vaporized hydrogen peroxide (H_2O_2), dry heat treatment, hot water contamination, moist heat and UV irradiation [27–32]. These methods can be implemented in the further necessary scale-up cases.

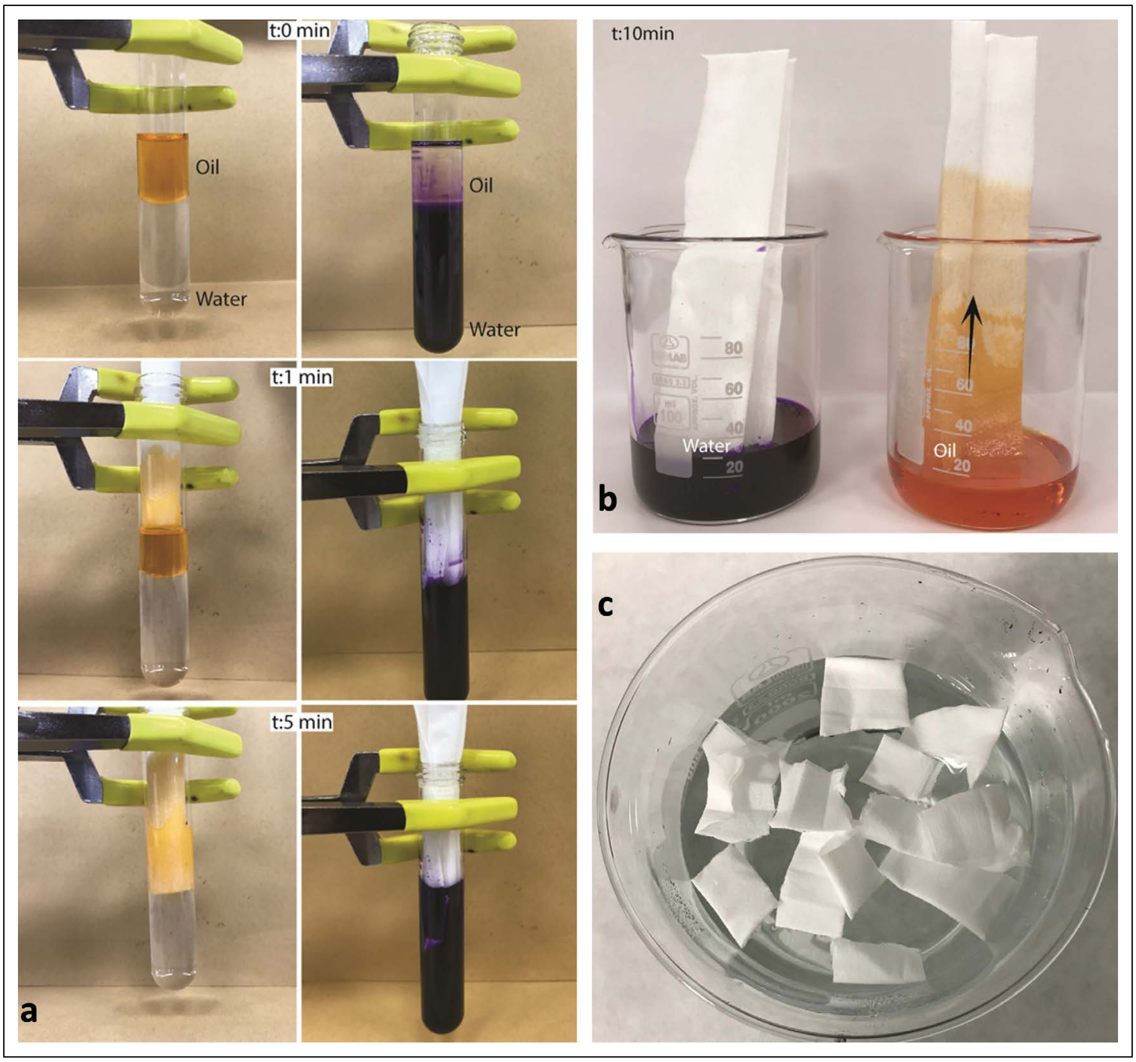

Figure 3. **(a)** Immersion of facemask into the oil/water mixture, **(b)** Wettability of facemask in oil and water, **(c)** Buoyancy of facemask in water medium.

Oil Absorption Experiments

As it mentioned before, to get reliable results and eliminate the risk of COVID-19 spread and transmission by used facemask, clean facemasks were used. Before swelling experiments, facemask is sliced equal parts to provide efficient absorption. For swelling experiments, different aromatic, aliphatic, halogenated solvents, vegetable oil, motor oils and petroleum-based fuel are used.

2x2 cm pieces of facemasks are dipped in various oils and oil absorbency are determined by gravimetric methods. To achieve this, a known amount of facemask was put in a wire mesh basket and immersed in oils. Then, the wire mesh basket was taken out after a certain time and drained for 5 s to remove excess oils and weighed. The oil absorbency was calculated with the following formula (1):

$$(W_c-W_b-W_k)*100/W_k \qquad (1)$$

where W_b is the weight of wetted empty stainless-steel mesh, W_k and W_c show the dry and swollen facemask materials, respectively.

For oil/water separation tests, toluene is mixed with distiller water, simulated (%3.5 NaCI) water and sub-zero water. For visualize the oil/water separation, the disperse red 1 and crystal violet dyes were used for colorization of toluene and water, respectively.

Instrumental Analyses

Structural analysis of facemask was obtained using Nicolet IS10 Fourier Transform Infrared Spectrometer (FT-IR) with an ATR system, at a resolution of 4 with 128 scans. Water and oil contact angles were determined via Drop shape analysis system (KRÜSS DSA 10-MK2).

RESULTS AND DISCUSSION

Structural Analysis of Facemasks

Single use facemasks contain some other units different than filter such as ear strap and metallic nose wire. In order to investigate the facemask, such units are removed and only filter part are left behind. FTIR is used to characterize the chemical composition of this part. As presented in Figure 1a, the peak at 1365 cm^{-1} are belong to the Symmetric

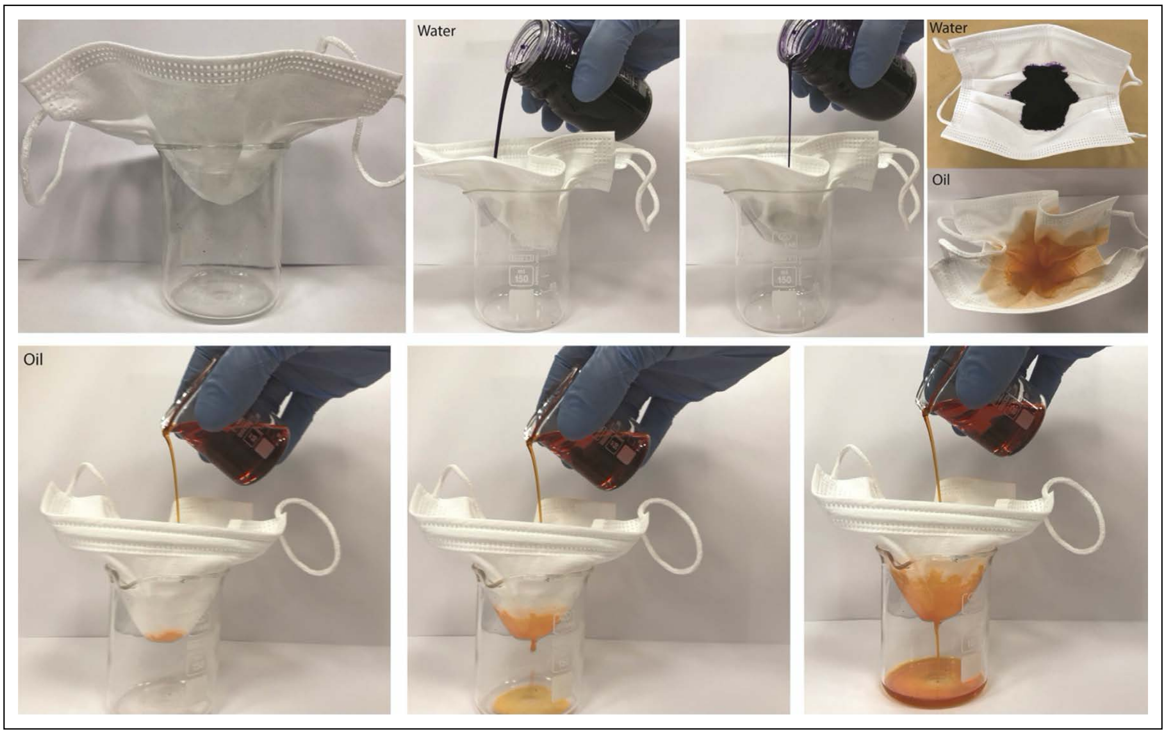

Figure 4. Liquid permeability performance of disposable facemask.

bending vibration mode of $-CH_3$ group, the peaks at 1451, 2827, 2913 cm^{-1} are attributed to attributed to $-CH_2-$ symmetric bending, $-CH_2-$ symmetric stretching and $-CH_2-$ asymmetric stretching, respectively [33]. The observed FTIR peaks fit very well with polypropylene characteristic peaks and these results clearly reveal that the inner and outer filter layer is made up with polypropylene polymer.

Layers of single-use facemask are displayed in Figure 1a. To observe fibrous structure of facemask, the outer and inner layer are disassembled and observed via optical microscopy. Optical microscope images of outer and inner surface are given in Figure 1. All images translucently show that the inner layer is denser than the outer layer.

The facemask exhibited hydrophobic character having a water contact angle of 116±2 ° for inner surface, 107±2 ° for outer surface and oleophilicity with almost 0° oil contact angle for different oils such as dichloromethane, toluene and euro diesel. As the water droplets were placed on inner and outer surface of facemasks, the droplets remained almost stable. However, the oil droplet is swiftly absorbed by facemask, as represented in Figure 2. Moreover, the water droplet is pulled from the surface without leaving any water residue, indicating its excellent water repellent and oil loving character of facemask.

To visualize swelling performance of facemask in oil and water, the disperse red 1 and crystal violet dyes were used for colorization of toluene and water, respectively. When facemask is dipped in mixture, the oil (orange color) is rapidly absorbed and fully swollen in 5 min as given in Figure 3a. As the facemask is dipped in oil/water mixture, no color change on the facemask surface, indicating water (dyed with Crystal Violet) does not penetrate the fibrous structure and does not go up. To detect interest facemask toward the oil and water for longer periods, a part of long piece facemask is immersed for about 5 min. At the end of this, oil is swiftly penetrated through the hydrophobic fibrous structure of facemask; water cannot diffuse the fibrous structure, implying that good candidate for practical applications, represented in Figure 3b. In addition, to observe buoyancy, facemask is pushed via forceps to submerge, but it still keeps floating character on the water surface indicating high interest toward organic liquids and low interest to water as seen in Figure 3c.

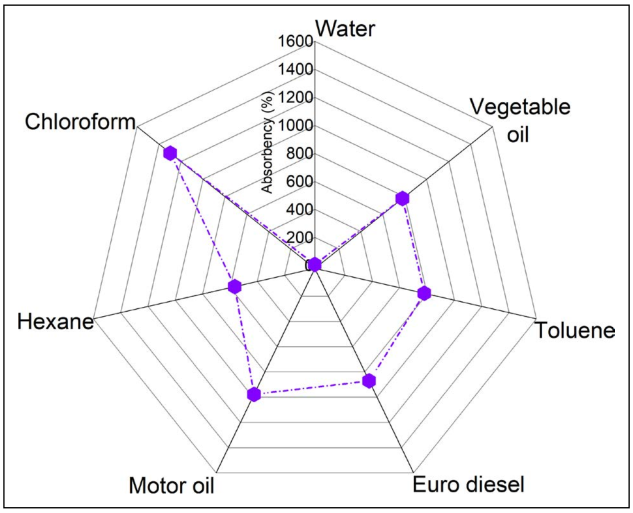

Figure 5. Oil absorbencies of facemask in different oils and water.

For further determination of oil/water interaction of facemasks and observe separation efficiency, waste facemask was placed on the top of a beaker. When water (purple) is

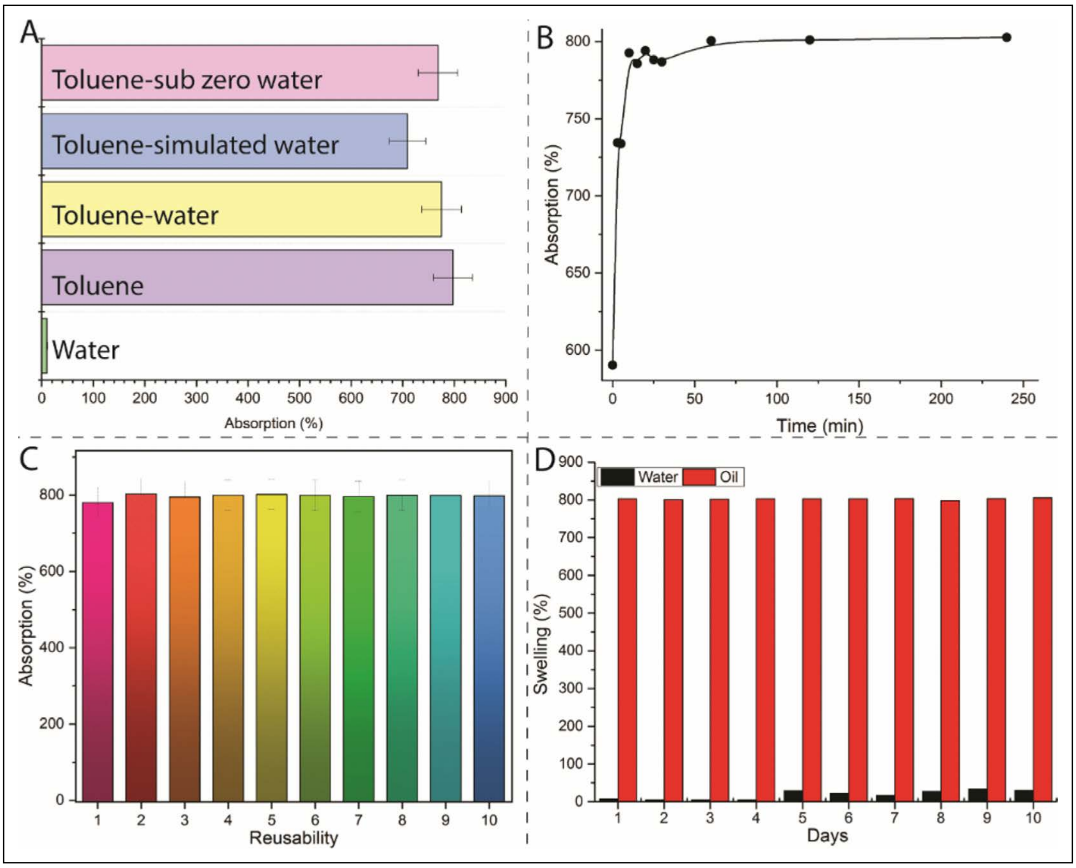

Figure 6. **(a)** Selective removal of oil in different water medium **(b)** Absorption kinetics of facemask in toluene **(c)** Reusability in toluene **(d)** Absorption stability of facemask in oil and water.

poured onto the facemask, water was retained without any water drop is crossed through fibrous structure. The water on the facemask have waited for a while (10 days) and no obvious droplet is seen on the beaker, implying high hydrophobicity and good oil selectivity of fibrous facemask. However, when oil is poured onto the facemask, the oil is immediately absorbed and diffused through the fibrous structure and collected at the bottom of beaker (Fig. 4).

Oil Absorption and Separation Characteristics

Prior to oil absorption experiments, Nose wire and ear strap of single-use facemask are removed and remained part is split into 2x2 cm pieces using scissors. Swelling measurements of fibrous facemask are achieved in different oils including toluene, hexane, chloroform, motor oil, gasoline and calculated according to the formula 1. The maximum oil absorbency of facemask is given in Figure 5. The absorption capacity of facemask for several kinds of oils is in the range between 565%–1300%, depending on their density and viscosity.

For practical applications, some characteristics including high absorbency, reusability, quick absorption feature and selectivity are the main significant performance parameters in the field of oil/water separation. Oil leakage could occur in environments such as sea, lake, drinking water mediums or harsh environments. To simulate the oil absorption behavior toward different conditions, facemask is dipped into oil (toluene is used as a representative solvent)/ lake, oil/ distilled water, oil/simulated water and oil/subzero water, seen in Figure 6a. It is clear that facemask exhibited high interest toward oil while low interest is shown into the water. Furthermore, facemask has almost reached their maximum capacity in different water environments including simulated, distillated or subzero waters.

It was shown from the absorption speed given in Figure 6b that it reaches 75% of maximum absorption capacity just in 1 min, reach their maximum absorbency in 3 min and keep swollen form for a long time without release of organic liquids.

Reusability is one another critical parameter for ideal absorbent materials in the field of oil absorbing applications. To detect the reusability performance, facemask is dipped in toluene for 24 h to make sure fully absorption is completed. After that, swollen fibrous mask are allowed to release the oil at room conditions. Then, dry fibrous facemask is again dipped in oil, repeated for 10 times. It can be clearly seen that fibrous facemask can reach their maximum absorbency each absorption test without significance change, seen in Figure 6c. Moreover, swelling performance is investigated to check stability of swollen fibrous facemask for 10 days indicating that facemask keep their fibrous structure and oil absorption features for a long time.

For comparison, different commercial polypropylene materials and other type of polymer materials were used and their properties are given in Table 1. It is clearly seen that waste facemask are competitive with some commercial PP

Table 1. Comparison of some materials as oil sorbents

Materials	Oils	Uptake*	Cycle	Ref.
Commercial pads	Diesel	8 g/g	n.a	[34]
PDMS sponge	Chloroform	1100%	20	[35]
Waste PET sorbents	Machine oil	2.43 g/g	3	[36]
3D PP sponges	Toluene	2100%	#6	[37]
Commercial PP (Mavisorb)	Toluene	11.4 g/g	n.a	[38]
Commercial PP	Diesel	8 g/g	n.a	[39]
Disposable facemask	Chloroform	1300%	10	This work
	Motor oil	977%		
	Euro diesel	871%		
	Toluene	798%		
	Vegetable oil	780%		
	Hexane	565%		

#: Decreasing absorption performance.

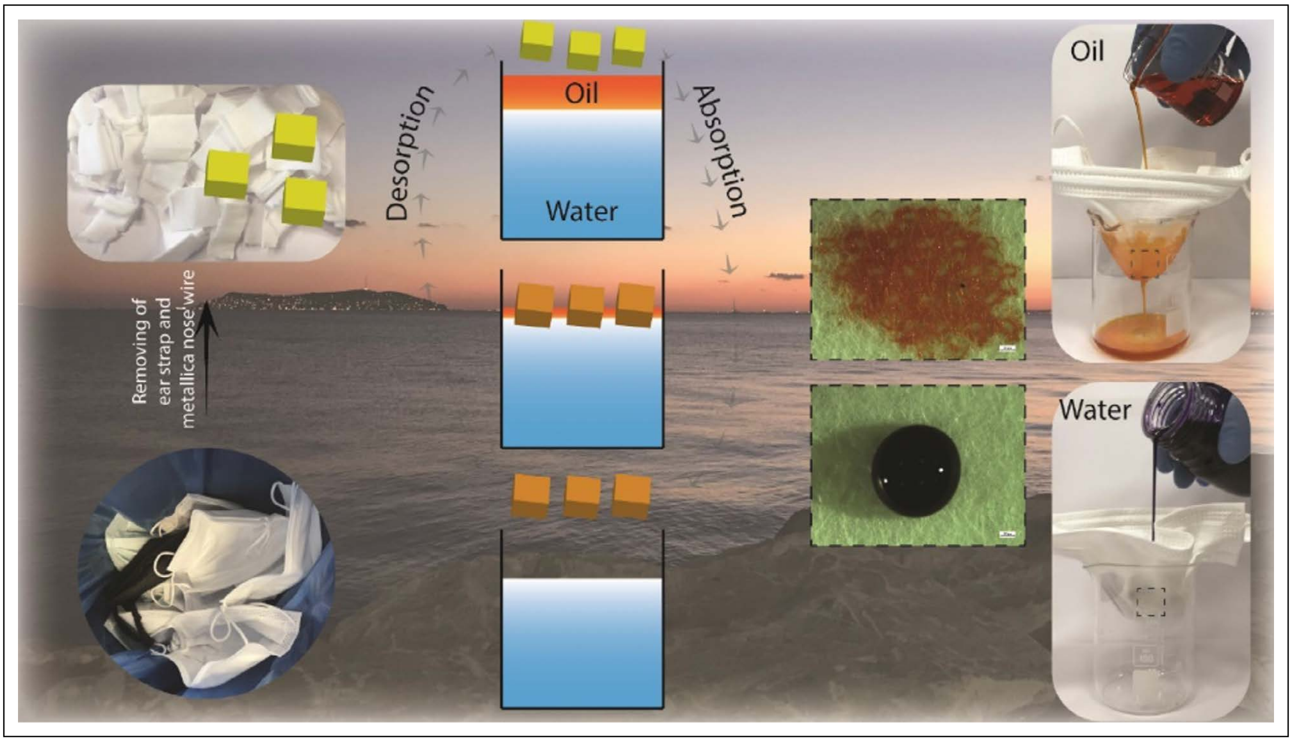

Figure 7. The illustration of disposable facemask for oil/water separation applications.

sorbents. Moreover, facemask could be reused for several times, which make them very favorable for efficient oil absorbent in rapid oil pollution situations.

CONCLUSION

It has been successfully demonstrated that the fibrous structure and hydrophobic character of the disposable facemask, which is the most used protection equipment during the pandemic, can be used in oil-water separation (Fig. 7). Fibrous facemask can absorb a variety of oils in a short time, ranged between 565–1300% depending on the oil types. Moreover, oils in the different water medium such as simulated, lake, seawater and sub-zero water can be effectively separated by fibrous facemask waste, with the same capacity in the oil medium and buoyant before and after oil sorption. Considering the uncertainty of when the Covid-19 pandemic will end and the inevitable necessity of facemask use, we believe that the facemask waste can be evaluated as oil sorbents. The disposable facemask could be collected, sterilized and get packed in the form of booms, pads or rolls. The waste polymeric facemask materials then could be used as collective materials, as the oil spill is occurred in personal mistakes, natural events.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] D. Taylor, A. C. Lindsay, and J. P. Halcox, "Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1," New England Journal of Medicine, Vol. 382(16), pp. 1564–1567, 2020. [CrossRef]

[2] O. O. Fadare, and E. D. Okoffo, "Covid-19 face masks: A potential source of microplastic fibers in the environment," Science of the Total Environment, Vol. 737, Article 140279–140282, 2020. [CrossRef]

[3] S. Sangkham, "Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia," Case Studies in Chemical and Environmental Engineering, Vol. 2, pp. 100052–100060, 2020. [CrossRef]

[4] N. U. Benson, D. E. Bassey, and T. Palanisami, "COVID pollution: impact of COVID-19 pandemic on global plastic waste footprint," Heliyon, Vol. 7(2), pp. e06343–e06351, 2021. [CrossRef]

[5] K. I. Olatayo, P. T. Mativenga, and A. L. Marnewick, "COVID-19 PPE plastic material flows and waste management: Quantification and implications for South Africa," Science of the Total Environment, Vol. 790, pp. 148190–148202, 2021. [CrossRef]

[6] C.S.G. Penteado, and M.A.S. de Castro, "Covid-19 effects on municipal solid waste management: What can effectively be done in the Brazilian scenario?", Resources, Conservation and Recycling, Vol. 164, pp. 105152–105160, 2021. [CrossRef]

[7] M. R. J. Rakib, G. E. De-la-Torre, C. I. Pizarro-Ortega, D. C. Dioses-Salinas, and S. Al-Nahian, "Personal protective equipment (PPE) pollution driven by the COVID-19 pandemic in Cox's Bazar, the longest natural beach in the World," Marine Pollution Bulletin, Vol. 169, Article 112497–112503, 2021. [CrossRef]

[8] J. Fernández-Arribas, T. Moreno, R. Bartrolí, and E. Eljarrat, "COVID-19 face masks: A new source of human and environmental exposure to organophosphate esters," Environment International, Vol. 154, pp. 106654–106661, 2021. [CrossRef]

[9] J. Ammendolia, J. Saturno, A. L. Brooks, S. Jacobs, and J. R. Jambeck, "An emerging source of plastic pollution: Environmental presence of plastic personal protective equipment (PPE) debris related to COVID-19 in a metropolitan city," Environmental Pollution, Vol. 269, pp. 116160–116169, 2021. [CrossRef]

[10] T. A. Aragaw, "Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario," Marine Pollution Bulletin, Vol. 159, pp. 111517–111523, 2020. [CrossRef]

[11] X. Chen, X. Chen, Q. Liu, Q. Zhao, X. Xiong, and C. Wu, "Used disposable face masks are significant sources of microplastics to environment," Environmental Pollution, Vol. 285, pp. 117485–117490, 2021. [CrossRef]

[12] G. L. Sullivan, J. Delgado-Gallardo, T. M. Watson, and S. Sarp, "An investigation into the leaching of micro and nano particles and chemical pollutants from disposable face masks - linked to the COVID-19 pandemic," Water Research, Vol. 196, pp. 117033–117043, 2021. [CrossRef]

[13] M. Ardusso, A. D. Forero-López, N. S. Buzzi, C. V. Spetter, M. D. Fernández-Severini, "COVID-19 pandemic repercussions on plastic and antiviral polymeric textile causing pollution on beaches and coasts of South America," Science of the Total Environment, Vol. 763, pp. 144365–144376, 2021. [CrossRef]

[14] Mckinsy. "When will the COVID-19 pandemic end?" https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/when-will-the-covid-19-pandemic-end Accessed on Nov 09, 2023.

[15] R. Maderuelo-Sanz, P. Acedo-Fuentes, F. J. García-Cobos, F. J. Sánchez-Delgado, M. I. Mota-López, and J. M. Meneses-Rodríguez, "The recycling of surgical face masks as sound porous absorbers: Preliminary evaluation," Science of the Total Environment, Vol. 786 pp. 147461–147469, 2021. [CrossRef]

[16] S. K. Lynch, M. Saberian, J. Li, R. Roychand, and G. Zhang, "Preliminary evaluation of the feasibility of using polypropylene fibres from COVID-19 single-use face masks to improve the mechanical properties of concrete," Journal of Cleaner Production, Vol. 296, pp. 126460–126467, 2021. [CrossRef]

[17] M. Saberian, J. Li, S. K. Lynch, and M. Boroujeni, "Repurposing of COVID-19 single-use face masks for pavements base/subbase," Science of the Total Environment, Vol. 769, pp. 145527–145534, 2021. [CrossRef]

[18] Z. U. Rehman, and U. Khalid, "Reuse of COVID-19 face mask for the amelioration of mechanical properties of fat clay: A novel solution to an emerging waste problem," Science of The Total Environment, Vol. 794, pp. 148746–148762, 2021. [CrossRef]

[19] C. W. Purnomo, W. Kurniawan, and M. Aziz, "Technological review on thermochemical conversion of COVID-19-related medical wastes," Resources, Conservation and Recycling, Vol. 167 pp. 105429–105441, 2021. [CrossRef]

[20] C. Park, H. Choi, K. Y. A. Lin, E. E. Kwon, and J. Lee, "COVID-19 mask waste to energy via thermochemical pathway: Effect of Co-Feeding food waste," Energy, Vol. 230, pp. 120876–120884, 2021. [CrossRef]

[21] J. Ge, H. Y. Zhao, H. W. Zhu, J. Huang, L. A. Shi, and S. H. Yu, "Advanced sorbents for oil-spill cleanup: recent advances and future perspectives," Advanced Materials, Vol. 28, pp. 10459–10490, 2016. [CrossRef]

[22] L. M. T. M. Oliveira, J. Saleem, A. Bazargan, J. L. D. S. Duarte, G. McKay, and L. Meili, "Sorption as a rapidly response for oil spill accidents: A material and mechanistic approach," Journal of Hazardous Materials, Vol. 407, pp. 124842–124861, 2021. [CrossRef]

[23] B. Doshi, M. Sillanpää, and S. Kalliola, "A review of bio-based materials for oil spill treatment," Water Research, Vol. 135, pp. 262–277, 2018. [CrossRef]

[24] S. Kizil, and H. B. Sonmez, "One-pot fabrication of reusable hybrid sorbents for quick removal of oils from wastewater," Journal of Environmental Management, Vol. 261, pp. 109911–109918, 2021. [CrossRef]

[25] S. B. Hammouda, Z. Chen, C. An, and K. Lee, "Recent advances in developing cellulosic sorbent materials for oil spill cleanup: A state-of-the-art review," Journal of Cleaner Production, Vol. 311, pp. 127630–127648, 2021. [CrossRef]

[26] Q. F. Wei, R. R. Mather, A. F. Fotheringham, and R. D. Yang, "Evaluation of nonwoven polypropylene oil sorbents in marine oil-spill recovery," Marine Pollution Bulletin, Vol. 46(3), pp. 780–783, 2003. [CrossRef]

[27] D. Wang, B. C. Sun, J. X. Wang, Y. Y. Zhou, Z. W. Chen, Y. Fang, W. H. Yue, S. M. Liu, K. Y. Liu, X. F. Zeng, G. W. Chu, and J. F. Chen, "Can masks be reused after hot water decontamination during the COVID-19 pandemic?" Engineering, Vol. 6(10), pp. 1115–1121, 2020. [CrossRef]

[28] L. F. L. Begall, C. Wielick, L. Dams, H. Nauwynck, P. F. Demeuldre, A. Napp, J. Laperre, E. Haubruge, and E. Thiry, "The use of germicidal ultraviolet light, vaporised hydrogen peroxide and dry heat to decontaminate face masks and filtering respirators contaminated with an infectious norovirus," Journal of Hospital Infection, Vol. 106(3), pp. 577–584, 2021. [CrossRef]

[29] H. P. Kim, M. S. Jo, C. H. Kim, J. S. Choi, and I. J. Yu, "Re-use of health masks after autoclaving," NanoImpact, Vol. 19, pp. 100231–100236, 2020. [CrossRef]

[30] D. F. Li, J. L. Cadnum, S. N. Redmond, L. D. Jones, B. Pearlmutter, M. F. Haq, and C. J. Donskey, "Steam treatment for rapid decontamination of N95 respirators and medical face masks,"American Journal of Infection Control, Vol. 48, pp. 853–858, 2020. [CrossRef]

[31] N. J. Rowan, J. G. Laffey, "Unlocking the surge in demand for personal and protective equipment (PPE) and improvised face coverings arising from coronavirus disease (COVID-19) pandemic – Implications for efficacy, re-use and sustainable waste management," Science of the Total Environment, Vol. 752, pp. 142259–142276, 2021.

[32] J. C. R. Romero, M. D. C. P. Ferreira, J. A. T. García, and S. C. Castro, "Disposable masks: Disinfection and sterilization for reuse, and non-certified manufacturing, in the face of shortages during the COVID-19 pandemic," Safety Science, Vol. 129, pp. 104830–104840, 2020. [CrossRef]

[33] A. Gopanna, R. N. Mandapati, S. P. Thomas, K. Rajan, and M. Chavali, "Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy and wide-angle X-ray scattering (WAXS) of polypropylene (PP)/cyclic olefin copolymer (COC) blends for qualitative and quantitative analysis," Polymer Bulletin, Vol. 76, pp. 4259–4274, 2018. [CrossRef]

[34] Y. H. Lee, E. J. Lee, G. S. Chang, D. J. Lee, Y. J. Jung, and H. D. Kim, "Comparison of oil sorption capacity and biodegradability of PP, PP/kapok(10/90wt%) blend and commercial(T2COM) oil sorbent pads," Textile Coloration and Finishing, Vol. 26, pp. 151–158, 2014. [CrossRef]

[35] S. J. Choi, T. H. Kwon, H. Im, D. Moon, D. J. Baek, M. L. Seol, J. P. Duarte, and Y. K. Choi, "A polydimethylsiloxane (PDMS) sponge for the selective absorption of oil from water," ACS Appl Mater Interfaces, Vol. 3(12), pp. 4552–4556, 2011. [CrossRef]

[36] E. A. Bukharova, E. A. Tatarintseva, and L. N. Ol'Shanskaya, "Production of polyethylene terephthalate based sorbent and its use for waste and surface water cleaning from oil products," Chemical and Petroleum Engineering, Vol. 50, pp. 595–599, 2015. [CrossRef]

[37] G. Wang, and H. Uyama, "Facile synthesis of flexible macroporous polypropylene sponges for separation of oil and water," Scientific Reports, Vol. 6, pp. 1–6, 2016. [CrossRef]

[38] D. Ceylan, S. Dogu, B. Karacik, S. D. Yakan, O. S. Okay, and O. Okay, "Evaluation of butyl rubber as sorbent material for the removal of oil and polycyclic aromatic hydrocarbons from seawater," Environmental Science and Technology, Vol. 43(10), pp. 3846–3852, 2009. [CrossRef]

[39] H. Zhu, S. Qiu, W. Jiang, D. Wu, and C. Zhang, "Evaluation of electrospun polyvinyl chloride/polystyrene fibers as sorbent materials for oil spill cleanup," Environmental Science and Technology, Vol. 45(10), pp. 4527–4531, 2011. [CrossRef]