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Original article

Extensive use of face masks during COVID-19 pandemic: (micro-)plastic pollution and potential health concerns in the Arabian Peninsula

Saddam Akber Abbasi [a], Amjad B. Khalil [b], Muhammad Arslan [c,d,*]

[a] Department of Mathematics, Statistics and Physics, Qatar University, Doha, Qatar
[b] Life Sciences Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia
[c] Environmental Biotechnology Division, National Institute for Biotechnology and Genetic Engineering, Pakistan
[d] Civil and Environmental Engineering Department, University of Alberta, Edmonton, Canada

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ABSTRACT

Face masks are primary line of defense to reduce the transmission risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). World Health Organization (WHO) has already updated the guidelines and advised the use of face masks in public areas essentially. This has dramatically increased the production and use of face masks in many parts of the world. Arabian Peninsula is comprised of six countries where the public perception of following WHO guidelines is high. In this study, we highlight the concerns relating to extensive use of face masks in this region, particularly in the context of (micro-) plastic pollution. We computed the number of face masks to be used in each of the countries of Arabian Peninsula for varying levels of acceptance rate and average number of daily usages. Accordingly, the amount of (micro-)plastic that could come into the terrestrial and marine environment is also reported. Saudi Arabia, being the most populated country in the region may contribute up to 32–235 thousand tons of (micro-)plastic which is nearly half of the amount in the whole Peninsula. On the other hand, an extremely high infection rate in Qatar (25.74%) may also lead to a significant increase of (micro-)plastic content due to high public acceptance rate and living standards. The high (micro-)plastic fraction is of significant concern because it ends up in the marine ecosystems. Further, it allows colonization of several pathogenic microorganisms (bacteria, viruses, fungal filaments, and spores) and might serve as carriers of disease transmission finally affecting the living organisms habituating these ecosystems. It is suggested that appropriate regulations on face masks waste should be devised to avoid any unwanted consequences in the near future.

1. Introduction

Arabian Peninsula is the landform surrounded by Southwest of Asia, northeast of Africa, and between Red Sea (west) and Persian Gulf (east). The six countries in the Arabian Peninsula (Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates, and Yemen) makes it a largest peninsula in the world which is spread over 3.2 million km^2 with a population of nearly 86.79 million. The peninsula holds significant importance in the world due to the availability of massive resources of oil and natural gas (Pitman et al., 2012; Khatib, 2014).

Recently, outbreak of coronavirus disease 2019 (COVID-19) has been emerged as a public health emergency of international concern (Shang et al., 2020). Accordingly, most of the governments in the Arabian Peninsula have enforced compulsory face mask policies which are being followed by high public acceptance rate (Hilton, 2020). This is due to the recent developments on viral transmission routes via virus-laden aerosols ($\leq$5 μm) and droplets (>5 to 10 μm) (Morawska and Cao, 2020; Anderson et al., 2020; Asadi et al., 2020). The aerosols are found to remain infectious in an indoor environment for hours, which could accumulate further by continuous breathing, speaking, coughing, and sneezing of infected persons (Prather et al., 2020). In a recent study, airborne transmission is suggested as a highly virulent and dominant route for the spread of the virus (Zhang et al., 2020).

* Corresponding author at: Civil and Environmental Engineering Department, University of Alberta, Canada.

E-mail address: arsilan324@gmail.com (M. Arslan).

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At one hand, the use of face masks have reduced the viral spread within societies; on the other hand, it is raising serious environmental concerns in terms of (micro-)plastic pollution. In a single N95 mask and a disposable surgical mask, there are approximately 11 and 4.5 g of polypropylene and/or other derivatives of plastics (e.g. polyethylene, polyurethane, polystyrene, polycarbonate, polyacrylonitrile), respectively (Potluri and Needham, 2005; Liebsch, 2020). The thermoplastic polymer fraction of this plastic content may disintegrate into smaller particles – known as microplastics – due to a combination of factors such as high temperature, UV exposure, hydrophobicity, and change in pH (Fig. 1) (Khoironi et al., 2020). The complete degradation/mineralization of polypropylene is not possible due to its exceptionally resistant nature, hydrophobic properties, high molecular weight, and high surface roughness (Jiang, 2018). Resultantly, a large portion of the polypropylene stays in environment in the form of microplastics.

Existing knowledge states that microplastic particles are able to invade almost every ecosystem (Lant, 2020). Nevertheless, a major fraction ends up in the water bodies, finally reaching the marine environment (Fig. 1). Earlier this year, a large number of face masks are found on a highway and drainage in Nigeria (Ile-Ife) as well as in the oceans of Hong Kong (Fadare and Okoffo, 2020). Fadare and Okoffo, (2020) studied the FTIR spectra of plastic degradation in the face masks found in the environment. The authors noticed peaks of polypropylene in the outer layer and polyethylene in the inner layer. Their findings suggested that the plastic particles may accumulate in the environment within a short time. Similar results are previously reported from eight sandy beaches and four sea surface stations along the coastline of Qatar (Abayomi et al., 2017). A high proportion of polypropylene (36 particles m^{-2}) and polyethylene (228 particles m^{-2}) was observed in the sandy beaches and sea surface stations. It is expected that such a fraction of (micro-)plastic will continue increasing in the next few years due to the excessive use face masks to fight covid-19 pandemic. Currently, no regulations exist in many parts of the world including Arabian Peninsula regarding microplastic pollution management strategies (Plackett, 2017). This situation may contribute to the longer persistence and transmission of pathogens including severe acute respiration syndrome coronavirus 2 (SARS-CoV-2) resulting in the future disease outbreaks. In this study, we computed the approximate number of face masks usage in the Arabian Peninsula leading to a rough estimate on (micro-)plastic content in the environment.

2. Methods

The disposable surgical masks and N95 masks are the most commonly used face coverings to guard against SARS-CoV-2. These masks are multi-layered and are made-up of non-woven fabric. The material mostly used for the making of masks is polypropylene. The polypropylene density in two layers of N95 masks is around 25–50 g/m^2 whereas for surgical masks it's around 20–25 g/m^2. This results in approximately 9 g of polypropylene for a single N95 mark and 4.5 g for a single disposable surgical mask. The N95 mask further uses 2 g of polypropylene in the filter (Liebsch, 2020). Although N95 masks give better protection against the virus, but these are mostly used by health care staff and doctors. The general public however mostly relies on the disposable surgical masks to protect themselves and others from the viral spread. The purpose of this study is to highlight the concerns related to the release of polypropylene fraction in the environment in terms of (micro-)plastic. For the calculation of amount of polypropylene, we considered 25% usage of N95 masks and 75% usage of disposable surgical masks.

The total number of masks (per year) to be used in each country in the Arabian Peninsula is calculated based on the total population (P), percentage of urban population (γ), acceptance rate (δ) for the usage of masks, and the average daily number of masks (β) used per person. The daily mask usage (DMU) is calculated as: $DMU = P \times \gamma \times \delta \times \beta$ (Nzediegwu and Chang, 2020). The annual mask usage (AMU) is given as: $AMU = DMU \times 365$. We considered different levels of δ and β in this study for different acceptance rates, i.e. δ = 0.5, 0.6, 0.7, 0.8 and 0.9 whereas β = 1, 2, 3 and 4. The AMU is determined for each combination of δ and β. We also computed the infection rate by using the following expression:

$$\text{Infection Rate} = \frac{Cases/million}{Tests/million} \times 100$$

3. Results

In this study, we focused on six countries in the Arabian Peninsula and a neighbouring island country Bahrain. The demographics of these countries, together with information about COVID-19 cases, are reported in Table 1.

As indicated in Table 1, Saudi Arabia is the most populated country that comprises ~50% of the population in the Arabian Peninsula. Bahrain is the densest country (2239 people/km^2) and Oman is the least dense country (16 people/km^2). As per the available data, Yemen is the least affected country from SARS-CoV-2 in the Arabian Peninsula with only 36 cases and 10 deaths per million population. Qatar attains a top position for the number of cases per million population, not just in the listed countries, but also in the whole world. Further, computed results of infection rate indicate that Qatar is on extremely high risk where the infection rate is 25.74, and is the highest compared to the other countries in the region. Bahrain, on the other hand, has the lowest infection rate (0.05%).

Considering different levels of δ and β, number of face masks to be used per year and the estimated content of polypropylene and derivatives (microplastic) that could be added in the environment are reported in Table 2. The highest number of face masks

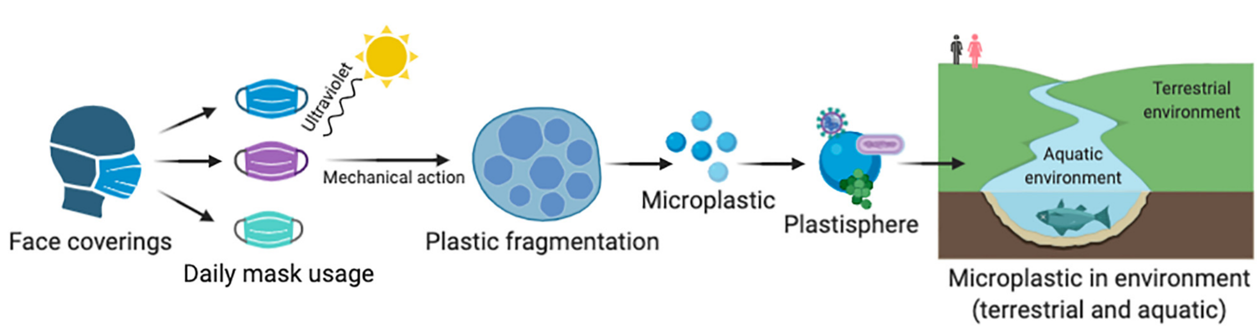

Fig. 1. A general description on the fate of microplastic in the environment originating from the face masks.

Table 1
Demographics and COVID-19 cases/deaths for different countries in Arabian Peninsula.

Country	Population	Urban population (%)	Density (P/km^2)	COVID-19 cases	Cases/million population	Tests/1 million population	Infection rate (%)
Saudi Arabia	34,813,871	84	16	170,639	4903	**47,092**	10.41
Qatar	2,881,053	96.2	248	91,838	32,708	**127,086**	25.74
Oman	5,106,626	87	16	34,902	6839	**37,493**	18.24
Kuwait	4,270,571	100	240	42,788	10,022	**90,600**	11.06
UAE	9,890,402	86.4	118	46,563	4709	**317,088**	1.49
Yemen*	29,825,964	38.4	56	1076	36*	**4***	900.00*
Bahrain	1,701,575	89.3	2239	24,081	14,167	**337,514**	0.05

Data source: www.worldometer.com (as of 26 June 2020).
* Potential error in data collection.

Table 2
Number of masks (in millions) and amount of polypropylene (in thousands of tons) for different countries in the Arabian Peninsula per year.

		Number of Masks (millions)					Polypropylene/(micro-)plastic (Thousands of tons)				
		δ					δ				
	β	0.5	0.6	0.7	0.8	0.9	0.5	0.6	0.7	0.8	0.9
Saudi Arabia	1	5336.97	6404.36	7471.75	8539.15	9606.54	32.69	39.23	45.76	52.30	58.84
	2	10673.93	12808.72	14943.51	17078.29	19213.08	65.38	78.45	91.53	104.60	117.68
	3	16010.90	19213.08	22415.26	25617.44	28819.62	98.07	117.68	137.29	156.91	176.52
	4	21347.87	25617.44	29887.01	34156.59	38426.16	130.76	156.91	183.06	209.21	235.36
Qatar	1	505.81	606.97	708.14	809.30	910.46	3.10	3.72	4.34	4.96	5.58
	2	1011.62	1213.95	1416.27	1618.60	1820.92	6.20	7.44	8.67	9.91	11.15
	3	1517.44	1820.92	2124.41	2427.90	2731.39	9.29	11.15	13.01	14.87	16.73
	4	2023.25	2427.90	2832.55	3237.20	3641.85	12.39	14.87	17.35	19.83	22.31
Oman	1	810.80	972.97	1135.13	1297.29	1459.45	4.97	5.96	6.95	7.95	8.94
	2	1621.61	1945.93	2270.25	2594.57	2918.90	9.93	11.92	13.91	15.89	17.88
	3	2432.41	2918.90	3405.38	3891.86	4378.34	14.90	17.88	20.86	23.84	26.82
	4	3243.22	3891.86	4540.51	5189.15	5837.79	19.86	23.84	27.81	31.78	35.76
Kuwait	1	779.38	935.26	1091.13	1247.01	1402.88	4.77	5.73	6.68	7.64	8.59
	2	1558.76	1870.51	2182.26	2494.01	2805.77	9.55	11.46	13.37	15.28	17.19
	3	2338.14	2805.77	3273.39	3741.02	4208.65	14.32	17.19	20.05	22.91	25.78
	4	3117.52	3741.02	4364.52	4988.03	5611.53	19.09	22.91	26.73	30.55	34.37
UAE	1	1559.52	1871.42	2183.33	2495.23	2807.13	9.55	11.46	13.37	15.28	17.19
	2	3119.04	3742.84	4366.65	4990.46	5614.27	19.10	22.92	26.75	30.57	34.39
	3	4678.56	5614.27	6549.98	7485.69	8421.40	28.66	34.39	40.12	45.85	51.58
	4	6238.07	7485.69	8733.30	9980.92	11228.53	38.21	45.85	53.49	61.13	68.77
Yemen	1	2090.20	2508.24	2926.28	3344.33	3762.37	12.80	15.36	17.92	20.48	23.04
	2	4180.41	5016.49	5852.57	6688.65	7524.73	25.60	30.73	35.85	40.97	46.09
	3	6270.61	7524.73	8778.85	10032.98	11287.10	38.41	46.09	53.77	61.45	69.13
	4	8360.81	10032.98	11705.14	13377.30	15049.47	51.21	61.45	71.69	81.94	92.18
Bahrain	1	277.31	332.77	388.23	443.70	499.16	1.70	2.04	2.38	2.72	3.06
	2	554.62	665.54	776.47	887.39	998.32	3.40	4.08	4.76	5.44	6.11
	3	831.93	998.32	1164.70	1331.09	1497.47	5.10	6.11	7.13	8.15	9.17
	4	1109.24	1331.09	1552.94	1774.78	1996.63	6.79	8.15	9.51	10.87	12.23

(5336–38426 million) and associated polypropylene/(micro-) plastic content (32.69–235.36 thousand tons) is estimated for Saudi Arabia. Yemen is the second country to be affected severely, however, it depends on the infection rate as stated previously. The total (micro-)plastic content is least for Bahrain and Qatar, i.e. 1.7–12.3 and 3.10–22.31 thousand tons, respectively. Considering the size and population of Qatar and Bahrain, even this amount of microplastic might still be a worrying sign and requires careful handling.

The graphical comparison of the polypropylene/(micro-)plastic content amount to be added in Saudi Arabia is presented in Fig. 2. The polypropylene is plotted against β at varying levels of δ. It can be observed that, with an increase in both δ and β, the amount of polypropylene/(micro-)plastic content will also increase. Fig. 3 compares the amount of polypropylene for the seven countries at varying levels of β when $\delta = 0.7$. For better comparison, we plotted log of polypropylene/(micro-)plastic for each of the country. It can be seen that among the different countries in Arabian Peninsula, Saudi Arabia is likely to observe highest increase for polypropylene whereas Bahrain would observe the least increase.

4. Discussion

Although Saudi Arabia observes the highest number of COVID-19 cases (4903 cases/million population), the infection rate (10.41%) remains lower compared to the other countries. Qatar displays highest number of cases/million and infection rate. In fact, Qatar has the highest amount of cases/million in the whole world, which is alarming. The amount of polypropylene/(micro)plastic (reported in Table 2) in Qatar will be on the higher side as the acceptance rate of mask usage and the average daily number of masks must be high to stop the flow of virus transmission.

As shown in Table 1, extremely low number of COVID-19 cases (36/million) in Yemen might not be a true picture of the outbreak in the country. A recent report published on BBC states that Yemen is suffering from extremely short supply of testing kits and lack of transparency (BBC, 2020). Furthermore, the Worldometer data suggests that the number of tests per million population are the lowest in the whole world. Yaakoubi (2020) mentioned that the COVID-19 numbers released by Yemen authorities are far less than the actual cases. Hence, it is likely that SARS-CoV-2 is quietly spreading across the country or the facts are being compromised

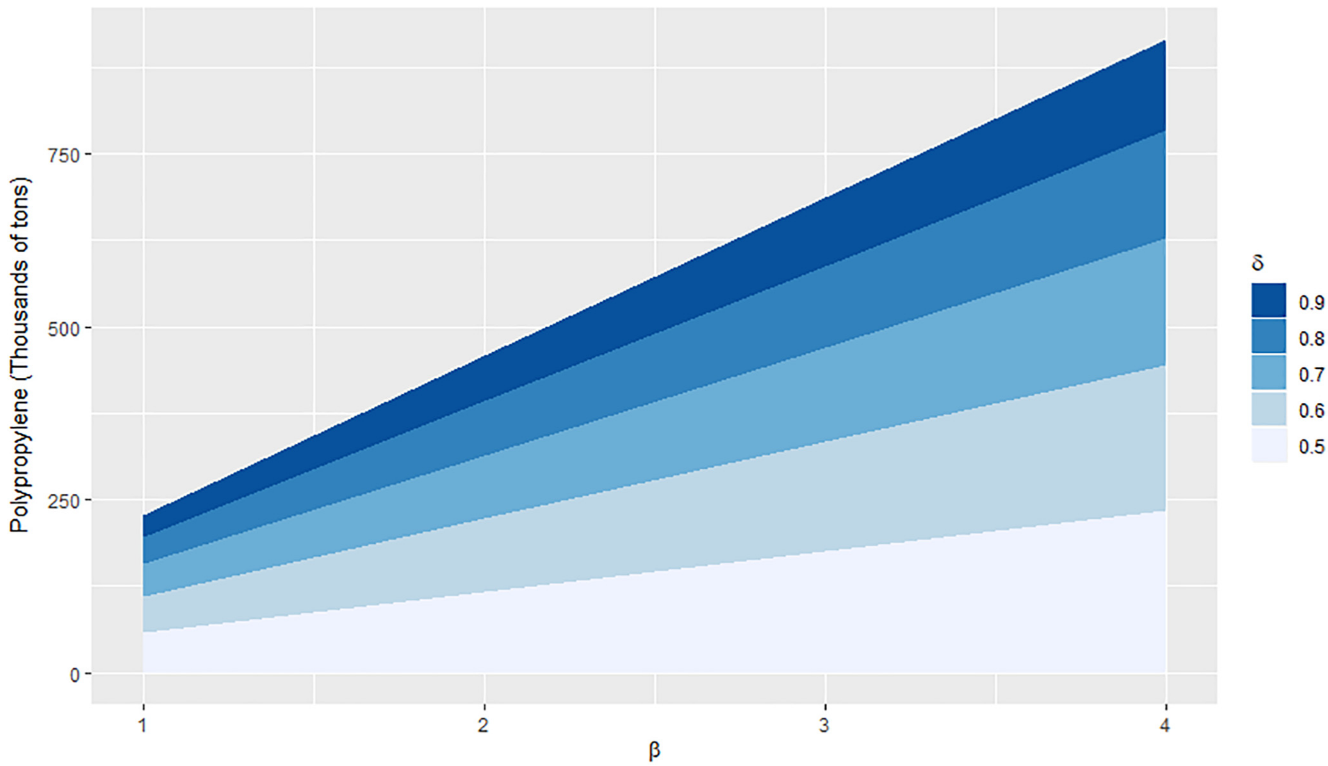

Fig. 2. Comparison of Polypropylene at different levels of δ and β for Saudi Arabia.

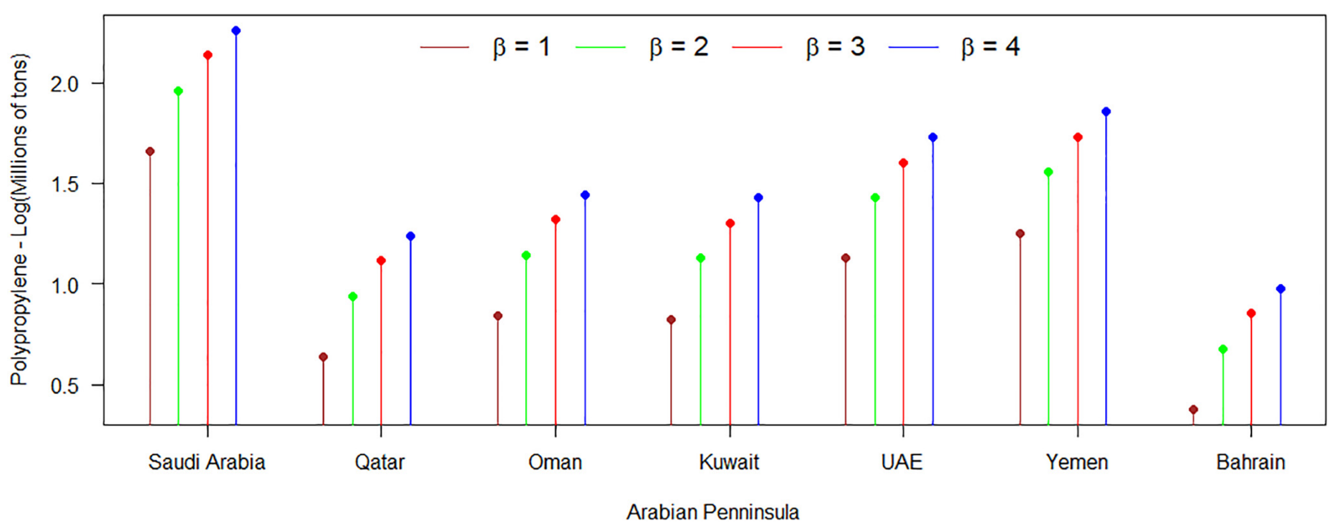

Fig. 3. Comparison of Polypropylene for different countries at varying levels of β when δ = *0.7*.

due to very little diagnostic practices. In this study, number of face masks and the amount of (micro-)plastic generation are under the assumption that the face masks should immediately made available in Yemen at an extremely low cost by World Health Organization (WHO) or other organizations. The United Nations International Children's Emergency Fund (UNICEF) has already sent the first batch of 10,000 COVID-19 kits to increase the testing facility (UNICEF, 2020).

Such a high usage of face masks is subject to high (micro-) plastic fraction in the terrestrial and aquatic environment of the Arabian Peninsula. It is a growing notion that plastic particles can act as a potential carrier of pathogenic microorganisms including viruses, bacteria, and fungi (Jiang, 2018; Neto et al., 2019). These organisms could develop biofilms or find niches on the surface of the microplastics (Zettler et al., 2013; Jiang, 2018). Zettler et al. (2013) observed a highly diverse microbial community on the surface of microplastics and termed it as a 'plastisphere'. Among them, pathogenic species such as *Vibrio parahaemolyticus* and *Aeromonas salmonicida* are detected that causes diseases in humans and fishes, respectively (Kirstein et al., 2016; Viršek et al., 2017). In the case of SARS-CoV-2, it was found that the virus was highly stable on plastic surfaces up to 72 h (van Doremalen et al. 2020). At one hand, this situation may lead to recurrent outbreaks of COVID-19 or other diseases (Orive et al., 2020); whereas, on the other hand, it could also impact the living organisms which are being directly exposed to the pathogens. This might be of further significant for the underprivileged societies such as Yemen (Mallapaty, 2020; Orive et al., 2020). Previously, periodic post-pandemic outbreaks of other viral diseases have been seen in different parts of the world (Rose, 1999).

In addition to human exposure and disease outbreaks, a general route of the (micro-)plastic transmission from all the countries in the Arabian Peninsula suggests its final fate in the Arabian ocean, Red Sea, Arabian Gulf, Gulf of Aden, and Gulf of Oman. These marine zones are well known for a variety of marine ecosystems such as marshes, estuaries, tidal zones, mangrove forests, sea floor, sea grass beds, and the coral reefs. Hence, the ongoing situation could lead to unwanted effects for the marine life which is highly diverse and unique in particular regions.

5. Conclusions

This study concludes that (micro-)plastic pollution in the Arabian Peninsula should be given a careful consideration during COVID-19 pandemic. Saudi Arabia and Qatar appears to be the major potential contributors and the high usage of face masks is expected to increase the (micro-)plastic load in the adjacent marine ecosystems. The harmful effects could be seen in the living organisms dwelling these marine habitats as well as in corresponding terrestrial habitats. Hence, timely and necessary actions should be taken to prevent any unwanted consequences in the near future.

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