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Sources, spatial distribution and characteristics of marine litter along the west coast of Qatar

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ABSTRACT

The spatial distribution, sources and characteristics of marine litter (ML) from 36 locations spread over 12 beaches along the west coast of Qatar have been assessed. A total of 2376 ML items with varying sizes were found with an average abundance of 1.98 items/m^2. The order of abundance of ML along the coast was as follows: plastics (71.4%) > metal (9.3%) > glass (5.1%) > paper (4.4%) > fabric (4.0%) > rubber (3.9%) > processed wood (2.0%). Locations in the south and northwest coasts of Qatar had significantly higher concentrations of ML. Surprisingly, nearly 47% of the beached polyethylene terephthalate (PET) bottles were derived from the countries bordering the Arabian/Persian Gulf (Gulf), and most of them were produced in the last 2 years. The plastic materials were drifted by winds and currents to the Qatar coast. Gulf circulation provides evidence to the pathways of ML beached on the Qatar coast.

1. Introduction

Marine litter (ML) is a major threat to the safety and health of global marine ecosystems (Serra-Goncalves et al., 2019). ML consists of any manufactured or processed solid material that was discarded or transported into the marine environment (Jeftic et al., 2009; EC JRC, 2013). Litter enters the sea from land-based and sea-originated sources - nearly 80% of ML is derived from land-based activities (EC JRC, 2013). Depending on density, majority of debris sink to the seabed, while the rest drift away by winds and currents and deposited along the coast, fragmenting over time (Turrell, 2018). Among these ML, plastics are the most harmful and dominant litter - 61 to 87% (Barboza et al., 2019). Jambeck et al. (2015) found that every year approximately 4.8 to 12.7 million metric tons of mismanaged plastic waste enter the oceans.

Many studies showed that ML can affect the economy of a country (McIlgorm et al., 2011; Jang et al., 2014), safety of marine vessels (Chen, 2015), survival of marine species (Gall and Thompson, 2015) and physical characteristics of the surrounding local marine environment (Taylor et al., 2014). In addition to direct (costs of vessel downtime due to ML entanglement on a vessel propeller) and indirect (tourism and health impact on marine biota and humans) economic impacts, ML also influences the activities at sea and on the shoreline. It has been estimated that plastic ML causes a financial damage of US$13 billion to global marine ecosystems each year (UNEP, 2014). McIlgorm et al. (2011) estimated that the ML related damage to marine industries costs US$1.26 billion per year in the Asia-Pacific region. In Europe, the cost of removing ML from the coasts was projected to be $720 million per year (UNEP, 2018). According to 2011 ecosystem service values, it was estimated that the cost of plastic ML, amounting to an annual cost in terms of reduced environmental value, is between $3300 and $33,000 per tonne of plastic ML (Beaumont et al., 2019).

The transport processes of ML in the sea have been studied extensively; for example, effects of ocean gyres (Lebreton et al., 2012; Neumann et al., 2014), oceanic convergences (Martinez et al., 2009), geostrophic currents (Law et al., 2010; Kukulka et al., 2012), direct wind forcing (Critchell et al., 2015; Critchell and Lambrechts, 2016; Chubarenko et al., 2016; Veerasingam et al., 2016a, 2016b), Ekman transport (Onink et al., 2019) and Stokes drift (Kubota, 1994; Stanev and Ricker, 2019; Durgadoo et al., 2019). Though a few studies have been attempted on the distribution of marine litter along the beaches of Gulf countries (Khordagui and Abu-Hilal, 1994; Al-Masroori et al., 2004; Claereboudt, 2004; Sarafraz et al., 2016; Martin et al., 2019; Lyons et al., 2020; Uddin et al., 2020), most of these studies are restricted to Iranian coast. A gap still exists in understanding the sources, quantity, composition and depositional trend of ML along the Qatar coast. Accordingly, we made an attempt to: (i) study the spatial distribution and abundance of ML along the west coast of Qatar, (ii) characterize the composition of ML and identifying their origin, (iii) understand the link between the coastal population and ML accumulation trend and (iv) investigate the influence of wind and

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hydrodynamics on the transport.

2. Materials and methods

2.1. Study area

The Qatar peninsula is located on the Arabian/Persian Gulf (hereinafter referred to as Gulf) in the mid-western coastline between 24 and 26°N latitude and 50°30′-51°31′E longitude. It has a coastline length of about 700 km, including a number of islands from the Salwa Bay at the border of Saudi Arabia to the border of United Arab Emirates, and covers an area of 11,651 km^2. The land area is largely flat and stony deserts, and experiences mild winters and very hot humid summers. The temperature of this arid climate region varies seasonally from 11 to 15 °C in the winter to 34–40 °C in the summer (Rezai et al., 2004). The mean daily temperature in summer is commonly 30–35 °C (temperature can exceed 50 °C), whereas the mean annual temperature is only 25 °C (Cheng et al., 2017). Therefore, as a result of high temperature and intense evaporation, the surface salinity can reach upto 58 psu in shallow region, especially in summer (Beltagy, 1983). Although summer can be humid, the area is very arid, with an annual mean rainfall of only 77 mm, much of which occurs as rare high intensity events (Slowakiewicz et al., 2016). The prevailing winds in the EEZ of Qatar are in the NW-N direction (Sandeepan et al., 2018). The extreme winds are associated with Shamal events, which occur during summer and winter (Yu et al., 2016; Senafi and Anis, 2015). Waves and surface currents are mainly generated by the NW-N winds, more frequently by the Shamal winds. Waves are higher during winter followed by spring, and weaker during autumn (Vieira et al., 2020). Mean significant wave height ranges from 0.3 to 1.5 m, with a maximum of 4.0 m during Shamal events. The tides are macro- (< 2.0 m), characterized by dominant semi-diurnal tidal constituents with diurnal asymmetry.

The population of Qatar has increased from 0.025 in 1950 to 2.83 million in 2019 (UN-DESA, 2019). The unprecedented rate of development has created significant environmental and socioeconomic challenges (Sheppard, 2016). The west coast of Qatar has been chosen for this study due to its important environmental and economic values: important coastal developments (oil industries, fishing and ports, and tourism), marine and coastal protected areas (i.e. Al Reem UNESCO-MAB Biosphere Reserve) and diverse ecosystems (mangrove forests, coral reefs, seagrass beds and intertidal mud flats (Sabkha)) (Soliman et al., 2014; Burt et al., 2017). Further details on study area, features of beaches and beach cleaning activities are presented in Table 1.

2.2. Marine litter survey method

The experts and well-trained team from Environmental Science Center (ESC), Qatar University conducted ML survey in 12 beaches from Abu Samra to Abu Dhalouf along the west coast of Qatar in September–November 2019 (Fig. 1 and Table 1). At each beach, three transects (low tide, high tide and berm line) measuring 100 m × 1 m of the strandline were surveyed. The boundaries of each transect were geo-referenced using GPS. ML items were sorted and classified according to the Master List of categories of the guidance document (TGML/JRC) (Galgani et al., 2013a). In each transect, all ML items larger than 2.5 cm (including caps, lids and cigarette butts) were considered and counted. During the survey, technological tools such as smartphone applications (Google maps app) and geo-referenced/geo-tagged photos have also been used to ensure proper sampling and data collection (Fig. S1). Based on the material composition, ML items were categorized as plastic, metal, glass, paper, fabric, rubber and processed wood. ML density was calculated (Lippiatt et al., 2013) as follows: $C_{ML} = n / (w \times l)$; where, '$C_{ML}$' is the density of marine litter (items/m^2), 'n' is the number of ML items counted, 'w' is the width (m), and 'l' is the length (m) of the sampled beach.

Table 1
Key features and characteristics of the surveyed beaches along the west coast of Qatar.

Name of the beach	Survey date	Description	Beach Type	Primary area usage	Distance from closest town (km)	Status of cleaning activities
Abu Samra	30/09/2019	Beach mainly consists of medium to coarse sand with scattered rocks, particularly at its southern part	Semi-rural	Tourism, recreation and winter camping	40	Occasionally by volunteers
Umm Bab	30/09/2019	Flat sandy beaches; located near the national cement industry	Semi-urban	Tourism, recreation and winter camping	4	Daily
Fahahil	30/09/2019	Flat sandy beaches	Semi-rural	Tourism	30	Occasionally by volunteers
Dukhan	19/09/2019	Long flat sandy beaches; situated near the largest onshore oil fields of Qatar; it has the largest inland sabkha ecosystem	Urban	Tourism and recreation	5	Daily
Zekreet	19/09/2019	Isolated sandy beaches	Semi-urban	Tourism, recreation and winter camping	10	Daily
Al Buruq	16/11/2019	Isolated with sandy beaches	Remote/natural	Fishing, tourism, recreation and winter camping	15	ND
West Island	09/10/2019	Isolated island with sandy beaches and scattered rocks	Remote/natural	Fishing	30	ND
Al Numan	10/10/2019	Sandy beaches with scattered rocks attached with tarmats	Remote/natural	Fishing	15	ND
Al Zubara	10/10/2019	Sandy beaches with scattered rocks attached with tarmats; UNESCO World Heritage site is situated here.	Semi-rural	Fishing, tourism, recreation and winter camping	25	ND
Al Arish	08/10/2019	Very flat coast with shoals extending for kilometers offshore	Semi-rural	Fishing, tourism, recreation and winter camping	15	ND
Al Jumail	08/10/2019	Flat coast with sandy beaches	Semi-rural	Fishing and winter camping	7	Occasionally by volunteers
Abu Dhalouf	08/10/2019	Sandy beaches; Al Ruwais port is situated.	Urban	Tourism, recreation and fishing	2	Daily

Fig. 1. The study area and sampling locations (marked in star).

2.3. Marine litter diversity indices

The univariate diversity metrics (Shannon-Wiener diversity index and Evenness index) were calculated to study the structure of ML communities along the west coast of Qatar. Shannon-Wiener diversity index (H′) was calculated as $H' = -\Sigma fr \times \ln(fr)$, where, fr is the relative frequency of each ML 'species' (Battisti et al., 2018; Dalu et al., 2019). H′ is a non-parametric diversity measure, which is based on the number of species and relative number of times the species occur. Evenness index (E) was calculated as: $E = H'/H'_{max}$, where, $H'_{max} = \ln S$ and S is total number of ML 'species' in the community (richness). E is a metric used for the measurement of sample heterogeneity of an assemblage based on the distribution of relative frequency of ML 'species'. When ML group evenness is high, the dominance of a specific ML group becomes lower (Pielou, 1975).

2.4. Clean coast index

In order to assess the current status of beach cleanliness along the west coast of Qatar, the Clean Coast Index (CCI) was calculated as: $CCI = C_M \times K$, where C_M is the density of ML items per m^2, and K is a constant that equals to 20 (Alkalay et al., 2007). CCI scale provides the degree of beach cleanliness as follows: values from 0 to 2 – very clean, 2 to 5 – clean, 5 to10 – moderately clean, 10 to 20 – dirty, and > 20 – extremely dirty. This evaluation method provides an aggregate indicator that translates the quality of the beaches in terms of potential and direct damage to the health of marine organisms and extension to human life.

2.5. Source identification

The sources of ML found on the coast can be identified using attribution-by-litter type method (Tudor and Williams, 2004). The sources of ML were classified into four categories: (i) Land-based, (ii) Sea-originated, (iii) Transboundary and (iv) Uncertain source. Land-based sources include mainly recreational use of the coast, public littering, industrial activities and sewage related debris (Veiga et al., 2016). ML can be transported to the sea by rivers, industrial discharges, run-offs or winds. The sea-originated source is that drifted to the coast from the sea, and this includes debris from commercial shipping, fishing and boating activities (fishing nets, traps, buoys, etc.), offshore oil platforms/hydrocarbon industries and aquaculture sites. Transboundary ML items are those transported from neighboring countries (identified through manufacturing country, barcode, telephone number, etc.) by winds and currents. Uncertain source could be either on land or at sea, and has no labels to indicate their origin (Galgani et al., 2015). All the above classifications have been applied in the present study for source identification.

2.6. Wind and hydrodynamics

The ERA 5 winds (U and V components) were retrieved from the European Centre for Medium-Range Weather Forecast (ECMWF) database (https://ecmwf.int). These winds are available at 30 km spatial grids for every 1 h interval (Hersbach et al., 2019). We used ERA 5 winds in the Gulf to identify the annual and seasonal patterns and their possible links with the transport of ML. The monthly mean surface currents in the Gulf were obtained from the COPERNICUS Marine Environmental Monitoring Service (CMEMS) database (https://marine.copernicus.eu/). The CMEMS produces daily mean and monthly mean current velocities in their Operational Mercator global ocean analysis and forecast system covering the global ocean with 1/12° resolution (~9 km in the Indian Ocean) and has 50 vertical layers. It uses a global ocean model based on NEMO code v3.1 (Madec, 2012) in the ORCA12

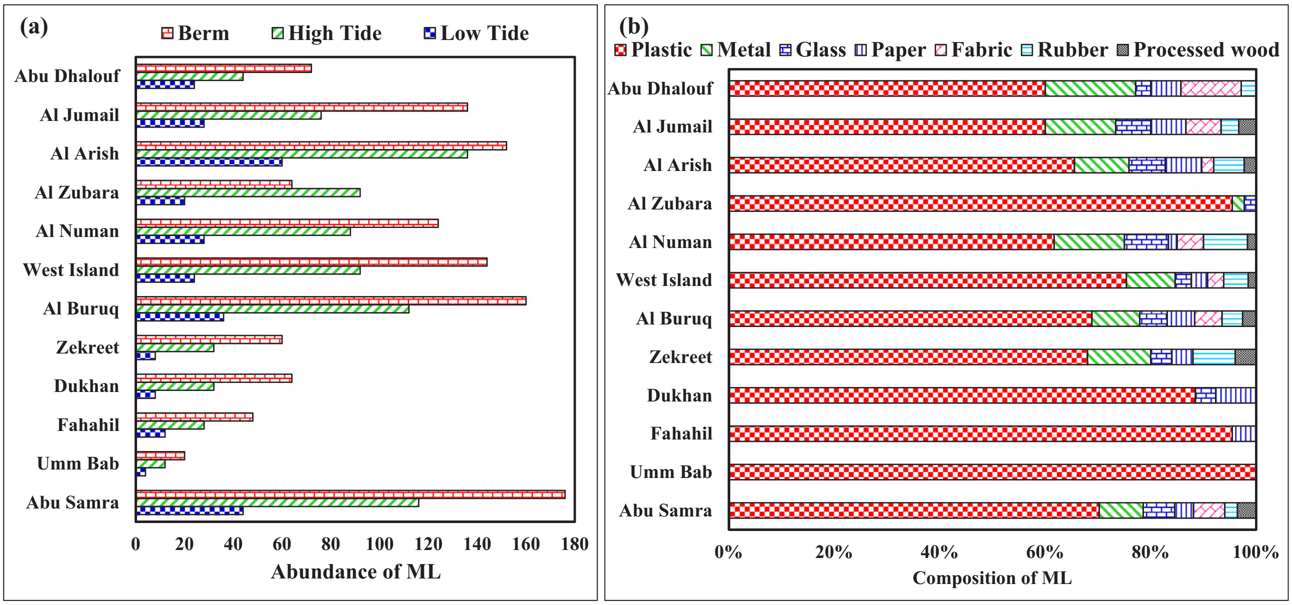

Fig. 2. (a) Spatial variation of ML abundance found in the low tide, high tide and berm line areas, (b) Distribution of different ML categories in the beaches along the west coast of Qatar.

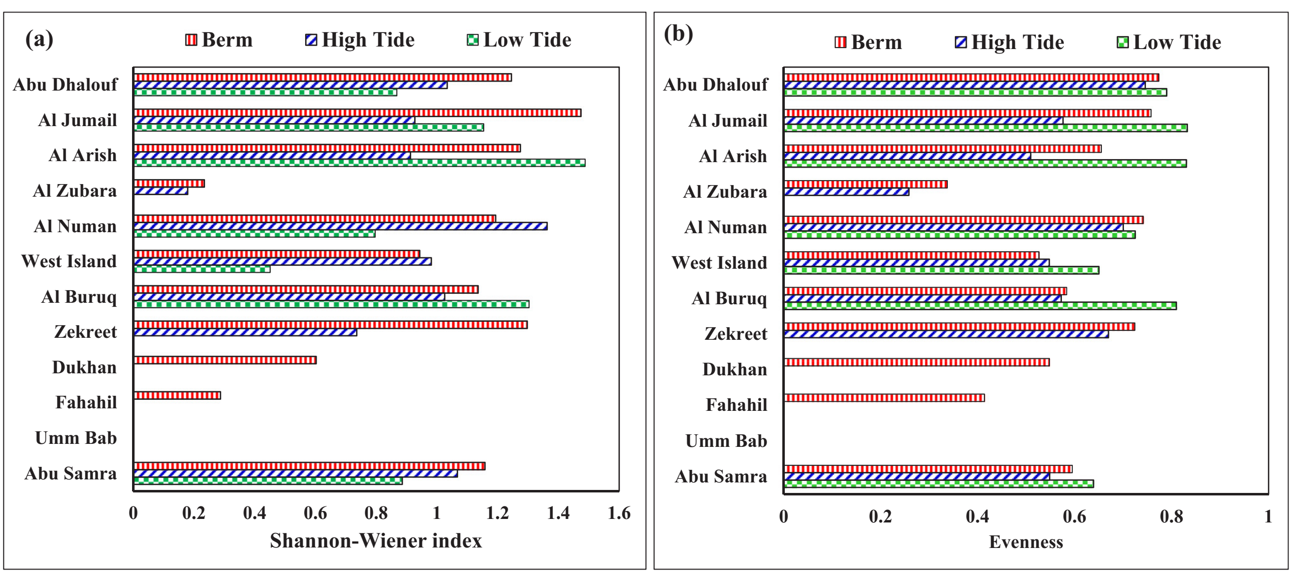

Fig. 3. Species diversity indices of ML: (a) Shannon-Wiener and (b) Evenness.

configuration, forced by 3-hourly ECMWF operational winds and corresponding heat and freshwater fluxes. It captures all effects in driving the ocean currents, including the Ekman drift from the wind. A range of satellite and in-situ data are used to update and correct the simulated ocean state (Lellouche et al., 2013, 2018). Stokes drift data has been obtained from CMEMS database - produced using the MFWAM wave model by the Météo-France global wave system, which is available at 1/12° resolution (Ardhuin et al., 2010). The CMEMS products (currents and Stokes drift) have been used earlier to simulate the drift of marine debris in the Indian Ocean (Durgadoo et al., 2019).

3. Results and discussion

3.1. Abundance, spatial distribution and composition of ML

A total of 2376 ML items with varying sizes were found along the west coast of Qatar. The ML densities ranged from 12 ± 8 items/100 m^2 in Umm Bab coast to 116 ± 49.2 items/100m^2 in Al Arish coast (Fig. 2a). Generally, there was a spatial gradient of ML with higher densities in the south (Abu Samra) and north-northwest (N-NW) beaches and lower densities in the central part of the west coast of Qatar. The density of ML on the west coast of Qatar (1.98 items/m^2) is higher than the global average of 1.0 items/m^2 (Galgani et al., 2015). Moreover, the average ML density is higher compared to that of other coastal regions (e.g., Red Sea (Martin et al., 2019), Italy (Giovacchini et al., 2018) and Slovenia (Laglbauer et al., 2014)), however, lesser than some other coastal regions (e.g., Iran (Sarafraz et al., 2016), Colombia (Rangel-Buitrago et al., 2017) and India (Jayasiri et al., 2013)). Overall, the quantity of stranded ML items along the coast shows the following order: low tide (296 items) < high tide (860 items) < berm line (1220 items). The abundance of ML along the low tide region is 4 times lesser than that found in the berm line. ML is less abundance (12.5%) in the low tide region since they remain there only for a few hours, and can be easily removed and pushed to the open ocean by tides

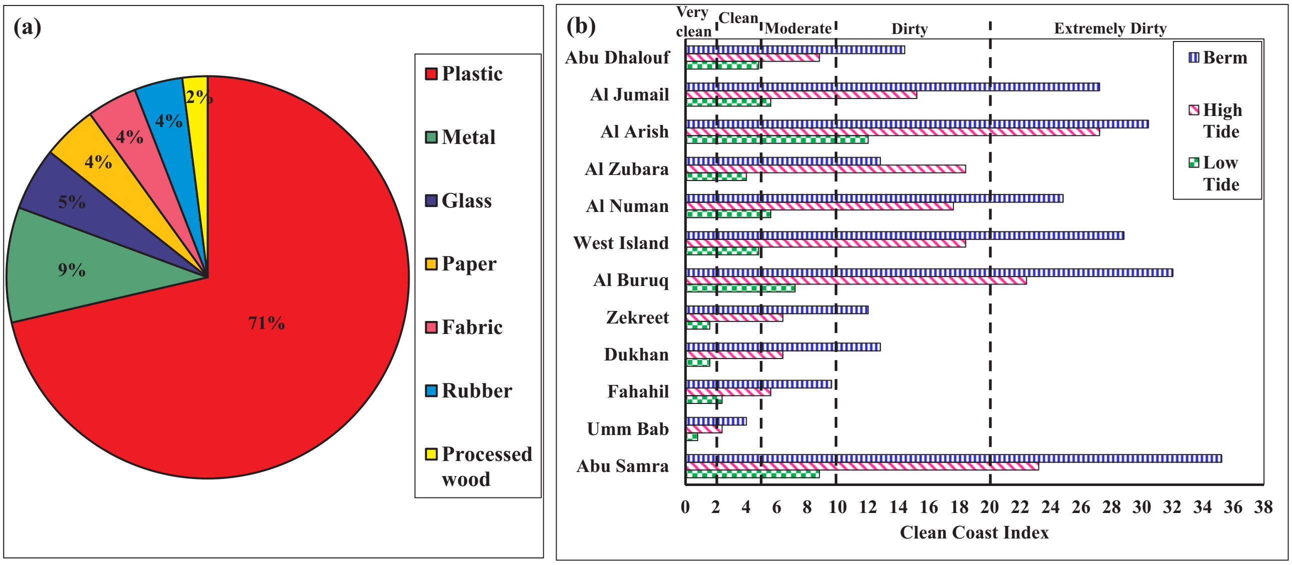

Fig. 4. (a) Average percentage of various ML categories and (b) Clean Coast Index for the beaches along the west coast of Qatar.

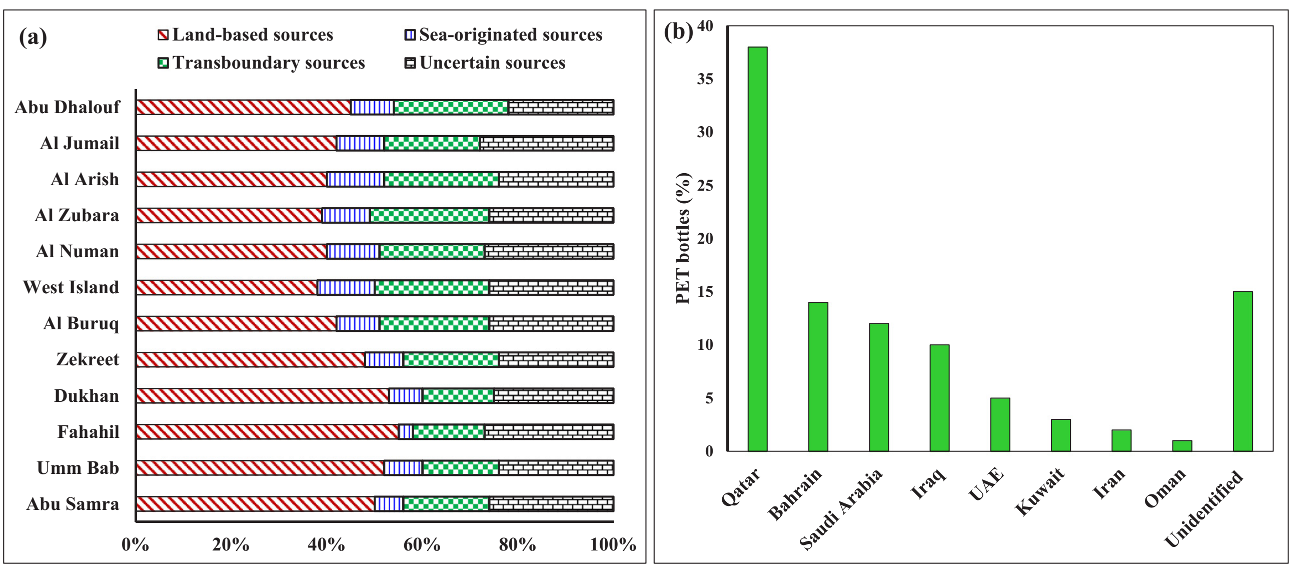

Fig. 5. (a) ML distribution by sources and (b) Origin of ML (especially PET bottles) recorded along the west coast of Qatar.

and waves.

The percentage contribution of each ML category along the west coast of Qatar based on the Master List (TGML/JRC) is presented in Fig. 2b. The most abundant ML type is plastic material in all the beaches – ranging between 60% (in Abu Dhalouf) and 100% (in Umm Bab). The ML 'species' diversity indices (Shannon-Wiener diversity index and Evenness index) declined from the northern part to the southern part and then increased at Abu Samra (Fig. 3a, b). The high evenness values in the low tidal region indicate less frequency of dominance of particular ML items. The significant differences highlighted by the Shannon-Wiener diversity index are due to variation in the abundance of ML observed in the intertidal region. The average composition of plastic in the Qatar coast is 71% (Fig. 4a), which is lesser than the global average of 75% (Galgani et al., 2013b). Among the ROPME sea countries, Qatar has a good plastic waste management practice (Tables S1, S2 and Fig. S2).

3.2. Beach quality assessment

The beach cleanliness quality is evaluated by computing clean coast index (CCI) (Fig. 4b). The CCI values in the intertidal regions of Umm Bab, Fahahil, Dukhan and Zekreet beaches are less than 10, whereas in the remaining beaches (especially in the northwestern part of the Qatar coast) higher than 10. According to CCI values, Umm Bab, Fahahil, Dukhan and Zekreet beaches could be categorized as very clean to moderately clean, and most of the beaches in the N-NW part of the study area (including remote islands) as dirty to extremely dirty. The distribution of ML along the beaches is negatively correlated with human population in nearby areas (Table S1). The higher values of CCI for beaches in the N-NW and southern (Abu Samra) part of the study area could be due to irregular beach cleaning activity and large amount of sea-originated ML input in these regions, whereas beaches in the hinterland of highly populated beaches (including Dukhan) have less CCI values due to regular beach cleaning activities as mentioned in Table 1.

3.3. Sources of ML

The ML input along the west coast of Qatar is primarily contributed by the following four main categories of sources: (i) land-based, (ii) sea-originated, (iii) transboundary and (iv) uncertain sources. The results of the analysis show that the composition of litter from the land-based sources contributes the highest number compared to all other sources. Overall, the land-based ML accounts for 45.3% of the items, sea-originated ML items 8.75%, transboundary ML items originated from neighboring countries 20.4% and 25.4% of ML items could not be identified (Fig. 5a).

In Qatar, the generation of plastic waste was 110,062 tons in 2010 to 162,749 tons in 2016, exhibiting an increase of more than ~50,000 tons with an annual growth rate of ~6.7% (Hahladakis and Aljabri, 2019). Moreover, it is estimated that plastics account for ~13% of the municipal solid waste (MSW) generated in Qatar (MDPS, 2014). Moreover, the results from this study also confirmed that the input of ML (especially plastic) from the land-based sources is higher in Qatar (Fig. 5a). More abundance of sea-originated ML in the N-NW beaches of Qatar could be related to intensive fishing activities in the offshore region. The satellite image (Fig. S3) also confirms that extensive fishing vessel activities are going on off NW part of Qatar. Therefore, when the intentional and/or unintentional discard of fishing nets and related debris lying on the seafloor or floating on the surface get refloated and drifted to the shores, the number of sea-originated items will increase. Besides fishing activity, oil tankers, shipping traffic and offshore activities in the region could also contribute considerably to the sea-based ML items.

The country of origin of 85% PET bottles was determined based on manufactured place, language and barcode, and the remaining bottles could not be identified (Fig. S4). It is interesting to observe that only 38% of the PET bottles are from Qatar, and remaining 47% bottles are from the neighboring countries (Fig. 5b). Among the surveyed beaches, the highest concentration of foreign ML was found from those beaches, which are in the close proximity to the neighboring countries.

3.4. Controlling factors for the transport and deposition of ML

The transboundary ML (20.4%) found along the west coast of Qatar was originated from the neighboring countries and beached on the Qatar coast by winds and hydrodynamics (Fig. 6). Jambeck et al. (2015) estimated that among the Gulf countries, the share of mismanaged plastic was high in Iraq, Iran, Bahrain, Saudi Arabia and Oman. Lebreton et al. (2017) estimated that 67.3 tons of plastic waste enter into the Gulf annually through Shatt Al-Arab (Iraq). The NW winds and currents in the northern Gulf modulate the SE transport of these mismanaged ML. The annual mean wind speed and current speed in the northern Gulf are about 5.5 m/s and 0.25 m/s, respectively. However, the stronger NW Shamal winds and associated currents (during December–March and June) enable a quicker transport than normal. The trajectories of spilled floating pollutants (oil slick and tar residues) released near the mouth of Shatt Al-Arab in the Gulf reached the NW part of Qatar within 15–30 days (El-Sabh and Murty, 1988; Al-Rabeh et al., 1993; Elhakeem et al., 2007). The currents show anomalous surface circulation in the Gulf, from counter-clockwise eddies-dominated summer currents to Shamal-modulated winter currents (Fig. 7). The directional shift of winds and currents from NW to N-NW, off the west coast of Qatar and around the Bahrain coast, enables a shoreward transport of the ML to the west coast of Qatar. The mean wind speed and current speed along the west coast of Qatar is about 4.0 m/s and 0.05 m/s, respectively. The Stoke drift components which drive the alongshore currents due to the action of wave-breaking are not well captured by the coarse resolution of the model outputs. However, its partial influence is recognizable in the offshore regions, with drifts of the order of 0.03 m/s. The settling of the ML occurs due to the weak currents along the west coast of Qatar. The high proportion of ML received along the coast of Abu Samra, Al Arish and Al Buruq is consistent with weak currents or by the net shoreward/bayward transport in these regions.

The manufacturing date of most of the transboundary PET bottles found along the west coast of Qatar fall in the last two years period (Fig. S4). We can assume that the empty and tightly closed PET bottles from the neighboring countries have been drifted by winds (especially Shamal) and currents in recent times, and beached on the Qatar coast. Apart from winds and currents, wave-induced longshore currents also transported the ML to the Qatar coast. However, fine resolution longshore current is required to emphasize its role in the alongshore transport of ML.

3.5. State of ML decay

The state of decay is an indicator of the age of ML. An intact, clean and freshly looking item can be assumed as if it has been released into the ocean recently, while a brittle or decomposed item may be assumed floating for a long time (Duhec et al., 2015). In the present study, various stages of decay of plastic ML have been identified as follows. Manufactured date of most of the stranded PET bottles along the west coast of Qatar shows that most of these items are of recent input. Most of the ML items found on the northwest part of Qatar were highly weathered (labels were degraded) and associated with barnacles and growth of microbes (cyanobacteria, fungi and algae). The ML items found on the islands in the northwest part of Qatar were covered with assemblage of more encrusting organisms, indicating long residence time at sea. Law (2017) also found that the presence of barnacles and development of algae on the PET bottles are the sign of long residence time of ML.

3.6. Beaches to consider for future ML monitoring programs

The removal of ML from the coastal areas is relatively easy compared to its removal from the sea surface due to feasibility and cost-efficiency (Hong et al., 2015). Based on the anticipated population growth in Qatar, MDPS (Ministry of Development Planning and Statistics) and QDB (Qatar Development Bank) estimated that plastic waste might be increased to ~20,000 tons by 2025 (Al-Maaded et al., 2012). The present study reveals that regular beach cleaning activities and long-term ML monitoring programs are required to reduce ML along the west coast of Qatar (especially, N-NW coast). The present results will be useful to study the following potential harmful implications of ML: (i) mortality of marine biota due to ingestion of ML, (ii) entanglement of ML leading to potential losses in biodiversity, (iii) bioaccumulation and transportation of persistent organic pollutants and release of toxic chemicals, and (iv) transport of alien species. Since the ML is transboundary in nature and continuous input of ML is expected along the Gulf coast, “thinking regionally and acting locally” is the key to reducing marine ecosystem threat from litter pollution in the Gulf through a combination of legislation, proper law enforcement and creating awareness in the ROPME countries.

4. Conclusions

This study provides a comprehensive information on spatial distribution, characterization, probable sources and beach quality index of marine litter along the west coast of Qatar. The density of ML on the west coast of Qatar (1.98 items/m^2) is higher than the global average. Relatively a high proportion of ML is deposited on the north-northwest coast of Qatar (including remote islands) from the land-based, sea-originated and transboundary sources. 47% of plastic bottles were originated from the neighboring countries, and those were manufactured in the last two years. The transport and accumulation of ML along the Qatar coast is controlled by the hydrodynamic forces. Qatar coast can be negatively impacted by ML originating from fishing activities and PET bottles coming from neighboring countries. Regular beach cleaning activities in the more populated areas significantly reduce the abundance of ML. The Regional Organization for the Protection of the Marine Environment (ROPME) of the Gulf countries

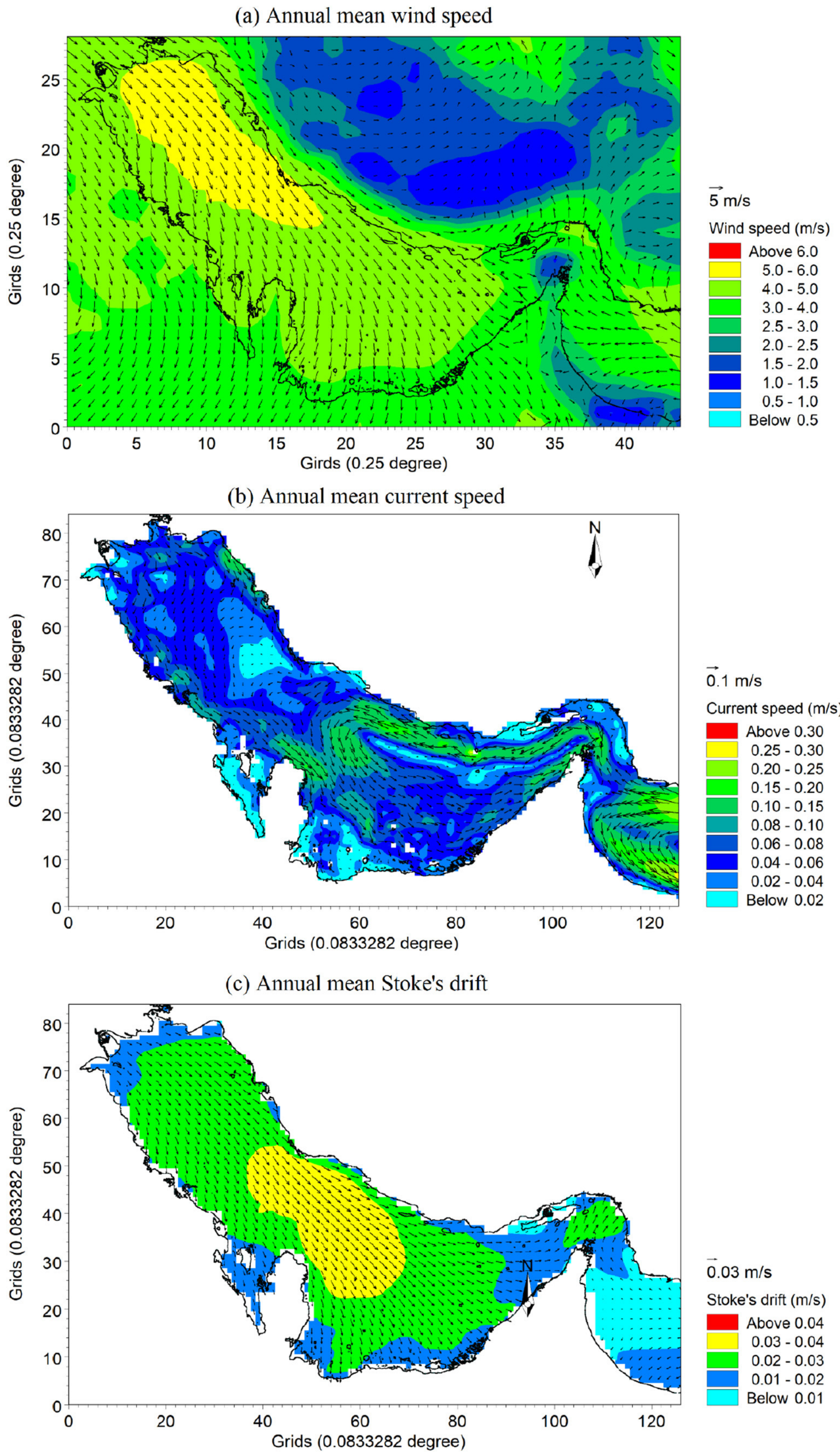

Fig. 6. The annual mean pattern of (a) wind speed (b) current speed and (c) Stokes drift.

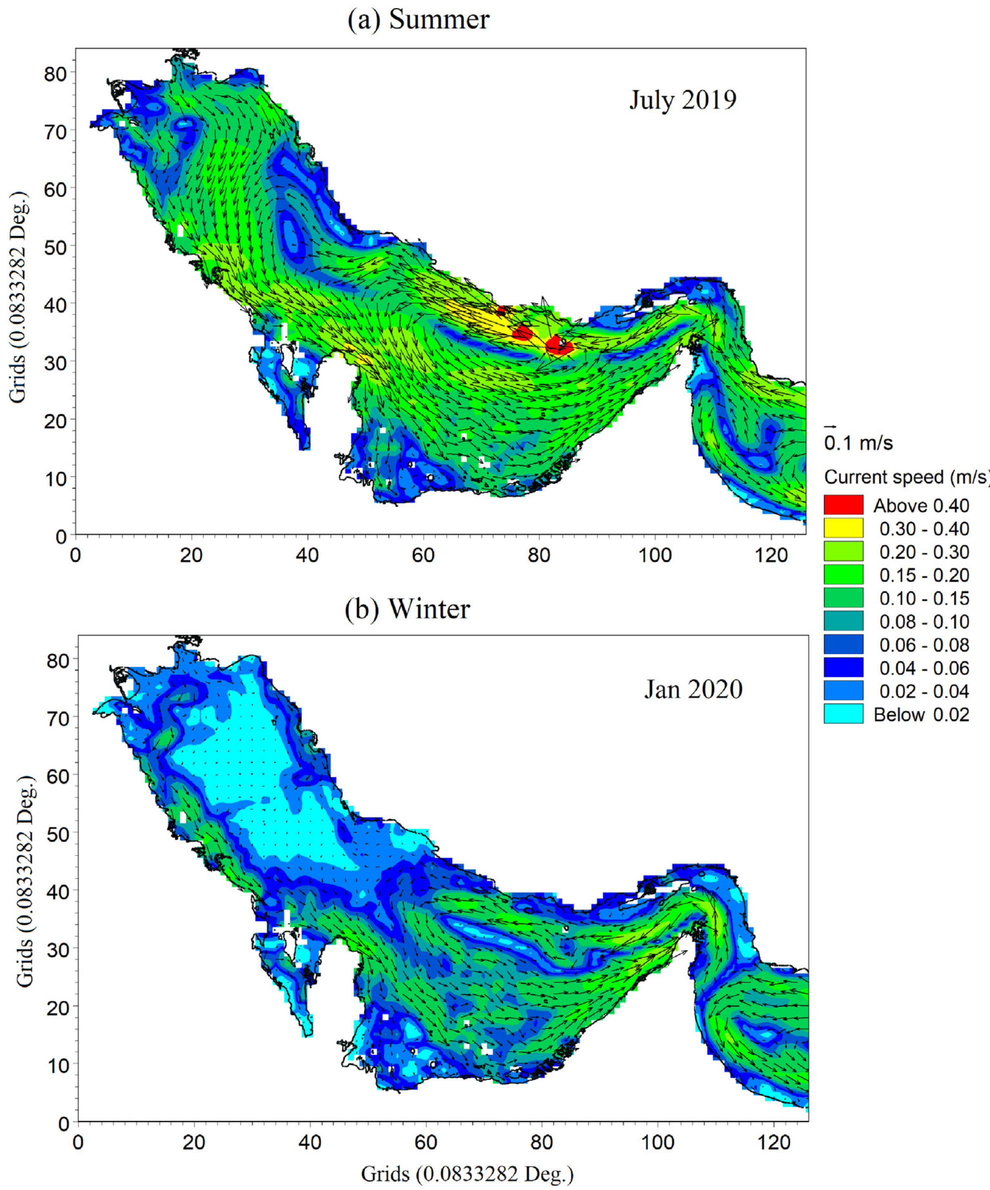

Fig. 7. The monthly mean currents in the Arabian/Persian Gulf representing (a) Summer (July 2019) and (b) Winter (January 2020).

has adapted the UN 2030 Agenda for the Sustainable Development Goals (SDG) to mitigate the marine litter pollution to restore and preserve the region's natural environment.

CRediT authorship contribution statement

S. Veerasingam: Conceptualization, Investigation, Methodology, Visualization, Writing - original draft, Writing - review & editing. **Jassim A. Al-Khayat:** Investigation, Methodology, Writing - review & editing. **V.M. Aboobacker:** Investigation, Methodology, Writing - review & editing. **Shafeeq Hamza:** Investigation, Methodology. **P. Vethamony:** Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Visualization, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2020.111478.

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