



Marine plastic debris in the Arabian/Persian Gulf: Challenges, opportunities and recommendations from a transdisciplinary perspective

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ABSTRACT

In recent years, the amount of plastic waste entering the marine environment around the world has gained increasing attention. Yet certain areas and regions remain relatively undocumented. Research findings on this topic within the countries adjacent to the Arabian/Persian Gulf comprised of Iran, Iraq, Bahrain, Saudi Arabia, Kuwait, Qatar, Oman and the United Arab Emirates is relatively sparse. Significant gaps remain regarding the precise details on the quantity, sources and impacts of plastic marine debris as well as appropriate management responses. This article addresses these shortcomings from a transdisciplinary perspective, drawing on science, engineering and law. Based on an analysis and overview of the scientific research on plastic pollution in the region, an estimate of mismanaged waste is developed, both on a national level as well as for selected coastal cities. The article then explores the applicable international and regional regulatory framework to address marine debris in the Arabian/Persian Gulf region. It provides one of the first accounts of this regional sea from a comprehensive marine litter regulatory perspective, incorporating scientific findings as well as modelling techniques. The article suggests possible ways to achieve synergies and cooperation among actors and proposes novel approaches on methods to address the problem with a view to the transboundary nature of the issue. The key to success lies in dedicated cooperative efforts within the region, both between the public and private sector and between government and civil society.

1. Introduction

Plastic marine debris (including microplastics or MPs) has been described as an ecological disaster [1]. Most recently available statistics and estimates surrounding the levels of use and disposal are indeed alarming. Globally, an estimated 2 billion metric tonnes of municipal solid waste were generated in 2016, and under a business-as-usual scenario this amount is expected to grow to 3.40 billion tonnes by 2050 [2]. 11 million MT of plastic were estimated to enter the oceans globally in 2016 [3]. Of the total 6.3 billion MT of plastics ever produced, 4.9 billion tonnes have been discarded either in landfills or elsewhere in the environment and this figure is expected to increase to 12 billion tonnes by 2050 unless action is taken [4]. By 2050, the World Economic Forum has estimated the plastic industry will be responsible for the consumption of 20% of total oil production and 15% of the

worldwide annual carbon budget [5]. As most plastic packaging is used only once before being discarded, it is estimated that 95% of the value of plastic packaging material represents an economic loss amounting to \$80–120 billion annually [5]. Given these figures, it is not surprising that plastics are increasingly at the centre of attention of decision-makers worldwide [6].

The Arabian/Persian Gulf is a sea area surrounded by 8 riparian states: the Kingdom of Bahrain (Bahrain), the Islamic Republic of Iran (Iran), the Republic of Iraq (Iraq), the State of Kuwait (Kuwait), the Sultanate of Oman (Oman), the State of Qatar (Qatar), the Kingdom of Saudi Arabia (Saudi Arabia) as well as the United Arab Emirates (UAE). Although knowledge gaps exist as to the current state of plastic marine debris in the region, an estimated increase in solid plastic waste generation is expected to not only result in environmental pollution, but also involve a loss of natural resources used for plastic production,

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posing a complex and long-term challenge for broader sustainability questions [7]. Despite recent efforts such as those undertaken by Lyons et al. [8] to investigate potential environmental impacts from marine litter in the Arabian/Persian Gulf (Gulf), including presenting an initial approach on how to develop and implement national and regional action plans, the region as a whole is still under-studied. This paper takes a complimentary and additive approach synergising legal, scientific and engineering data and perspectives, including making a regional estimate on quantities of plastic entering the environment from mismanaged waste. Marine plastic debris within the Gulf remains a challenge because of a lack of information on the sources and distribution of plastic in the environment as well as a fragile geopolitical system among the riparian States. Finding solutions to address plastic waste in the marine environment might be a scientific common denominator which transcends these regional geopolitical tensions.

2. Plastic marine debris research in the Arabian/Persian Gulf region

2.1. Brief overview of the scientific literature

Peer-review articles in English language on plastic and MP pollution within the Gulf are not extensive, but have increased in the last few years. This upturn in interest in the presence, abundance, and characterisation of MPs has been documented within recent review articles [9, 10]. Thus, the aim of this section is not to provide a comprehensive treatise of the literature which can be found elsewhere, but rather give a brief overview of which topics relating to MPs are being investigated and where possible knowledge gaps still exist, as well as highlighting the variation in scientific production between the different Arabian/Persian Gulf States.

The earliest reports of plastic debris in the Gulf were from the late 1980s and mid-1990s on the beaches of Kuwait [11] and the UAE [12, 13]. Densities as high as 80,000 particles/m² along the coast of the United Arab Emirates were recorded [12]. A decade later, plastic beach debris from 11 beaches along the coast of Oman were surveyed [14]. Among the locations studied, there were significant differences in levels of debris with the highest recorded level of six items/m². Recent research, from about 2016 onwards, has focussed primarily on the prevalence of MPs in coastal marine waters [e.g., [15–18]], sediments and beaches [e.g., [19–22]].

In line with MP research from around the world, these studies have quantified levels of pollution in their respective environmental compartments, as well as describing MPs by shape and polymer. The range of polymers including polyethylene and polypropylene [16], polystyrene, polyamide, polymethyl and cellophane [15], as well the dominant MPs described as fibres or fibrous [17], are consistent with results found elsewhere. MPs have typically been attributed to both land-based (recreational, wastewater treatment) and marine (fishing) activities. The presence of MP in coastal surface of Chabahar Bay (Gulf of Oman) appeared to be related to human population densities [16]. However, oil-rig installations and shipping operations may also be important sources since the Gulf is the leading oil producer in the world and consequently there are high levels of plastic solid waste generation linked to the petrochemical industry [9,15]. At Iran's main oil terminal on Khark Island, the presence of MPs linearly related to the quantities of metals and polycyclic aromatic hydrocarbons (PAHs) present, indicating the importance of industrial sources and the co-localisation of MPs with other released pollutants [23]. The role of wastewater treatment plants (WWTPs) as a potential source of MPs has only been investigated in respect of one site (Bandar Abbas City, Iran) to date in the Gulf [24]. Although 88% of recovered MPs were found in the sludge fraction, the 12% in wastewater could, when extrapolated for length of time and flow rate, release 1.2×10^8 MPs day⁻¹ into the Gulf [24].

The presence of MPs in resident aquatic biota has also received attention, with commercial fish species and edible shellfish being

investigated for the ingestion of MPs [e.g. [25–28]]. All studies reported the presence of MPs in animal tissue and levels were consistent with those reported in other regions of the world. The average ingestion of MPs from the consumption of seafood was estimated at five MPs per day from one study [26] and from another study, based upon an adult eating a weekly portion of 300 g of fish, 169–555 MPs could be ingested depending on the fish species [29].

Amongst the riparian States of the Gulf, researchers in Iran have produced the greatest number of scientific articles within English language peer reviewed journals, typically publishing in a subset of journals from the fields of environmental science and marine pollution [e.g., [19–21,23–27]]. Fewer studies have originated from Oman [e.g., [17]], Qatar [e.g., [15,16]], UAE [e.g., [22]] and Kuwait [e.g. [18,28]], but there is still some data available on the presence and abundance of MPs. To date there is a single study quantifying MP pollution in Iraq which was conducted along the Euphrates River [30]. At the time of writing and to the author's best knowledge, no published literature is available for Saudi Arabia or Bahrain. Thus, although valuable information is emerging from the Gulf regarding the prevalence of MPs, knowledge gaps persist relating to national coverage and, as with many regions of the world, more information is needed about the sources of plastic pollution. This latter information is required to devise and prioritise mitigation strategies.

2.2. Plastic waste generation and management in the Arabian/Persian Gulf region

Land-based activities and associated plastic waste management have previously been tied to the presence of plastic debris in the ocean [31]. Rivers have been identified as an important carrier of plastic waste generated in inland communities to the marine environment [32,33]. Whilst rivers provide a point source for pollution, the transfer of plastic waste from land to sea may also occur diffusely via groundwater, surface run-off, rainfall or wind [34]. Of the 8 million MT of plastic debris estimated to enter the ocean in 2010, the Arabian/Persian Gulf countries contributed 76,900 MT, representing only 0.97% of the global input. This small contribution is likely driven by the smaller relative population, which represents 1.25% of the global coastal population in 2010. Nonetheless, the mean per capita mismanaged plastic waste rate in the region is twice that of global high-income (HIC) countries (i.e., 0.02 kg/day vs. 0.01 kg/day, respectively) despite six of the eight Gulf countries being considered to belong to this high income classification [2].

Based upon reported values in Kaza et al. [2], 58 million MT of municipal solid waste (MSW) were generated in 2016 within the Arabian/Persian Gulf region, of which 5.9 million MT were plastic waste. Per capita waste generation rates in the region range from 0.6 to 1.8 kg per day, with a daily average of 1.3 kg, nearly double the global average rate of 0.74 kg per person per day. The fraction of plastic in the waste stream among the Gulf countries varies widely from 5.3% in Iraq to 21% in Oman, with an average of 13%, close to the global average of 12%. Iraq, Bahrain, and Iran have the smallest fractions of plastic in the waste stream at 5.3%, 7.4%, and 8.5% respectively [2]. Income level is a predictor of plastic consumption, however, in this case, Bahrain has a particularly low rate. HICs in the Gulf generally have a larger proportion of plastic in the waste stream, with an average of 15%, compared to an average of 6.9% plastic in Iran and Iraq [2]. This would suggest that efforts targeting reduction in plastic use and waste generation in the HIC countries in the region may influence quantities leaked into the environment.

Arabian/Persian Gulf countries report markedly high levels of waste collection, with four out of eight countries reporting 100% collection. Although collection rates are high, open dumping is prevalent among countries in the region, with it being the primary mode of disposal for Iran, Iraq, Kuwait, Oman, Qatar, and the UAE. Open dumping is the deposition of solid waste on the surface, ground, or water as the primary

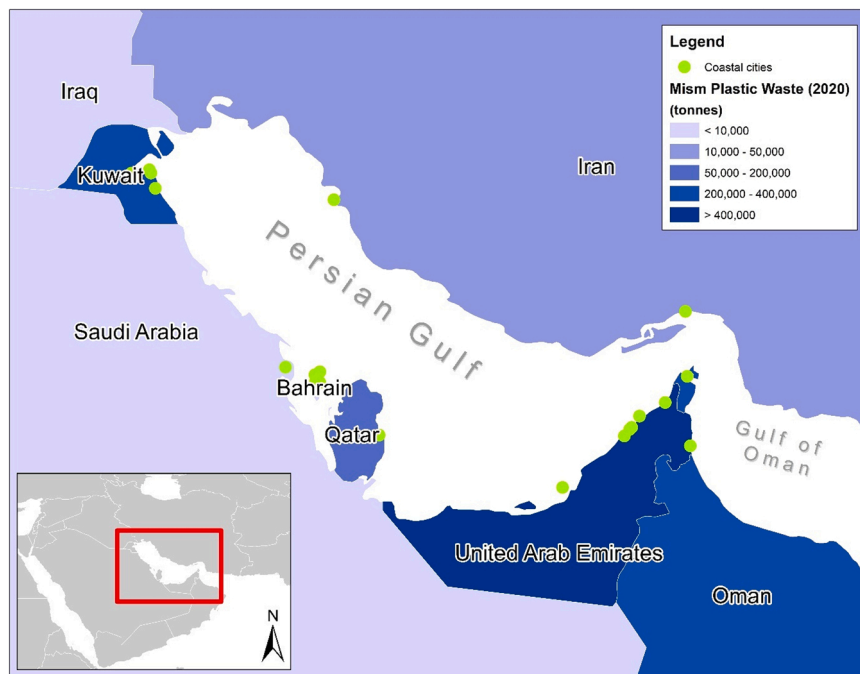


Fig. 1. Estimated mismanaged plastic waste by country in the Arabian/Persian Gulf in 2020.

waste treatment method. This dichotomy may derive from a socio-technical disconnection, where the innate desire to remove waste is structurally and economically supported but is met with lacking technical infrastructure to manage it properly. Although this challenge may be recognised at the national scale, efforts are being made sub-nationally to improve the treatment of waste through methods such as waste-to-energy, composting, and recycling, particularly in countries of the Gulf Cooperation Council (GCC) [2]. Although the UAE report high levels of open dumping, the country also reports the highest rate of recycling in the region at 20%. Bahrain and Saudi Arabia report high levels of management via controlled landfills (92% and 85%, respectively).

To inform policy and decision making for improving waste management infrastructure and capturing mismanaged plastic waste that could be deposited in the marine environment, the quantities of plastic waste being generated and mismanaged within coastal communities along the Arabian/Persian Gulf were estimated using the most recent data from the World Bank [2]. This data indicates that 1.6 million MT of plastic waste was generated by coastal populations of the Arabian/Persian Gulf in 2020 (see Fig. 1). Within the region, an estimated 1.31 million MT were managed inadequately (i.e., open dumping) and 19,000 tonnes were littered, resulting in a total 1.33 million MT of mismanaged plastic waste available to enter the ocean from coastal Arabian/Persian Gulf in 2020. Because open dumping is the prevalent treatment method in the region, this mismanaged quantity represents 82% of the total plastic waste generated. Based on the mid-range estimate reflecting 25% of the mismanaged plastic waste [[2]; [Supplementary materials](#)] an estimated 132–532 thousand MT of land-based plastic waste entered the Arabian/Persian Gulf in 2020. Under business-as-usual conditions this will likely increase along with population growth. By country, the UAE had the highest quantity of plastic waste generated and mismanaged contributing to 34% of the regional total for mismanaged plastic waste. However, if normalised by coastal population, Kuwait had the highest per capita mismanaged plastic waste rate at 0.31 kg per day. In contrast, Bahrain and Saudi Arabia had the lowest per capita mismanaged plastic waste rate at < 0.01 kg per day, which was driven by their high rates of waste managed via controlled landfills. [Table S1](#) provides a summary overview of waste estimates by

country in 2020.

National and sub-national efforts in the Arabian/Persian Gulf countries targeting improved plastic waste management systems are underway. For instance, nearly all countries in the region except for Iran and Iraq have some sort of national legislation targeting single-use plastic bags. The UAE and Saudi Arabia have national legislation that regulates plastic bag consumption through restrictions like thickness thresholds, while Qatar has a national law requiring recycling of plastic bags plastic waste and litter reduction [35]. Effective as of January 1st, 2020, Kuwait similarly banned single use plastics on board Kuwaiti ships and foreign ships at port or place in Kuwait [36]. While it is imperative that plastic waste is properly managed throughout the coasts and the nations in the Arabian/Persian Gulf, it may be strategic to target interventions toward urban areas with dense human activity located within the coastal region of the Persian Gulf. In addition, rural areas lacking infrastructure can generate higher rates of litter ending up in the environment [37,38]. Although many plastic products are imported from other regions of the world, waste generation inherently occurs at the local level, requiring localised socio-technical infrastructure systems for managing waste. For example, the Omniya Recycling project headquartered in Kuwait City [39] aims to increase education and improve collection of PET bottles for recycling, with collection points located in 70 locations throughout the country. The Emirate of Abu Dhabi, the capital city region and second most populated emirate located on the coast of the Arabian/Persian Gulf in the UAE, has recently established ambitious efforts toward waste management and plastic pollution. Under the UAE Federal Law No. (12) of 2018 on Integrated Waste Management, there have been key developments toward improved collection and treatment of waste and efforts to implement the circular economy, extended producer responsibility, and reduction in consumption of single-use products [40]. Abu Dhabi manages most MSW via open dumping (59.8%), but has increasingly implemented and invested in advanced waste treatment systems [41]. In March of 2020, the Emirate released an ambitious and comprehensive Single Use Plastic Policy. The policy details a comprehensive approach to reduce single-use plastic consumption and waste generation through policy tools such as a sub-national, emirate-wide ban on plastic bags in 2021, collecting data on plastic in the waste stream and leaked debris in terrestrial and aquatic environments, and

declaring the Abu Dhabi emirate government single-use plastic free in 2021 [42]. Efforts to implement the policies and address compliance of the policy has since been delayed due to COVID-19 [43]. Fig. 1 below shows coastal mismanaged plastic waste by country as well as locations of key cities in the Arabian/Persian Gulf.

3. Existing measures to address marine plastic debris

When recommending and developing adequate measures to address plastic waste in the region, it is appropriate to first consider the applicable regulatory framework relating to plastic marine debris in the Gulf region. Regulatory and policy instruments may drive and influence plastic marine debris recommendations. Given that marine plastic debris transcends national boundaries, international and regional public laws provide appropriate frameworks for an initial analysis. Lyons et al. [8] proposed a governance and legal framework that primarily dealt with actions on a national level. Arguably, however, a regional regulatory framework greater takes into consideration the transboundary nature of marine debris. The analysis in this study indicates that there is a fragmentation of international and regional regulatory obligations in the region, stemming from different commitments and indeed obligations to comply with (marine) environmental protection instruments.

Some countries in the region have recently collaborated in the development of international and regional measures. For example, Saudi Arabia as a member of the Group of Twenty (G20) hosted the Riyadh Summit in 2020 and dedicated its presidency to addressing plastic pollution [44]. Also, during the recently convened (September 2021) Ministerial Conference on Marine Litter and Plastic Pollution [45], the following governments of the region sent delegates to contribute to the deliberations: Bahrain (delegates came from the Supreme Council of the Environment), Oman (Environment Authority), Qatar (delegates came from the Ministry of Municipality and Environment), Kuwait (delegates came from the Environment Public Authority). The deliberations to establish an Intergovernmental Negotiation Committee may provide an opportunity within the region to develop a regional strategy.

3.1. Applicable international regulations

Given the primary impact of marine debris on the marine environment, the United Nations Convention on the Law of the Sea (UNCLOS) [46] is a suitable starting point for an analysis of the regulatory framework in the Gulf region. UNCLOS serves as an overarching international legal framework and law by stipulating environmental-protection clauses relating to ocean-based and land-based sources of marine pollution and establishing a fundamental marine environmental protection framework. Art. 192 UNCLOS sets out the general obligation that States must “protect and preserve the marine environment”. This extends to all maritime zones and all activities undertaken in the maritime area [47]. Art. 194 UNCLOS specifically requires that measures taken shall include, inter alia, “those designed to minimise to the fullest possible extent the release of toxic, harmful or noxious substances, especially those which are persistent, from land-based sources, from or through the atmosphere or by dumping” [46]. All riparian states except Iran and United Arab Emirates have signed and ratified UNCLOS and are therefore bound by it [48]. Iran and the UAE Emirates have signed, but not ratified the Convention and are therefore not bound by its provisions. They are, however, required to adhere to such norms that reach the threshold of customary international law. In relation to the protection of the marine environment, the obligation to protect and preserve the marine environment as stipulated in Art. 192 UNCLOS is considered to constitute customary international law [49]. Iran and UAE are therefore under the obligation to exercise due diligence in ensuring the protection of the marine environment. It remains to be determined what such a due diligence requirement fully entails in this context. Overall, this means that a patchwork regime might prevail regarding differing rights and obligations relating to

protecting the marine environment from plastic pollution.

3.2. Addressing the major sources of marine debris

3.2.1. Regulatory framework of sea-based sources of marine debris in the Gulf

The International Maritime Organization (IMO) addresses sea-based pollution, and several conventions have been adopted that are relevant to the issue of marine debris. The International Convention for the Prevention of Pollution from Ships (MARPOL) [50] stipulates a general obligation to prevent the pollution of the marine environment by the discharge of harmful substances or effluents from ships. MARPOL Annex V specifically addresses pollution from garbage by vessels and is the only global instrument addressing a point source of marine debris [50], Art.1]. Although MARPOL Annex V forms an integral part of the MARPOL Convention, its status as an “optional annex” indicates that States may opt not to ratify it. All the littoral States of the Arabian/Persian Gulf have ratified MARPOL Annex V and are therefore bound to implement its obligations [52]. This is particularly pertinent to the protection standard of the Arabian/Persian Gulf vis-à-vis vessel source marine debris pollution as this is a key instrument to prevent plastic pollution from shipping.

The specific approach and protection standard of MARPOL Annex V is based on four themes: discharge standards, operational requirements, port reception facilities as well as Port State Control (PSC) requirements. Generally, the disposal of all garbage is prohibited [50].

The Arabian/Persian Gulf is subject to a specific protection standard under MARPOL Annex V in that the area is a designated Special Area under Annex V [53]. The area-based requirements of the MARPOL Annex V obligations came into effect on 1 August 2008 [53] and since then the Gulf's Area enjoys a high environmental protection standard#. The implementation of Special-Area status is based on two requirements: increased discharge standards applicable to the region as well as the provision of adequate port reception facilities along the coast designed to receive specific materials, in this case ship-generated waste [50]. This implies that there are incentives in place to land the onboard generated waste in the ports as well as concrete and measurable enforcement parameters to be verified by harbour police and PSC agents. The obligation extends to all 155 countries (98.49% of the world's gross tonnage) which have ratified MARPOL Annex V [51] and therefore vessels flying the flag of any of these countries are obliged to adhere to the protection standards.

With regard to enforcement of MARPOL Annex V obligations, the Riyadh Memorandum of Understanding (Riyadh MoU) is relevant in the Gulf Area [54]. The Riyadh MoU contains a commitment by the maritime authorities of the six signatories (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and UAE) to develop a harmonised system of PSC measures and to enable information exchange (section 1.4 Riyadh MoU). Adequate monitoring and enforcement mechanisms are provided for in the form of inspections. In 2019, PSC officers of the Riyadh MoU authorities performed 3207 inspections. During these inspections, 38 deficiencies regarding MARPOL Annex V infringements were found, making up 1.40% of all deficiencies ascertained [54]. Due to its designation as a MARPOL Annex V Special Area, the Gulf hence enjoys, in principle, a high environmental protection standard with a view to marine debris arising as a result of shipping activities,

With regard to the dumping of waste, which might lead to marine debris, global environmental protection standards are established through two international agreements: the London Convention (LC) [55] and the associated London Protocol (LP) [56]. The London Convention has been in force since 1975 and aims to control all sources of marine pollution, with the goal of preventing pollution of the sea through regulation of dumping of waste materials into the sea. In 1996, Contracting Parties to the London Convention adopted the London Protocol with a view to bringing the Convention in line with modern waste-management approaches and emerging principles of international

Table 1
Overview of the applicable regulatory framework regarding marine debris.

	Approach	Framework	Potential application to the Arabian/Persian Gulf region	Ratification
International Regulatory Framework	Sea-based sources of marine debris	UNCLOS	Overall regulatory framework relating to any sea-based activity, not all countries have ratified UNCLOS	Bahrain (1985), Iraq (1985), Oman (1989), Kuwait (1986), Qatar (2002), Saudi Arabia (1996)
		MARPOL 73/78 Annex V	Discharge prohibition of onboard generated waste, Persian Gulf and Gulf of Oman Special Area under Annex V, all countries have ratified this instrument, Riyadh Memorandum of Understanding	Bahrain (1991), Iran (2003), Iraq (2018), Oman (1988), Kuwait (2007) Qatar (2006), Saudi Arabia (2005), United Arab Emirates (2007),
		1972 London Convention and 1996 London Protocol	Depending on instrument, different dumping standards prevail, waste assessment guidelines exist, very fragmented status of ratification = patchwork regime	LC: Iran (1997), Oman (1984) and UAE (1975)
Regional Regulatory Framework and/or Policy Framework	Land-based sources of marine debris	UNCLOS GPA	Overall regulatory framework related to land-based activities GPA not legally binding, provides an umbrella framework for land-based activities with relevance to marine debris	LP: Iran (2016) and Saudi Arabia (2006) UNCLOS: See above.
		ROPME	Mandate to address land-and sea-based sources of marine debris	Bahrain, Iraq, Iran, Kuwait, Oman, Qatar Saudi Arabia and UAE
		GCC	General Principles of Environment Protection, Joint Environmental Actions envisaged, limited to GCC members	Bahrain, Oman, Kuwait, Qatar, Saudi Arabia, UAE

Sources [46,50–52,60,61].

environmental law [57]. The LC pursues a listing approach, which establishes a dumping prohibition for all substances listed in Annex I and allows, in principle, for all substances listed in Annex II to be dumped [55]. The LP applies a more restrictive approach in that it applies a reverse listing approach prohibiting dumping in general, exempting those materials explicitly permitted.

Considerable divergence remains among the littoral States around the Gulf with regard to ratifying both agreements. The result is a patchwork of different legal obligations: Bahrain, Iraq, Kuwait, and Qatar have ratified neither the LC nor LP [52] and are therefore not bound by LC and LP protection standards to the extent that these do not reflect customary international law. Oman and the United Arab Emirates have ratified the LC but not the LP and Saudi Arabia and Iran are both parties to the LP [47]. Concerning the prevention of marine waste, ratifying the LP provides several benefits. As only Annex I substances may be dumped after a permit process, the permitting State ensures control over substances dumped at a particular location, thereby enabling a framework for resource efficiency. A related issue that may be of particular relevance in the region is the practice of placing artificial reefs in the Gulf area. The displacement or fragmentation of these reefs may contribute to the overall marine debris problem [58]. In 2009, Contracting Parties of the LP and LC as well as Member States of the UN Environment Programme developed Guidelines for the Placement of Artificial Reefs to address concerns that the placement of these reefs could legitimise the dumping of waste that would usually be non-permissible, a practice which has also been planned in the Arabian/Persian/Gulf area [58].

3.2.2. Applicable regional regulatory framework

In addition to these partially applicable and diverse universal regulatory measures, a further avenue that could prove effective in the avoidance of introduction of pollutants into the marine environment or to mitigate their effects is to leverage coordination through pre-existing regional seas programmes. For the Arabian/Persian Gulf, the responsible organisation is the Regional Organization for the Protection of the Marine Environment (ROPME), as established by the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (the Kuwait Convention) [59]. Iran, Saudi Arabia, Iraq, Kuwait, Qatar, Oman, and the UAE are Contracting Parties to the Convention. In its preamble, the Kuwait Convention outlines the “need to ensure that the processes of urban and rural development and resultant land use should be carried out in such a manner as to preserve, as far as possible, marine resources and coastal amenities” [59].

The Convention also recognises the need to develop “an integrated management approach to the use of the marine environment and the coastal areas which will allow the achievement of environmental and

developmental goals in a harmonious manner” as well as “the need for a carefully planned research, monitoring and assessment programme” [59]. In general, all Contracting Parties shall individually or jointly, take all appropriate measures to prevent, abate and combat pollution of the marine environment. The Kuwait Convention sets out obligations relating to pollution from shipping, dumping, land-based sources and other human activities, clearly following an integrated approach to address anthropogenic pressures [59]. With a view to substantiating the obligations from the Kuwait Convention, several protocols have been adopted [60]. All except one of the Protocols necessitates additional signatures and ratification by the Contracting Parties. Whereas the Kuwait Convention appears to have highly relevant obligation in place, its work on plastic marine debris has been very limited.

Actions carried out under the umbrella of regional cooperation related to plastic marine debris need to include both sea- and land-based activities. This facilitates targeted national action plans as well as addressing both the urban and rural environment already outlined as concerns in Section 2.2 above.

Another regional actor with the potential to influence the question of plastic marine debris, is the Cooperation Council for the Arab States of the Gulf (GCC), a trading bloc comprising of the Bahrain, Kuwait, Oman, Qatar, Saudi Arabia as well as the UAE [61], although it should be noted that this body does not cover the entirety of littoral states. It aims at enhancing the coordination, cooperation and integration between [the member states] in all fields. This includes a “joint environmental action for converging policies, unifying environmental laws and legislation, enhancing national and regional capacities, training of labour force, raising environmental awareness among citizens and conservation of natural resources” [61] (Table 1).

4. Opportunities and recommendations

4.1. Cooperation towards a regional action plan on marine debris through existing mechanisms

Given its scope, ROPME in collaboration with GCC, could provide an ideal coordination platform to further intensify regional cooperation regarding marine debris. As already established and/or underway in different regions in the world [62], the development of Regional Action Plans on Marine Debris allow for tailor-made prioritisation and development of actions. The development of a Regional Action Plan on Marine Debris for the Arabian/Persian Gulf could be an important cooperation mechanism to integrate disparate challenges in a coordinated manner.

ROPME could also serve as a clearing-house mechanism for scientific (plastic) marine debris-related information in the region, based on the

Table 2
Outline of opportunities and obstacles for regional actions to address marine debris.

Opportunities	Obstacles	Recommendations
<p>Regional cooperation: Regional cooperation mechanisms through ROPME to expand monitoring and assessment aspects of plastic pollution as well as coordinated management responses</p>	<p>Missing political will to develop specific targets to address marine plastic pollution through multilateral actions, either through ROPME in collaboration with GCC.</p>	<p>Use momentum under the current efforts to develop an International Treaty on Plastic Waste and the Marine Environment as well as efforts to develop regional action plans on marine debris.</p>
<p>Address knowledge gaps in the spatial and temporal prevalence of plastics Research is currently conducted in on an ad-hoc basis with individual studies conducted in different locations and environmental compartments.</p>	<p>Individual studies are not coordinated to provide a complete picture of plastic pollution in the region</p>	<p>The need for a continuous environmental monitoring programme that encompasses water, sediment and biota sampling at a number of repeated sites. The UN Decade of Ocean Science and corresponding regional and national activities might be an opportunity to advance on this.</p>
<p>Improve comparability between studies The use of different methodologies hinders the comparability between studies.</p>	<p>The issue of standardisation and harmonisation of plastic and microplastics research is of concern in the field and thus not limited to the Gulf region.</p>	<p>International recommendations are emergent for best practices in both the analysis and reporting of plastic and microplastic prevalences. Once agree these need to be adopted widely in the region.</p>
<p>Address mismanaged waste: High potential to address mismanaged waste, among other due to open dumping.</p>	<p>Missing capacity and infrastructure, current legislative framework focuses mainly on linear waste disposal, limited information on waste and circular economy</p>	<p>Infrastructure, legislative framework and strategies need to be put in place to mitigate mismanaged waste, inventory of data</p>
<p>Focusing on hot spots: Urban areas or rural with lack of infrastructure. Urban areas should be targeted areas of interventions regarding mismanaged waste and circular economy. Rural areas without any infrastructure may also have higher contributions.</p>	<p>Predominant waste management in several countries is open dumping. Waste generation inherently occurs at the local level, requiring localised socio-technical infrastructure systems for managing waste.</p>	<p>Provide socio-technical infrastructure systems and scaling up of already existing projects as outlined in Section 2.1.</p>
<p>Involvement of business and industry: Develop regional responses and incentives to promote circular economy and prevention of waste by all sectors, through among others: sharing best practices, plastic consumption and reduction targets based on modelling above.</p>	<p>Current plans and project mainly focused on specific regions and /or sectors within the Gulf region. Economies of scale. Limited effectiveness of compliance and enforcement.</p>	<p>Through improvement of solid waste management, business opportunities may relate to material recovery and waste-to-energy facilities [64] Inclusion of industrial companies as well as small and local business to take into account the localised waste generation.</p>

shared structure and framework of already existing regional actions plans. Within the regulatory framework of ROPME, the Protocol for the Protection of the Marine Environment Against Pollution from Land-Based Sources could be used as the legal basis to adopt such a regional action plan. The Protocol addresses land-based sources, in particular pollution from rivers, outfalls, and pipelines, fixed or mobile offshore facilities for any other use except the exploration and exploitation of the

seabed, its subsoil and the continental shelf as well as any other land-based sources, be it through water, the atmosphere or directly from the coast [\[60\]](#). To that end, Annex III to the Protocol provides provisions for guidelines, regulations and permits for the release of waste. Regional Regulations with associated programmes, measures and timetables should be developed for land-based waste [\[60\]](#). These actions could be closely developed in cooperation with the GCC states and responsible ministries.

4.2. Developing a regional marine litter action plan

Opportunities and Recommendations As plastic marine debris is transboundary, cooperation among countries both within and among sectors that are likely to create plastic marine debris is needed, as well as among researchers and scientists. Societal, economic and environmental axes of collaboration are all essential [\[8\]](#). Opportunities to act on the reduction of marine debris are both direct and indirect. In addition to the impacts for ecosystems and potentially also human health, marine debris pollution has a strong economic dimension which clearly transcends a simple classification as a “marine” problem [\[63\]](#). Therefore, a regional action plan should include actions taken by key business sectors and industry in collaboration with actions taken by government or academia. These efforts may be tied with other regional processes and initiatives undertaken currently ([Table 2](#)).

If an action plan were to be developed, it could be administered by a cooperative platform established regionally so that the proposed responses are coordinated, and then regular meetings ensure continued collaborative implementation. Admittedly, the opportunities identified here go beyond government intervention extending to the important role of both civil society, non-governmental organisations and business, including the plastics industry. A regional action plan could also establish drivers to address resource efficiency and create value for plastic, such as recycling or plastic consumption targets. This could be established based on best available data, including bans of specific marine debris items that are known to occur most frequently and cause the highest impacts. Studies of debris that are more localised, but regionally and globally comparative, provide meaningful context for local decision-makers where solid waste management most often occurs [\[38\]](#).

Addressing marine debris is also closely related to the move to sustainable consumption and production patterns. Every country needs to take action to create enabling conditions to advance towards this aim based on their country-specific socio-economic circumstances. Looking ahead to the prediction of the enormous growth of plastic production, businesses need to play a key role, providing leadership and sharing best practices. The use of market-based instruments and access to finance and investments could be first steps in catalysing business sector actions. In addition, for legal obligations, the role of compliance and enforcement is an important factor in ensuring the achievement of environmental objectives.

5. Conclusions

There is currently uncoordinated action in the Arabian/Persian Gulf on marine plastic debris, and this synergistic article found that there are opportunities to collaborate. It has been found that, in 2020, an estimated 1.33 Mt or 82% of the total amount of plastic waste generated was mismanaged, of which 25% likely entered the marine environment. An overview of the scientific literature indicates that research on marine debris in the Arabian/Persian Gulf has been increasing recently, but data on impacts and distribution, as well as longer term monitoring in the Gulf are still lacking. An initial analysis of international and regional law indicates that a patchwork regime of various legal obligations of the riparian states exist, and some treaties, agreements and one mechanism for cooperation are already in place. While these have had some impact, the approach to date has been piecemeal and without any collaborative

strategic aims. Similar to approaches taking in other geographies, the adoption of a regional action plan is suggested. Besides the obligations related to the implementation of international agreements, this synergistic study recommends new commitments relating to infrastructure development and monitoring, including mapping and target setting of marine plastic debris sources and distribution in the Gulf Region.

CRedit authorship contribution statement

Aleke Stöfen-O'Brien: Conceptualization, Investigation, Validation, Writing – review & editing. **Abolfazl Naji:** Investigation, Validation, Writing – review & editing. **Amy L. Brooks:** Methodology, Investigation, Validation, Data curation, Writing – review & editing. **Jenna R. Jambeck:** Methodology, Investigation, Validation, Data curation, Writing – review & editing. **Farhan R. Khan:** Conceptualization, Investigation, Validation, Writing – review & editing.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.marpol.2021.104909](https://doi.org/10.1016/j.marpol.2021.104909).

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Glossary

- GCC*: Cooperation Council for the Arab States of the Gulf
GPA: Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
HIC: High Income Countries
ICJ: International Court of Justice
LC: London Convention Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter
LP: London Protocol Protocol to the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter
MARPOL: International Convention for the Prevention of Pollution from Ships
MP: Microplastic
MT: Metric Ton
PSC: Port State Control
Riyadh MoU: Riyadh Memorandum of Understanding
ROPME: Regional Organization for the Protection of the Marine Environment
UAE: United Arab Emirates
UNCLOS: United Nations Convention on the Law of the Sea
UNEP: United Nations Environment Programme