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Economic Cooperation

Best Practices and Recommended Policies for Optimising the Plastic Supply Chain in Southeast and East Asia

APEC Ocean and Fisheries Working Group

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Produced by

Professor Dr Wan Izatul Asma Wan Talaat, FASc
Institute of Oceanography (INOS), Universiti Malaysia Terengganu

Professor Dato' Dr Aileen Tan Shau Hwai, FASc
Centre for Marine and Coastal Studies (CEMACS), Universiti Sains Malaysia

Professor Datuk Dr Ahmad Fauzi Ismail, FASc
Advanced Membrane Technology Research Centre (AMTEC), Universiti Teknologi Malaysia

Professor Dato' Dr Ahmad Bin Ibrahim, FASc
Tan Sri Omar Abdul Rahman Centre for Science, Technology and Innovation (STI) Policy Studies, UCSI University

Professor Ts. Dr Mohd Hafiz Dzarfan B. Othman.
Advanced Membrane Technology Research Centre (AMTEC), Universiti Teknologi Malaysia

Associate Professor Dr Eric Chan Wei Chiang
APEC Sustainable Coastal Cities Research Consortium, UCSI University

Associate Professor Ts Dr Goh Pei Sean
Advanced Membrane Technology Research Centre (AMTEC), Universiti Teknologi Malaysia

Associate Professor ChM Dr Poh Seng Chee
Faculty of Science and Marine Environment, Universiti Malaysia Terengganu

Dr Farahdilah Ghazali
Institute of Oceanography (INOS), Universiti Malaysia Terengganu

Cheryl Rita Kaur
Centre for Straits of Malacca, Maritime Institute of Malaysia (MIMA)

For
Asia Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

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Scientific committee

Assistant Professor Dr. Chew Yik Ling
Faculty of Pharmaceutical Sciences, UCSI University.

Associate Professor Dr. Wong Chen Wai
Faculty of Applied Science, UCSI University.

Assistant Professor Ts. Dr. Tan Mei Ching
Faculty of Engineering Technology & Built Environment, UCSI University

Dr. Lai Li Sze
Faculty of Engineering Technology & Built Environment, UCSI University

Symposium Speakers and Moderators

Opening

YB Dato' Sri Dr. Adham Bin Baba
Ministry of Science, Technology and Innovation (MOSTI), Malaysia

Professor Datuk Ir. Ts. Dr. Siti Hamisah Binti Tapsir
UCSI University, Malaysia

Associate Professor Dr Eric Chan Wei Chiang
UCSI University, Malaysia

Issues and Challenges on Marine Debris faced by APEC Cities

Professor Dato' Dr. Ahmad Bin Ibrahim, FASc
UCSI University, Malaysia

Nur 'Aishah Binti Md Norodin
Penang State Secretariat, Malaysia

Cheryl Rita Kaur
Maritime Institute of Malaysia (MIMA)

Best Practices in Addressing Marine Debris

Dr Nguyen Thu Trang
World Wildlife Fund (WWF), Viet Nam

Dr Mohammed Rizman Idid
Universiti Malaya, Malaysia

Lena Kampe
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany

Hery Gunawan Daulay
Ministry of Marine Affairs and Fisheries, Indonesia

Role of Non-Governmental and Community Engagement in Addressing Marine Debris

Professor Dr Shigeyuki Baba
International Society for Mangrove Ecosystems (ISME), Japan

Dr Abdhesh Kumar Gangwar
Regional Centre of Expertise (RCE) Srinagar, India

Hao Xin
Green Zhejiang, China

Dr Lin Yola
Universitas Indonesia, Indonesia

Shantini Rajan
World Wildlife Fund (WWF), Malaysia

Role of Public-Private Partnership in Addressing Marine Debris

Jacqueline Chang
Circular Economy Institute, Malaysia

Cheng Hsiu Tsai (Damon)
Plastics Industry Development Center (PIDC), Chinese Taipei

Seah Kian Hoe
Heng Hiap Industries (HHI), Malaysia

Saltanat M Kazi
The Energy and Resources Institute, India

Professor Dr Richard Bellerby
SKLEC-NIVA Centre for Marine and Coastal Research, China

Dr Raslan Ahmad
Malaysia Industry-Government Group for Higher Technology (MIGHT), Malaysia

Technology and Innovation for Sustainable Coastal Cities

Dr Chia-Ying Jessie Ko
National Taiwan University, Chinese Taipei

Dr Chao Fang
Ministry of Natural Resources, China

Associate Professor, Dr Goh Pei Sean
Universiti Teknologi Malaysia

Dr Kuit Sui Hyang (Vivian)
Blue Communities, Malaysia

Professor, Ts. Dr. Mohd Hafiz Dzarfan Othman
Universiti Teknologi Malaysia

Professor Dr Mohd Razman bin Salim
UCSI University, Malaysia

Dr Rinny Rahmania
Ministry of Marine Affairs and Fisheries (MMAF), Indonesia

Professor Dr Thamarat Koottatep
Asian Institute of Technology (AIT), Thailand

Associate Professor Dr Matthew Tan
Asia of Assentoft Aqua Asia Pte Ltd., Singapore

Closing

Professor Datuk Dr. Asma binti Ismail
Akademi Sains Malaysia (ASM)

Focus group participants

Senior Professor Dr. Phang Siew Moi, FASc (UCSI University)

Professor Dr Che Abd Rahim Mohamed (Universiti Kebangsaan Malaysia)

Professor Dr Lim Phaik Eem (Universiti Malaya)

Professor Dr Mohd Razman Bin Salim (UCSI University)

Professor Dr Sumiani Binti Yusoff (Universiti Malaya)

Professor Dr Yeong Siew Wei (UCSI University)

Professor Dr Thamarat Koottatep (Asian Institute of Technology)

Professor Ir Dr Suzana Yusup (Universiti Teknologi PETRONAS)

Associate Professor Dr Chia-Ying Ko (National Taiwan University)

Associate Professor Dr Juhana Jaafar (Universiti Teknologi Malaysia)

Associate Professor Dr Jun Bo (Third Institute of Oceanography)

Associate Professor Dr Norhaniza binti Yusof (Universiti Teknologi Malaysia)

Associate Professor Dr Yim Hip Seng (UCSI University)

Assistant Professor Dr Michelle Soo Oi Yoon (UCSI University)

Dato' Paduka Ir Dr Keizrul Abdullah (Wetlands International Malaysia)

Ts Dr Chung Ying Tao (UCSI University)

Ts Dr Ng Jing Lin (UCSI University)

Dr Chung Ying Tao (UCSI University)

Dr Hasrinah Hasbullah (Universiti Teknologi Malaysia)

Dr Jian-Wu Lai (National Academy of Marine Research, Chinese Taipei)

Dr Lai Li Sze (UCSI University)

Dr Lin Yola (Universitas Indonesia)

Dr Mazlan Madon (University of Oxford)

Dr Ng Fong Lee (Universiti Malaya)

Dr Nur Haliza Hassan (UCSI University)

Dr Tran Thi Ngoc Diep (RCE Southern Vietnam)

Amira Aqilah Shaidin (Akademi Sains Malaysia)

Daniel Loo (Malaysian Recycling Alliance)

Faisal Abdur Rani (Impact Revolution Enterprise)

Hoang Nhat Truong (RCE Southern Vietnam)

Jacqueline Chang (Circular Economy Institute)

Lee Kwai Han (generaSEED)

Min Zhang (Third Institute of Oceanography)

Mukvinder Sandhu (UCSI University)

Naventhan a/l Ahrasan (Penang Green Council)

Nor Aslinda Awang (National Hydraulic Research Institute Malaysia)

Pauline Goh (Malaysian Recycling Alliance)

Rinny Rahmania (Ministry of Marine Affairs and Fisheries, Indonesia)

Shamili Nair A/P Ravindran Nair (Universiti Malaya)

Tan Thung (Penang Green Council)

Wong Fen Thong (Penang Green Council)

Executive Summary

Marine debris, including plastic litter in the marine environment, is a global and multidisciplinary challenge. This report highlights successful policies and good practices within the context of the APEC Roadmap on Marine Debris launched in 2019. The recommendations and highlights of this report are follows:

1. Policy Development and Coordination
   - Clear and consistent policies are the key drivers for implementation.
   - Inter-agency coordination and clear jurisdiction can further accelerate implementation.
   - Policies support strategies and promote knowledge sharing.

2. Capacity Building
   - Capacity building must be supported by behavioural change and infrastructure
   - Segregation at source is still the most important driver for recycling
   - Waste collection in many APEC economies is supported by informal waste collectors
   - Banning waste imports would not compel more recycling or promote segregation
   - Long-term solutions involve improving existing supply chains.
   - There is commercial interest in pyrolysis to convert non-recyclable plastics into fuel
   - Different APEC Economies have unique solutions to local challenges such as infrastructure, accessibility, and plastic hotspots.

3. Research and Innovation
   - Science-based and data driven decision making empowered by research on plastic distribution and monitoring are important
   - Co-production and citizen science promotes resource sharing, collaboration technology uptake
   - Waste management in remote islands require specialized technologies
   - Technologies to remove microplastics from water are not widespread and microplastics can promote biofouling
   - Artificial intelligence (AI)-precision technology offers opportunities for reduced leakage and improved segregation

Information for this report was collected from the APEC Sustainable Coastal Cities Symposium, which was held from 24 to 26 November 2021 to ascertain the local situation with marine debris in APEC Economies. Engaged stakeholders and participants included government agencies, non-governmental agencies, industry and academia from12 APEC Economies and two non-member Economies. The report was compiled by a team of senior academics well versed in the issue of marine debris and its challenges.

Challenges

Marine debris, including plastic litter in the marine environment, is an increasing global challenge in need of a cooperative response. The severity of the marine debris problem is particularly acute in the Asia-Pacific Economic Cooperation (APEC) region, underscoring APEC's strategic role in driving initiatives on finding solutions to this particular problem. APEC's important position as a regional forum to facilitate the discourse on marine debris and in developing the required management and prevention approaches to mitigate its impediments to sustainable economic growth in the Asia-Pacific is undeniably crucial.

Plastic is estimated to account for 80% of all marine debris in the oceans. Therefore, the majority of marine debris can be addressed through plastic value chains (IUCN, 2018). The issues around single -use plastic is significant due to its high consumption, generating huge amounts of waste after a relatively short lifespan. Yet, there is notable absence of a systematic and integrated response to guide regional actions in addressing the issue of marine plastic pollution, thus impeding upon national efforts to tackle the problem.

Background

Marine debris is a global and multidisciplinary challenge. A well-known study by Jambeck et al. (2015) listed many APEC Economies as being among the top 20 contributors to mismanaged Plastic Waste, including China, Indonesia, Philippines, Viet Nam, Thailand, Malaysia and even the United States. Marine debris such as microplastic, bring adverse effects to human health as well as to food security and safety (Barboza et al. 2018). Microplastics contamination has been reported in food items such as seafood, table salt and drinking water (Zhang et al. 2020). Despite the urgent need to address these harmful impacts, issues such as separation at source and the quality of imported plastic wastes have remain unresolved. Thus, besides assessing their potential health and environmental risks, the exploration of innovative analytical tools and effective separation methods are also important to address the alarming current issues.

International and Regional Measures

Several non-legally binding international frameworks have been outlined in the Southeast Asia region to address marine pollution, including the 2030 Agenda for Sustainable Development and Sustainable Development Goal (SDG) 14 on life below water (UNEP 2019). According to the recently released ASEAN Regional Action Plan on Combating Marine Debris 2021-2025, more policy efforts are needed to look into various aspects of single-use plastic items, including examining the root causes that have engendered the culture and habit of using disposable items (ASEAN 2021). This Regional Plan of Action (RPOA) calls for a systematic and integrated response to guide regional actions in relation to marine plastic pollution, which is to be followed with national action plans by the individual ASEAN Member States (AMS).

In recent years, international organisations have revised trade standards and multilateral environment agreements to take into account the growing trade in waste, including the amendment to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The 14th meeting of the Conference of the Parties to the Basel Convention (COP-14), held from 29 April to 10 May 2019, adopted amendments to Annexes II, VIII and IX to the Basel Convention with the objectives of enhancing the control of the transboundary movements of plastic waste and clarifying the scope of the Convention as it applies to such waste (Uhm 2020). This recent amendment that enters into force starting in January 2021 empowers countries to stop the import of plastic waste (ASEAN 2021).

According to the UN Environment Programme (UNEP), the amendment to Annex VIII of the Basel Convention involved insertion of a new entry A3210, which clarifies the scope of plastic wastes presumed to be hazardous and are therefore subject to the Prior Informed Consent (PIC) procedure. The amendment to Annex IX, with a new entry B3011 replacing the existing entry B3010, clarifies the types of plastic wastes that are presumed to be not hazardous and, as such, not subject to the PIC procedure.

Wastes listed in entry B3011 include: -

1. A group of cured resins, non-halogenated and fluorinated polymers (provided the waste is destined for recycling in an environmentally sound manner and almost free from contamination and other types of wastes).
2. Mixtures of plastic wastes consisting of polyethylene (PE), polypropylene (PP) or polyethylene terephthalate (PET) – (provided they are destined for separate recycling of each material in an environmentally sound manner and almost free from contamination and other types of wastes).

The third amendment is the insertion of a new entry Y48 in Annex II which covers plastic waste, including mixtures of such wastes, unless these are hazardous (as they would fall under A3210) or presumed to not be hazardous (as they would fall under B3011).

Since China's restriction on waste imports, many countries in Asia have followed suit, including in several AMS, many of which are also APEC Economies (Wang et al. 2019). For example, Viet Nam limited plastic scrap imports by strengthening inspection standards (only 'clean' plastic scrap with less than 2 percent impurity can be imported) and limited the issuance of plastic waste import licenses. Similarly, Malaysia recently returned 42 shipping containers of illegally imported plastic waste to the UK, sending a clear message that Malaysia does not want to become the dumpsite for foreign plastic waste. There is a need for the coordination of regional efforts in addressing the plastic waste trade to align with the above amendments to Annexes II, VIII and IX to the Basel Convention.

APEC Measures

The APEC Roadmap on Marine Debris, which was launched during the Third Senior Officials' Meeting in Puerto Varas, Chile on 29-30 August 2019, aims to encourage member economies to take voluntary and concrete steps while taking into account their respective internal circumstances. In view of the APEC Roadmap being seen as a living document, the APEC Sustainable Coastal Cities Symposium invited stakeholders from all 21 APEC Economies to discuss on technologies and policies that are necessary for the persistence and sustainability of coastal cities into the next century. Many of the APEC Economies from the East and Southeast Asian region responded to the call for speakers as they view marine debris as a major priority. With the region being a major contributor to marine debris, accounting for 60% of mismanaged plastics, this Symposium sought to address the problem and the impact of plastic pollution on the marine environment (Jambeck et al. 2015).

This is also in line with the APEC Oceans and Fisheries Working Group (OFWG)'s mission to promote institutional capacity building in a regional setting, advancing discussions on solutions for the protection of marine ecosystems. The Symposium would serve as a policy dialogue to prepare an APEC publication on sustainable city planning policies and as a capacity building platform. Public officials and representatives from non-governmental organisations (NGO), civil society organisations (CSO) and small-medium enterprises (SME) from economies which are less successful at managing their plastic waste, would be engaged and would able to learn from best practices of other APEC Economies.

The Symposium responds to the 2020 APEC Malaysia's call to 'Optimise Human Potential towards a Future of Shared Prosperity.' By inviting stakeholders comprising senior public officials, policy makers, researchers, recyclers, manufacturers and plastic waste importers, the Symposium supports all three priorities announced by Malaysia, namely:

1. Promoting human resources and society through the empowerment of local communities.
2. Sharing prosperity through reduced reliance on petroleum-based plastics.
3. Protecting the future by reducing plastic debris which threaten the marine ecosystem.

Based on the APEC principles of consensus, non-binding voluntary participation, cooperation and flexibility as well as taking into account APEC Economies' diverse policy objectives and priorities and domestic laws and regulations, the APEC Sustainable Coastal Cities Symposium began its deliberations with the following three pre-symposium focus group sessions: -

1. Government policies towards addressing marine debris on 3 September 2021.
2. Non-governmental initiatives and practices for addressing marine debris on 10 Sept 2021.
3. Innovation and technologies for addressing marine debris on 17 September 2021.

The Symposium on 24-26 November 2021 started with a public officials' forum, where government officials and people involved with policy from various think tanks shared current policies and best practices on marine debris. This was followed by a stakeholder meeting which also included representatives from NGOs and private companies, who shed the light on current and future efforts to alleviate marine debris. On the third day, academics converged to share information on current research and technologies related to marine debris at the Inauguration of the APEC Sustainable Coastal Cities Research Consortium.

Policy Development and Coordination

Recommendations and highlights:

1. Clear and consistent policies are the key drivers for implementation.
2. Inter-agency coordination and clear jurisdiction can further accelerate implementation.
3. Policies support strategies and promote knowledge sharing.

Clear and Consistent Policies

Marine debris come from land-based sources that include personal care products (microbeads), textiles (synthetic fibre) and retail (packaging). However, sea-based sources from aquaculture and fishing are also significant contributors. Policies addressing marine debris must therefore also address leakage of plastics from both land and sea-based sources, the reduction of plastics in circulation, recycling and the recovery of plastics from the oceans.

The APEC Sustainable Coastal Cities Symposium was held from 24 to 26 November 2021 to ascertain the local situation with marine debris in APEC Economies. Engaged stakeholders from government agencies, non-governmental agencies, the industry, and academia from 12 APEC Economies and two non-member Economies participated. Focus group discussions were held earlier in September of the same year for a more in-depth discussion with stakeholders. The majority of the stakeholders engaged were from the East and Southeast Asian APEC, where marine debris challenges are more pertinent (Figure 1).

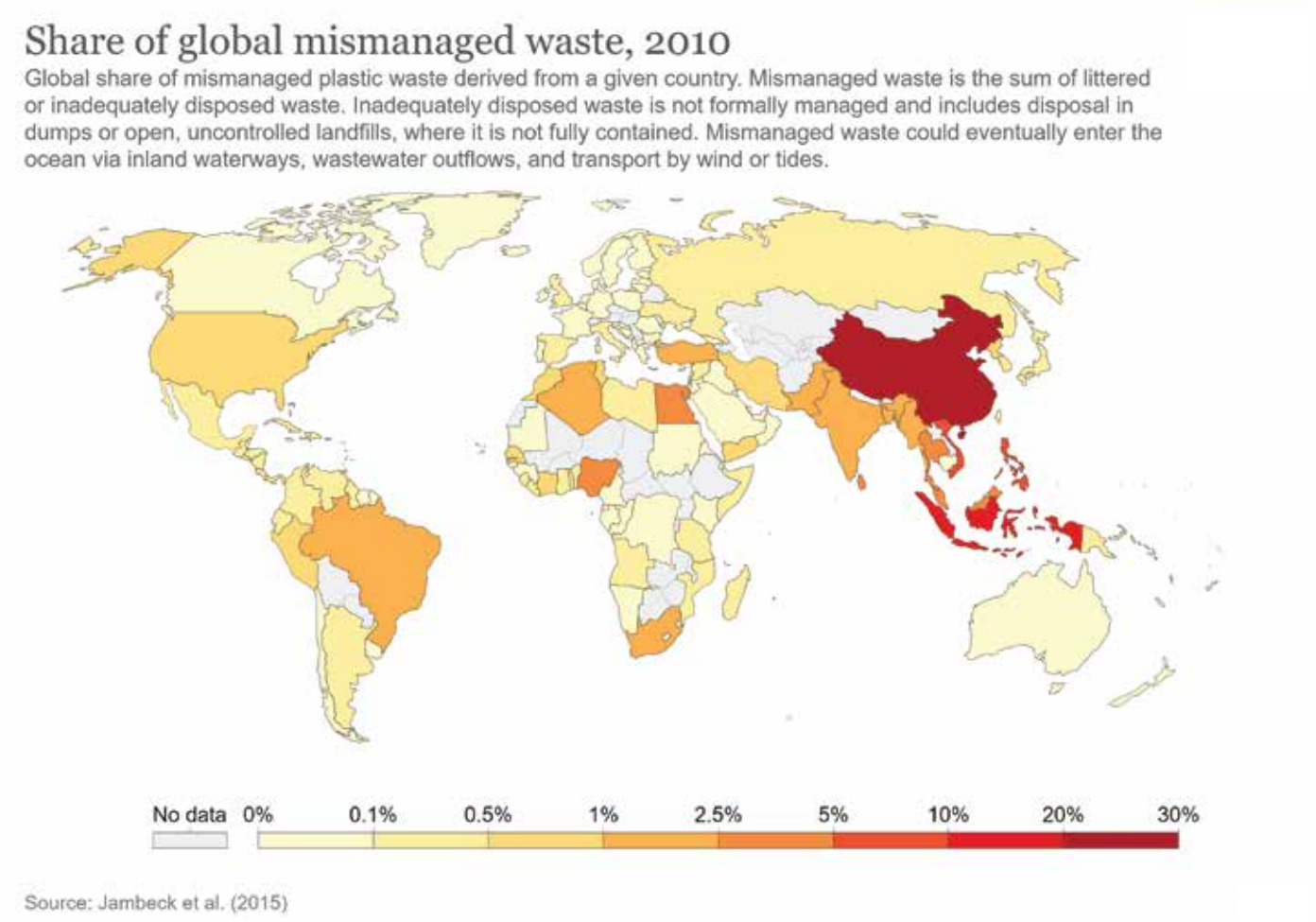

Figure 1: Share of Global Mismanaged Waste, 2010 (Jambeck et al. 2015)

A prevailing theme raised by stakeholders, especially those from governmental and non-governmental agencies, was that clear policies are important as they clarify the national agenda, enabling better cooperation. Clarity and consistency are crucial because marine debris is a transboundary issue with large quantities of debris adrift in international waters beyond the 200 nautical miles of coasts. Furthermore, policies help guide government funding and private sector investments.

The most effective national policies are those which reduce the circulation of plastic such as Malaysia's Roadmap Towards Zero Single-Use Plastics. Other APEC Economies such as China and Chinese Taipei, have implemented Extended Producer Responsibility (EPR) policies. There are currently very few policies in relation to the removal of marine debris from the ocean, but several have been implemented in recent years. These include the buyback programmes and Fishing-For-Litter projects carried out by several APEC Economies to incentivise fishermen not to discard used fishing gear and to deposit hauled marine debris at proper waste management facilities.

Malaysia's Roadmap Towards Zero Single-Use Plastics was gazetted in 2018 because there was previously no uniform approach to address single-use plastics. The framework outlines several measures such as the replacement of shopping bags with biodegradable alternatives, levying tax on plastic manufacturers and developing rapid test kits for identifying biodegradable plastics.

EPR, despite its success in some APEC Economies, has also been a challenge to implement in others. These include not only difficulty in properly assigning responsibility, but also its possible impact on the livelihood of informal waste collectors. A good EPR implementation would include an infrastructure plan, a recycling value chain and a material flow analysis. Such measures would ensure that the EPR supports informal waste collectors and facilitates the transition to a more formal waste collection. A clear recycling value chain would promote entrepreneurship among waste collectors and allow manufacturers to properly plan supply chains for utilising waste plastics.

The buyback and clean fisheries programmes have seen successes in Korea and Japan as an integral part of the UNEP Northwest Pacific Action Plan (NOWPAP) on Marine Litter. The Clean Fishery Communities Programme incentivises fishermen not to discard shipborne waste into the ocean and provides facilities at convenient onshore locations (UNEP 2008). The buyback programme and Fishing-For-Litter project give a clear monetary incentive for depositing old fishing gear and haul up marine debris respectively.

Inter-agency Coordination

Marine debris circulating in the oceans mostly comprise plastics from inland sources. The collection and recycling of waste in most APEC Economies are handled by municipal councils and private companies. However, the jurisdiction of waste that is already circulating in the environment is much less clear. There are departments with the mandate to manage forests and fisheries but these usually do not have jurisdiction over waste.

Clear policies are necessary to promote sustainable waste management as well as the reduction and prevention of leakage of waste from land and sea-based sources, at all levels of government including, different jurisdictions and coordination with non-governmental agencies. These policies would identify broad areas to facilitate coordination and collaboration. The APEC Roadmap on Marine Debris published in 2019 has clearly defined the broad areas of Policy Coordination, Capacity Building, Innovation and Financing. The newly published National Marine Litter Policy and Action Plan of Malaysia has five pillars, as shown in Figure 2 (KASA 2021).

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Figure 2: Five pillars of Malaysia's National Marine Litter Policy

Other APEC Economies and regional coordinating agencies such as ASEAN, have also devised similar action plans with different emphasis reflecting the local situation, such as managing marine debris on small islands. Regional action plans by coordinating bodies and APEC Economies discussed during the Symposium included:

Coordinating Bodies Action Plans

1. ASEAN Regional Action Plan
2. SIWI Source-to-Sea Framework for Marine Litter Prevention

APEC Economies Action Plans

1. Law Number 11 of 2020 concerning Job Creation (Indonesia)
2. Law Number 27 of 2007 concerning Management of Coastal Areas and Small Islands as amended by Law Number 1 of 2014 concerning Amendment of Law Number 27 of 2007 in relation to the Management of Coastal Areas and Small Islands (Indonesia)
3. Presidential Regulation No. 121 of 2012 concerning the Rehabilitation of Coastal Areas and Small Islands (Indonesia)
4. Presidential Decree No. 83/2018 on Marine Debris Handling (Plan of Action on Marine Plastic Debris 2017-2025) (Indonesia)
5. Government Regulation No. 27 of 2021 concerning the Implementation of the Maritime Affairs and Fisheries Sector (Indonesia)
6. Sanmen County Government Action Plan (China)

The Sanmen County Government Action Plan implemented by China attempts to tackle the issue of jurisdiction directly with the implementation of a multi-co-governance system, integrating urban and rural areas, as summarised in Table 1. This involves appointing top officials as a 'Bay Chief' who are empowered to take steps to control pollution, restore degraded ecosystem and monitor the health of a predefined coastline. This would include clear the division of labour and responsibilities as well as facilitate collaborative efforts between different stakeholders. Similar 'Bay Chief' systems have also been implemented in other localities such as Hainan Island.

Table 1: Sanmen County Government Action Plan (China)

Policies	**Action**
Implementation Measures on Further Strengthening the Treatment of Plastic Pollution	By the end of 2025, a multi-co-governance system integrating urban and rural areas will be formed and plastic pollution will be effectively controlled.
Sanmen County 'Zero Waste City' Construction Implementation Plan (2020-2021)	In 2021, the construction of a 'Zero Waste City' within the county will be completed.
Sanmen County Implementation Plan of the 'Bay Chief System'	In 2021, the construction of a 'Zero Waste City' within the county will be completed.
	Establish and improve the 'Bay Chief System' long-term management mechanism with clear division of labour, responsibilities, orderly collaboration and efficient operation.
Sanmen County Ship Pollution Control Action Plan	Reduce pollution risks, pollution emissions and improve emergency response capabilities to solve the county's ship pollution problems.

Policies Supporting Knowledge Sharing

Shared and mutual learning can take place between the various APEC Economies, given their unique individual local conditions. This is in line with the APEC Roadmap on Marine Debris which encourages the use of available scientific information for the development of policies. Some pertinent observations of policies that successfully promote knowledge sharing include policies which:

1. Focus on supply and demand, using market driven forces to promote adoption.
2. Promote entrepreneurship by private stakeholders.
3. Provide platforms for networking and interaction.

Malaysia's new National Marine Litter Policy and Action Plan also include provisions for supporting knowledge sharing. These include organising expert exchange platforms and establishing an information platform for education and promoting innovative solutions. Mechanisms for implementing such platforms were also described, which included Massive Open Online Courses (MOOCs) in multiple languages on topics related to nature-based solutions, closing the loop, EPR toolbox and promoting circular economy. This boosts networking and interaction between experts and stakeholders, empowering private stakeholders to initiate new ventures.

A similar knowledge sharing platform has also been established for the East and Southeast Asia regions, some of which are funded by external parties such as the European Union ECESP (2021). One such platform, Rethinking Plastics, was set up as a cooperation between the EU and seven economies in East and Southeast Asia supporting circular economy transition, waste reduction and leakage reduction. The platform established more than 20 pilot projects in China, Indonesia, the Philippines, Thailand and Viet Nam to test new approaches or scale up best practices.

In another similar collaboration, the World Wildlife Fund (WWF) teamed up with Eurocities to establish the Plastic Smart Cities initiative (WWF 2018), another knowledge sharing platform on plastics, where stakeholders work collectively towards a vision of a Plastic Free Ocean. The Expert Review Panel comprises the world's premiere experts in their respective fields to review actions and practices to be collated on the platform. It has three core activities: to educate, motivate and mandate, the latter of which is to promote regulatory changes.

Pilot projects from such collaborations are a worthwhile investment as they have improved infrastructure. The practices learned from such projects have also been incorporated into policy. This is highlighted in Viet Nam's National Strategy for Integrated Solid Waste Management which advocates technical solutions, technical exchange and technical cooperation (ASEMConnect 2017). Viet Nam's national strategy is a comprehensive document outlining the Economy's strategy to have waste collected, reused and recycled using advanced and environmentally friendly technologies by 2050.

2. Capacity Building

Recommendations and Highlights:

1. Capacity building must be supported by behavioural change and infrastructure
2. Segregation at source is still the most important driver for recycling.
3. Waste collection in many APEC economies is supported by informal waste collectors
4. Banning waste imports would not compel more recycling or promote segregation
5. Long-term solutions involve improving existing supply chains.
6. There is commercial interest in pyrolysis to convert non-recyclable plastics into fuel
7. Different APEC Economies have unique solutions to local challenges such as infrastructure, accessibility, and plastic hotspots.

Behavioural Change

Capacity building must be supported by behavioural change which is highly influenced or determined by social norms. Education plays a pivotal role. Teachers and their interaction with students have a big role to play in normalising behaviours which promote segregation at source and recycling. Some examples of such efforts include the WWF teacher's handbook and classroom activities on 'Oceans and Plastics Pollution'. In line with this effort, the WWF is also securing recycling pledges. Such pledges have been shown to normalise recycling by harnessing the power of individual choice.

Infrastructure-wise the ease of recycling and availability of infrastructure heavily influences recycling behaviour. The Clean Fishery Communities Programme of the UNEP NOWPAP is an example of this, harnessing volunteerism instead of using enforcement (UNEP 2008). Convenient onshore facilities are set up for fishermen to deposit waste that would otherwise be discarded into the sea and this has been shown to promote volunteerism. Even the recycling bin has a role to play. The use of different shaped bin openings promotes segregation and accordingly, standardised bins provide recognisability and assurance that the segregated waste would indeed be recycled.

Clean-up activities are short-term solutions and often cannot bring about a lasting change. Nonetheless, these activities are important for education and raising awareness. APEC economies such as Indonesia and China have invested heavily in such activities with their Gerakan Cinta Laut and National Beach Clean-up Activity, respectively. Both are linked up with infrastructure development and long-term waste reduction initiatives. Inevitably, clean-up activities serve to promote awareness and cultivate public support for longer term initiatives.

Gerakan Cinta Laut or the Ocean Care Movement in Indonesia was initiated in 2002 which was expanded in 2017 to involve new programmes such as beach clean-ups and gazetting Sekolah Pantai or Coastal Schools (KKP 2002; KKP 2017). The movement has since expanded to conduct beach clean-up in 29 locations. It has also carried out school awareness building activities and establish eco-friendly fishing ports with proper waste treatment facilities and R&D activities.

In China, the National Beach Clean-up Activity is an important national agenda which was also initiated in 2017 by the China Oceanic Development Foundation, working together with NGOs like Green Zhejiang and RCE Hangzhou (Arong et al. 2017). This initiative was implemented on a grand scale over China's large coastline and tied in together with other waste reduction activities.

Segregation at Source

Figure 3: Marine debris accumulated on a beach on Iriomote Island
(Source: International Society for Mangrove Ecosystems 2020)

Local clean-up activities with enough support from companies and the local community can also evolve into something bigger. Japan's Iriomote Island Eco Project, a monthly beach clean-up activity organised by the local tourism association gathers on average 5,000 litres of plastic monthly from which the Styrofoam is segregated and sent to Hatoma Island for conversion into fuel (Iriomote Island Eco Tourism Association 2021). In 2020, over 60,000 litres of plastic were collected. Consistent collection activities can evolve into a local industry. It is possible to create a consistent supply chain of waste plastics for recycling and conversion to fuel, but it is also a grim reminder of how much debris accumulates on shores daily (Figure 3; Figure 4). Similarly, China cha been conducting its National Beach Clean-up Activity, engaging 50,000 participants from more than 100 cities over a 20,000 km long coastline.

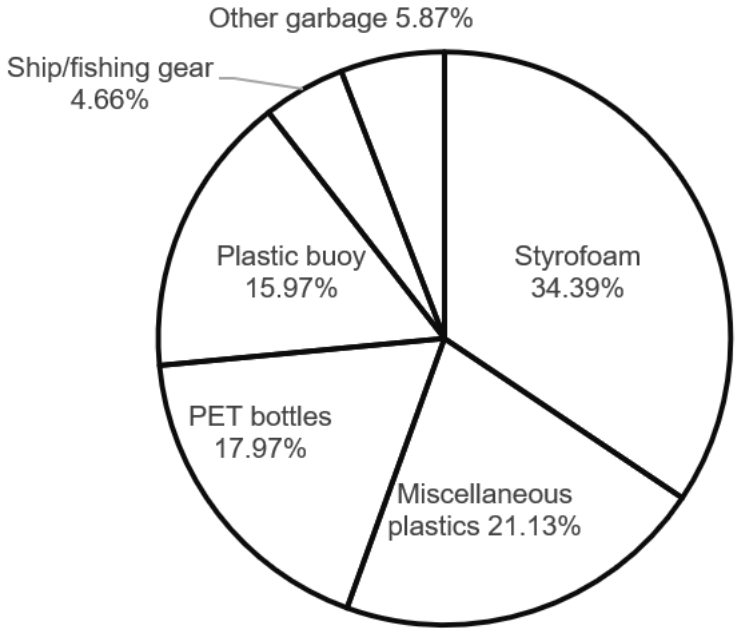

Figure 4: Breakdown of plastics collected by the Iriomote Island Eco Project. PET bottles are easily recyclable and Styrofoam, which forms the largest category, is converted into green diesel
(Source: Iriomote Island Ecotourism Association 2021)

Informal waste collection

Segregation is important to aggregate plastics into commercially viable quantities for recycling. Many APEC economies rely on informal waste collectors that are often highly skilled at collecting waste with high commercial value. Waste is skilfully sorted, cleaned and compacted for transport to recycling facilities. This creates a conundrum for low value plastics and difficult-to-recycle plastics such as shopping bags. Low value plastics make up about 80% of plastic waste collected in Viet Nam, China, Indonesia, Thailand and the Philippines (UNEP 2019).

Banning waste imports

Banning waste imports would not compel more recycling or promote segregation. Recyclers importing waste plastics to meet demand is often symptomatic of inadequate support for informal collectors, whether it is from the perspective of lack of recognition or inadequate infrastructure. Normalising the import of waste runs contrary to promoting behavioural changes for recycling. This creates very negative optics, prompting policy makers to ban or limit the amount of waste imported. However, banning or limiting waste plastic imports does not solve the supply and demand issue.

Circularisation of Supply Chains

Long-term solutions involve improving existing supply chains. In some cases, changes can occur organically but for many others, governments have to intervene in the form of policies, regulations and direct investment. The Sanmen County Government Action Plan in China is one such undertaking, where plans to create a 'Zero Waste City' promote collaboration between government agencies and private stakeholders are being implemented. Similarly, Rethink Plastics, a project supporting the transition towards circular economy for plastics in East and Southeast Asia, receives its funding from the European Union and the German Government.

To promote changes to supply chains, the Rethink Plastics project focuses on reducing single-use plastics whilst encouraging sustainable consumption and production. Initiatives of the project include:

1. Regional guide on how to promote reusable packaging in food delivery and takeaways.
2. Elaboration of a voluntary guideline on reducing single-use plastic in Thailand.
3. Webinars and workshops on phasing out single-use plastics.
4. Mapping of stakeholders along the plastic bag value chain in Indonesia.

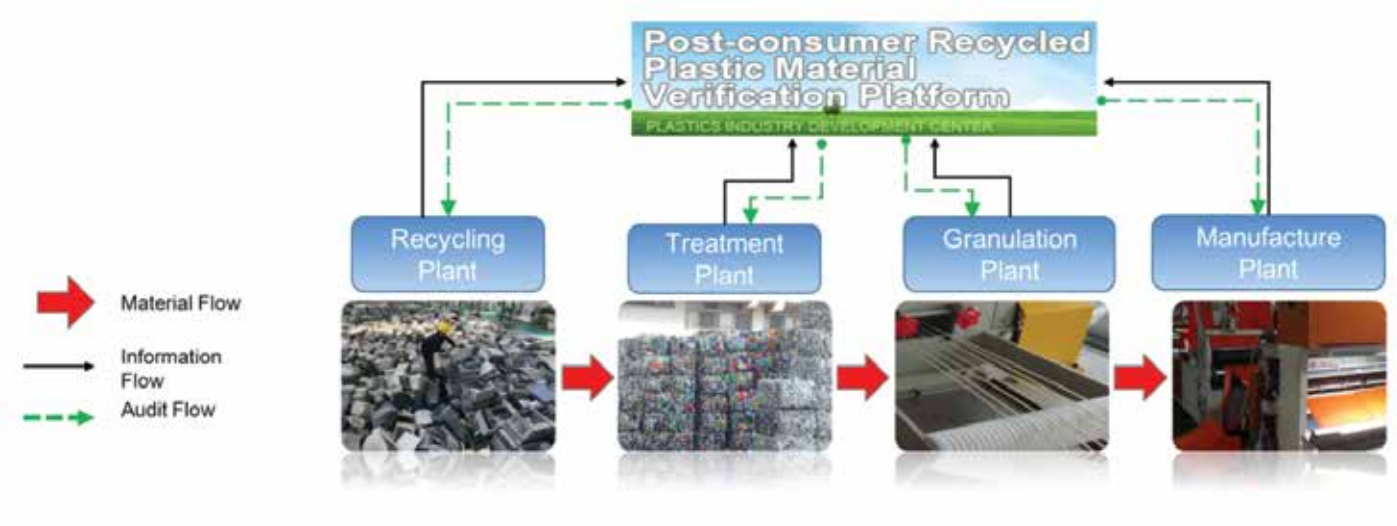

Figure 5: Part of Chinese Taipei's Marine Debris Management platform
(Source: Plastics Industry Development Centre 2021)

Chinese Taipei is also developing a Marine Debris Management Platform which would encourage public-private partnership in reducing plastic use, prevent plastic leakage and facilitate the removal of plastic from the sea (Figure 5). Where possible, plastics are replaced with biodegradable alternatives. Recovered plastic marine debris is also segregated, given a value and introduced into circulation. The Ocean Plastic Coalition was also established with several local companies to create a new supply chain which converts recovered fishing nets into eyeglass frames for brands like Decathlon and Julbo (Figure 6).

Figure 6: Circular economy supply chain for converting fishnets into sunglasses
(Source: Plastics Industry Development Centre 2021)

In Malaysia, private stakeholders are making big investments into developing products from recycled plastics. Heng Hiap Industries Sdn. Bhd, a leading Malaysian plastic recycling company that transforms ocean bound plastic waste into manufacturable materials, is the first in the world to receive the Ocean Bound Plastic certification. They convert waste plastics into usable resins that are comparable to newly manufactured plastics via their Plashaus product line.

Fuel from non-recyclable plastics

Non-recyclable plastics can be burned down, which is a much better alternative than dumping them in landfills. There is a growing interest by companies in pyrolysis technologies for converting plastics into liquid fuel. Liquid fuel conversion has the advantage of it being usable in diesel gensets as compared to being directly incinerated for generating electricity. Many rural and isolated locales still rely on gensets for electrification.

In Malaysia, Heng Hiap Industries produces green diesel from the pyrolysis of non-recyclable plastics, in addition to their recycled plastic resins. In Japan, pyrolysis pilot projects have been established on Tsushima and Hatoma islands in the Nagasaki and Okinawa prefecture, respectively. The latter works with the Iriomote Island Eco Project to produce fuel from Styrofoam. Establishing such facilities on islands is strategic as it improves local access, while many boats still rely on diesel gensets for electricity.

Adaptation to Local Challenges

It is apparent that each APEC Economy faces unique local challenges and subsequently, has been developing specific solutions with regards to marine debris. Indonesia and Japan both face access issues to waste management facilities since the majority of their population reside on islands. Indonesia is in the process of testing ship borne incinerators to efficiently dispose of collected plastics. Japan, on the other hand, is creating a logistic network with waste management facilities on strategically located islands.

Indonesia and Viet Nam which have a large informal waste collection sector are investing to improve its efficiency and the livelihood of waste collectors. This would be useful for locales with limited access to infrastructure. Malaysia is promoting upcycling and banning single-use plastics in certain localities. It is hoped that such measures would spur private companies into creating new circular supply chains.

Beyond just supply chains, coastal towns and cities are under constant threat of sea-level rise. Engineering solutions can sometimes aggravate existing issues with marine debris. This is especially true for island populations. Informal settlements are sometimes built over the sea such as those in Palembang and a number of other places. A survey conducted by Universitas Indonesia showed that in Palembang, 52.47% of informal settlements were built on water. Houses built on jetties often trap debris on their stilts and waste collection is difficult to administer whilst the infrastructure is insufficient.

Similarly, the giant sea wall of northern Jakarta was constructed as part of the Indonesia National Capital Integrated Coastal Development (NCICD) to prevent erosion. The NCICD's giant seawall is built in the form of the mythical Garuda bird with large lagoons created to buffer the outflow from the 13 rivers in Jakarta. It is also part of a plan to boost local infrastructure, land value and investments. However, recent research has shown that plastics are accumulating in the lagoons.

Plastic hotspots such as the Palembang settlements and NCICD's giant seawall are both a problem as well as an opportunity. Accumulated plastics are no longer circulating in the ocean and engineering

3. Research and Innovation

Recommendations and Highlights:

1. Science-based and data driven decision making empowered by research on plastic distribution and monitoring are important
2. Co-production and citizen science promotes resource sharing, collaboration technology uptake
3. Waste management in remote islands require specialized technologies
4. Technologies to remove microplastics from water are not widespread and microplastics can promote biofouling
5. Artificial intelligence (AI)-precision technology offers opportunities for reduced leakage and improved segregation

Science-based and Data-driven Decision Making

Science-based and data-driven decision making is important, given the large geographic coverage of marine debris. The full scale of the problem is well beyond the jurisdiction of local municipal councils. Data is required to provide information on marine debris distribution, microplastic prevalence and scientific information for setting acceptable limits of microplastics in water. Therefore, data is important, and the APEC Roadmap on Marine Debris encourages two specific priorities, namely:

1. Encourage the use of available scientific information for the development of policies.
2. Promote research to identify policy drivers of marine debris and promote the development and implementation of innovative solutions.

Marine debris is weathered overtime into microplastics and these have been found in the Artic and within benthic organisms based on research undertaken by China's Second and Third Institute of Oceanography in collaboration with the National Marine Environmental Monitoring Center (Fang et al. 2018). Perhaps, most surprisingly is the finding of recent studies indicating that microplastics can change gene expression, thus altering the transcriptome of marine organisms.

Microplastics have a negative impact on embryogenesis and modulate the immune response of the marine medaka Oryzias melastigma (Chen et al. 2020). Other fish species may also be similarly affected and this could have long-term impact on the viability of fisheries. Climate change is already changing species interaction, which in turn affects the sensitivity and robustness of the fishery populations. How this would affect commercially important fish species is still an area of active investigation.

Plastic pollution in many areas is seasonal as ocean currents change. Many APEC Economies are investing into research which track the drifting of plastics in the sea. The Indonesian government is undertaking a study using GPS drifters to determine how plastic flows and accumulates in the oceans. Researchers from Chinese Taipei proposed an Integrated Marine Debris Observing System which uses UAV in combination with drifters to track plastic drifts in the sea (Liau et al. 2020). It was found that drifting trajectory is greatly affected by ocean currents and asymmetrical geometries of the drifters increase the uncertainty of drifting trajectory. Wind effects can also affect the drifting trajectory which is often overlooked.

Co-production and Citizen Science

Co-production and citizen science promote resource sharing and collaboration. This is of relevance to data collection and technology uptake. Co-production is a form of knowledge production based on the dynamic interaction between technology and society where technical experts and other groups come together with their different ways of viewing and analysing the world and, in the process, generate new knowledge and technologies. Citizen science, also called crowd science, is scientific research conducted, in whole or in part, by non-professional scientists. It can be described as public participation in scientific research.

Despite efforts to study the distribution of marine debris and the resulting microplastics, data is still lacking in many localities. Co-production and citizen science can help fill the gap. Blue Communities based in Southeast Asia is a research capacity building programme which supports the development, implementation and management of initiatives that promote sustainable utilisation and protection of marine ecosystems. It is a citizen science agency focused on academic-stakeholder collaborations, community co-creation and co-delivery. The International Seakeepers Society engage yacht owners to assist with data collection and environment education. Co-production allowed Norwegian researchers to collaborate with fish farmers to collect seawater samples in the vicinity of fish farms, an endeavour that would have otherwise been impossible.

Technologies such as biodegradable plastics are not universally applicable but engaging plastic manufacturers and recyclers as co-producers can improve technology uptake. Biodegradable plastics may hinder segregation and recycling efforts and waste to fuel pyrolysis may be a better alternative for mixed plastic. In Malaysia, Heng Hiap Industries Sdn. Bhd. is taking the lead as a plastic recycler as well as a waste-to-energy producer.

Waste Management on Remote Islands

Similarly, waste management on remote islands require specialised technologies. Japan harnesses its well-established infrastructure to create a logistic network where waste is transported to island-based facilities, from which plastics can be recycled, incinerated or converted into fuel. Notable examples include the Tsushima and Hatoma island pyrolysis pilot projects (Ishida 2020). Indonesia, on its part, is developing incinerator vessels for the disposal of plastic waste on remote islands. This is a better solution for localities where the infrastructure is insufficient for a reliable logistic network.

Removal of microplastics from water

Reverse osmosis can reliably remove microplastics. Coastal population including those on islands also rely on reverse osmosis for desalination. However, microplastics can promote bacterial growth and biofouling of membranes (Xiong et al. 2021). The stimulation of microbial activity by microplastic contributes to membrane fouling in ultrafiltration (Journal of Membrane Science, 635, 119477.). Microplastics have also been reported to stimulate microbial activity which increases extracellular polymeric substances (EPS) which would in turn promote biofouling. This would necessitate better screening and ultrafiltration techniques. Surface modification of filtration membranes to reduce fouling and enhance microplastic rejection are among the active areas of research.

Opportunities Offered by AI-precision Technology

AI-precision technology could pave the way forward by promoting behavioural change that favours plastic segregation, thus reducing the plastic footprint of aquaculture. Klean Malaysia Sdn Bhd uses reverse vending machines to encourage consumers to deposit used plastic packaging. An AI algorithm is used to screen deposited plastics to determine if it is recyclable. Combined with and incentivisation platform, this could be used to promote segregation by consumers.

Similarly, the aquaculture and fishery industries are big contributors to marine debris. Here, AI-precision technology would allow the creation of smart urban aquaculture farms that are resource and space efficient. Such farms would have a much smaller plastic footprint compared to sea-based farms and leakage of plastics can be totally prevented. Being resource efficient, such farms would also stave off global food shortage which is projected to occur in year 2050 when world population is projected to reach 9.1 billion. This means that the world would be requiring an estimated 70% increase in food production (FAO 2009).

Recommendations

The overall recommendations of this report can be summarised as follows:

1. Establishing a coordinating body to facilitate the implementation of policies and inter-agency coordination has shown to be effective in some APEC Economies.
2. Awareness, adequate infrastructure and commercial interests are important driving forces in promoting behavioural change and improving supply chains.
3. Co-production of science promotes resource sharing to fill the gaps in data related to the distribution and effects of microplastics. Co-production of technology promotes the uptake of technology by engaging private companies in the developments.

Conclusion

The present report provides a snapshot of the current status of good policies and practice related to marine debris in the midst of the COVID-19 pandemic. While the pandemic itself did not substantially change practice with regards to solid waste, adaptations to other challenges such as sea-level rise and coastal erosion did create new obstacles. Coastal walls built over the sea surface have been able to trap substantial amounts of marine debris.

Some of the most surprising topics discussed during the Symposium which is presented in this report was that microplastics can bioaccumulate in benthic organisms and alter gene expression. These changes were sufficient to affect embryogenesis and modulate the immune response of at least one finfish species. The impact of microplastics on fisheries is no longer experimental.

Furthermore, many of the technologies that were presented were very much dependent on local situations. Incinerator vessels may be a good waste management strategy for populations dispersed over many small islands with poor infrastructure, while a good logistics network for waste management for island populations with good infrastructure will work for the latter. Other technologies such as reverse vending machines and AI-precision urban aquaculture are also better suited for areas with good infrastructure and good internet access.

This goes to show that science and data-based policies are important in relation to their varied roles in identifying marine debris hotspots, seasonal distribution of marine debris or waste management strategies relevant to the local contexts. Policies promote good practices and collaboration which can, over time, change behaviour. Co-production of scientific data and policies with stakeholders can help fill the gaps in data and the engagement would promote technology uptake.

Lasting impact on the present marine debris situation would require behavioural change and a rethinking of current supply chains to promote a more circular economy.

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