Sustainable Management of Plastic Wastes and Promotion of Circular Economy

Prof Sumiani Yusoff

Director of Institutue of Ocean and Earth Science

Chairperson of Universiti Malaya Eco-campus

sumiani@um.edu.my

Presentation Outline:

1. Introduction and background
2. Literature: Research on Plastic Pollution in ASEAN countries
3. Mapping of IOES projects to UN Sustainable Development Goals
4. Plastic Waste Management Hierarchy
5. National Integrated Plastic Waste Management Framework
6. Conclusions and Recommendation

1. Marine Plastic Waste: A Global Concern

Plastic products have become an integral part of our daily life as a result of which the polymer is produced at a massive scale worldwide.

Impact:

- Groundwater and soil pollution
- Pollution in oceans
- Dangerous for human life (open burning of plastic)

Do you know that:

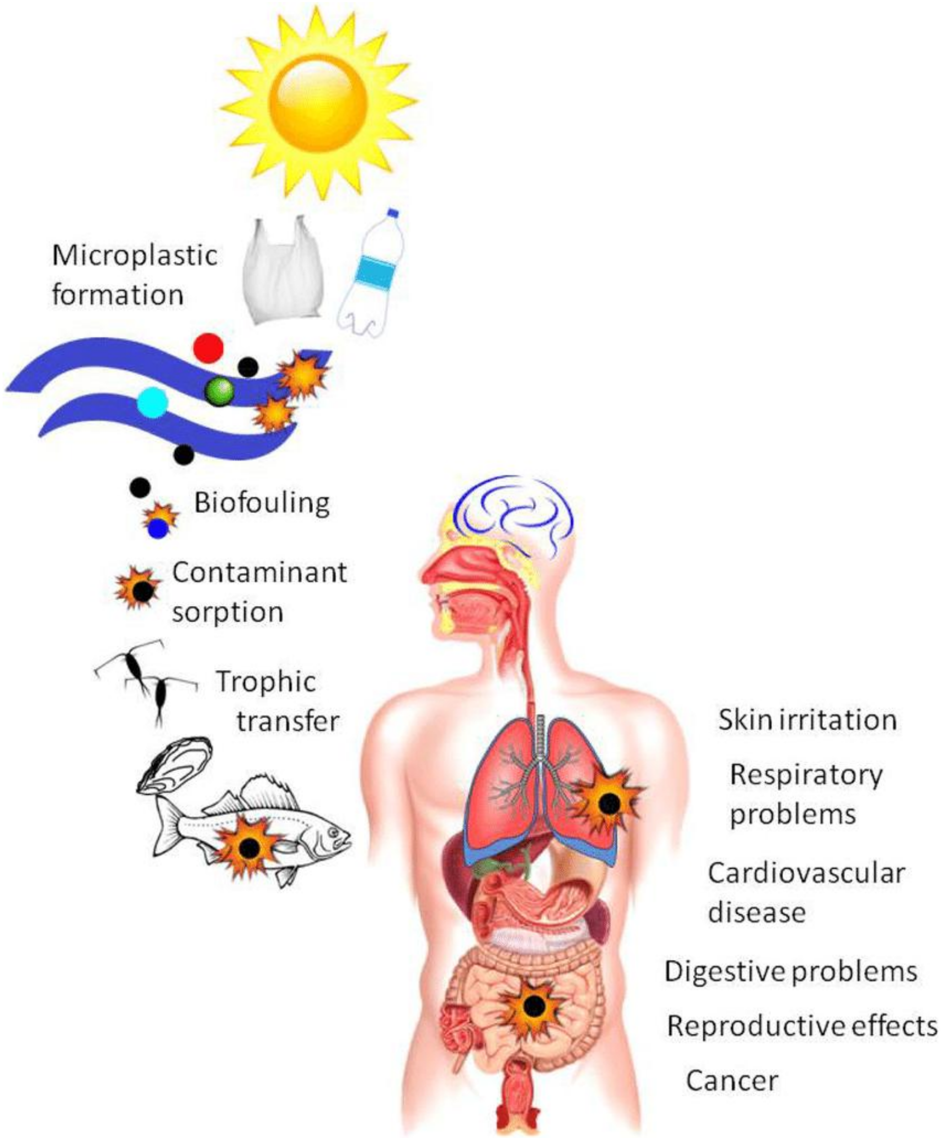
Only 60% of the plastic produced is recycled, balance 9400 Tonnes of plastic is left unattended in environment causing land, air and water pollution.

70% of Plastics packaging products are converted into plastic waste in a short span

Plastic Waste Poses a Huge Threat to Marine Ecology

There are **8 million** tonnes of plastic waste entering the ocean every year	The total plastic in the ocean amounts to **150 million tonnes**	Plastic packaging accounts for **62%** of all items recovered in coastal clean-up efforts	In 2014, there was **1 kg of plastic in every 5kg of fish** in the ocean, and by 2050 there will be more plastic than fish.

1.1 Microplastic Effects on Health



- Microbeads and microplastics generally are toxic to an array of biological systems. The level of toxicity depends on the size and specific chemical makeup of microbead or microplastic particle.

- In mammals, tiny microplastics have been found able to move through the gastrointestinal tracts to the lymphatic and circulatory systems, which are absorbed into the lungs when inhaled.

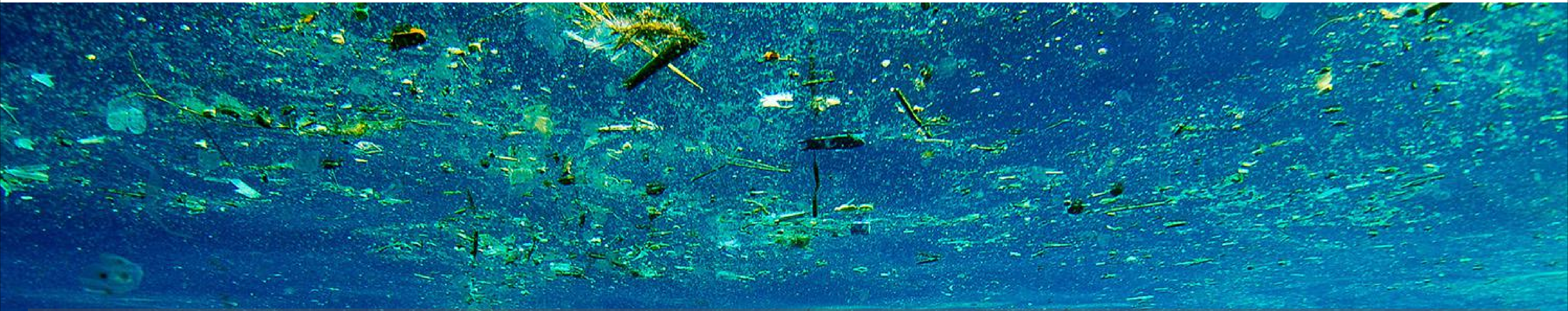
- Although the American Dental Association lacks clinical evidence, dental professionals have reported microbeads imbedded in patient's gums as a result of using toothpastes containing microbeads. They suspect this might lead to gingivitis and periodontal disease.

1.2 Marine Plastics in South East Asia

Table 1: Top 8 ASEAN member states that mismanaged plastic waste in 2010. ppd, person per day; MMT, million metric tonnes. (Table adapted from Jambeck et al., 2015).

Rank	Country	Waste generation rate (kg/ppd)	Plastic waste (%)	Mismanaged waste (%)	Plastic marine debris (MMT/year)
1	Indonesia	0.52	11	83	0.48-1.29
2	Philippines	0.5	15	83	0.28-0.75
3	Vietnam	0.79	13	88	0.28-0.73
4	Thailand	1.2	12	75	0.15-0.41
5	Malaysia	1.52	13	57	0.14-0.37
6	Myanmar	0.44	17	89	0.07-0.18

1.3 Objectives



1) To review the literature search on studies carried out by South East Asian members on plastics pollution

2) To identify the gap of research in relation to marine plastic pollution

3) To present relevant studies by Institute of Ocean and Earth Science (IOES) Universiti Malaya and mapping of IOES projects to Sustainable Development Goals

4) To discuss the challenges in plastic waste recycling and recommend National Integrated Plastic Waste Management Framework

2

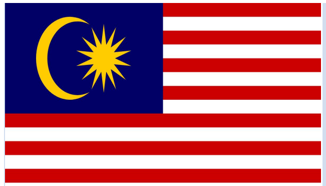
LITERATURE: RESEARCH ON PLASTIC POLLUTION IN SOME ASEAN COUNTRIES

Plastic waste generation (per year)	Current plastic waste reduction initiative	Survey and Monitoring	Source Differentiation	Hotspots	Ecological and Environmental Impacts	ALDFG
	**Indonesia**					
Generate more than **3.4 million tonnes of plastic waste in 2012** and expected to increase to **8.3 million tonnes by 2025** (Hoornweg and Perinaz, 2012; Jambeck et al., 2015; Shukar and Cadman, 2018).	• Indonesia's Plan of Action on Marine Plastic Debris 2017-2025 • Committed to a goal of 70% reduction in marine plastic by the year 2025	Various research to quantify the amount of plastics in the marine environment: •**along the coast** (Syakti et al., 2017; Purba et al., 2018a) •**on the sediment surface** (Willoughby et al., 1997; Manalu et al., 2017; Alam et al., 2019), •**on the water surface** (Syakti et al., 2018; Alam et al., 2019) •**deep sea** (Cordova and Wahyudi, 2016).	• Ramos et al. (2018) stated that plastics from the Pacific Ocean are unable to enter Indonesian waters • Handyman et al. (2019) showed that microplastics currently in the Java Sea were from South China Sea	• City rivers have plastics composition of 20% to 38% (Shukar and Cadman, 2018) • Java Seas is likely to host the largest patch of microplastic in Indonesia Handyman et al. (2019)	The impact of marine plastics were examined through: •**green mussel** (Cordova and Riani, unpublished work), •**fishes** (Ismail et al.,2018; Rochman et al., 2015), •**shellfish** (Rochman et al., 2015) •**coral** (Syakti et al., 2019)	• Richardson et al. (2018) conducted interviews with fishermen to understand the circumstances that gave rise to loss and abandonment of fishing gear

Plastic waste generation (per year)	Current plastic waste reduction initiative	Survey and Monitoring	Source Differentiation	Hotspots	Ecological and Environmental Impacts	ALDFG
	**Philippines**					
Generate more than **1.5 million tonnes of plastic waste in 2012** and expected to increase to **4.0 million tonnes by 2025** (Hoornweg and Perinaz, 2012; Jambeck et al., 2015; Shukar and Cadman, 2018).	Government ranks marine litter a **top priority** in coastal and marine projects.	• Quantification of marine plastics was carried out along the coastline (Abreo et al., 2018) and • The first microplastic research was conducted on beach surface sediments in 2018 (Kalnasa et al., 2018).	n/a	n/a	The ecological and environmental impacts were assessed through quantifying the amounts of marine plastics ingested by •**beaked whale** (Abreo et al., 2016), •**green sea turtle** (Abreo et •al., 2016), •**whale shark**s (Abreo et al., 2019) •**Bali Sardines** (Palermo, unpublished work). A review of photographs on social media showing effects of marine plastics on megafauna was also published	n/a

Plastic waste generation (per year)	Current plastic waste reduction initiative	Survey and Monitoring	Source Differentiation	Hotspots	Ecological and Environmental Impacts	ALDFG
	**Singapore**					
Generate more than **0.3 million tonnes of plastic waste in 2012** and expected to increase to **0.4 million tonnes by 2025** (Hoornweg and Perinaz, 2012).	• National Recycling Programme in 2014 introduces rubbish chutes designed for refuse and recyclables to be installed in homes • Recycling corners are encouraged in schools.	Two large international surveys: •International Coastal Cleanup (ICC) •PADI's Project AWARE Dive Against Debris. One published study on survey and monitoring of marine plastics from Ng and Obbard (2006).	n/a	n/a	• Marine plastic wastes were revealed in the gut of female sperm whale (Chua et al., 2019) • Bioaccumulation of nanoplastics in the barnacle nauplii (Bhargava et al., 2018) • Bacteria was found on the surface of microplastics collected have harmful effects on humans (Curren and Leong, 2018)	Derelict fishing gear were reported to have impacts on marine organisms.

Plastic waste generation (per year)	Current plastic waste reduction initiative	Survey and Monitoring	Source Differentiation	Hotspots	Ecological and Environmental Impacts	ALDFG
Thailand						
Generate more than **1.7 million tonnes of plastic waste in 2012** and expected to increase to **2.5 million tonnes by 2025** (Hoornweg and Perinaz, 2012).	• Five-year programme "National Waste Management Master Plan" from 2016 to 2021 • Four-year "Plastic Debris Management Plan" from 2017 to 2021.	• Department of Marine and Coastal Resources documented plastic disposables as the top marine debris. • The work expanded to the sampling and quantification of microplastics, with the establishment of a long term monitoring plan by 2019.	n/a	n/a	• The impact of microplastics on marine organisms have been studied on sessile marine organisms like bivalves, barnacles and a periwinkle (Tharamon et al., 2016; Thushari et al., 2017). • The type of plastic was examined and the accumulation rate in the organism reported.	n/a

Plastic waste generation (per year)	Current plastic waste reduction initiative	Survey and Monitoring	Source Differentiation	Hotspots	Ecological and Environmental Impacts	ALDFG
	**Malaysia**					
Generate more than **0.9 million tonnes of plastic waste in 2012** and expected to increase to **2.2 million tonnes by 2025** (Hoornweg and Perinaz, 2012; Saeed et al., 2009).	• Set overall waste reduction and recovery at 17% and the recycling target at 20% by 2020 • Malaysia's Road Map towards Zero Single-use plastics 2018-2030 by government of Malaysia.	The quantification of marine plastics are conducted in: •**mangrove forests** (Barasarathi et al., 2014) •**sandy beaches** (Fauziah et al., 2015; Noik and Tuah, 2015) •**water of ports** (Khalik et al., 2018) •**marine parks** (Prakash et al., unpublished work)	n/a	n/a	Research efforts were concentrated on the impact of plastics in marine organisms: •**sea turtle** (Horcajo-Berná et al., unpublished work) •**sea cucumber** (Anuar et al. unpublished work) •**ark shell** (Ibrahim et al., 2016), •**sea bass** (Ibrahim et al., 2017) •**other seafood** (Karami et al., 2017, 2018) •**commercial salt** (Karami et al.,2017) •**wild caught and farmed marine** (Ibrahim et al., 2017)	n/a

2.1 Gap of Research on Plastic Pollution

a) Little is known about the **current status** of marine plastic pollution

b) There is a lack of **standardised protocols** for detection, sampling and extraction of plastics.

c) While the knowledge gap for the effects of microplastics on human health is narrowing, further work is needed to establish the **effects of it on our health**.

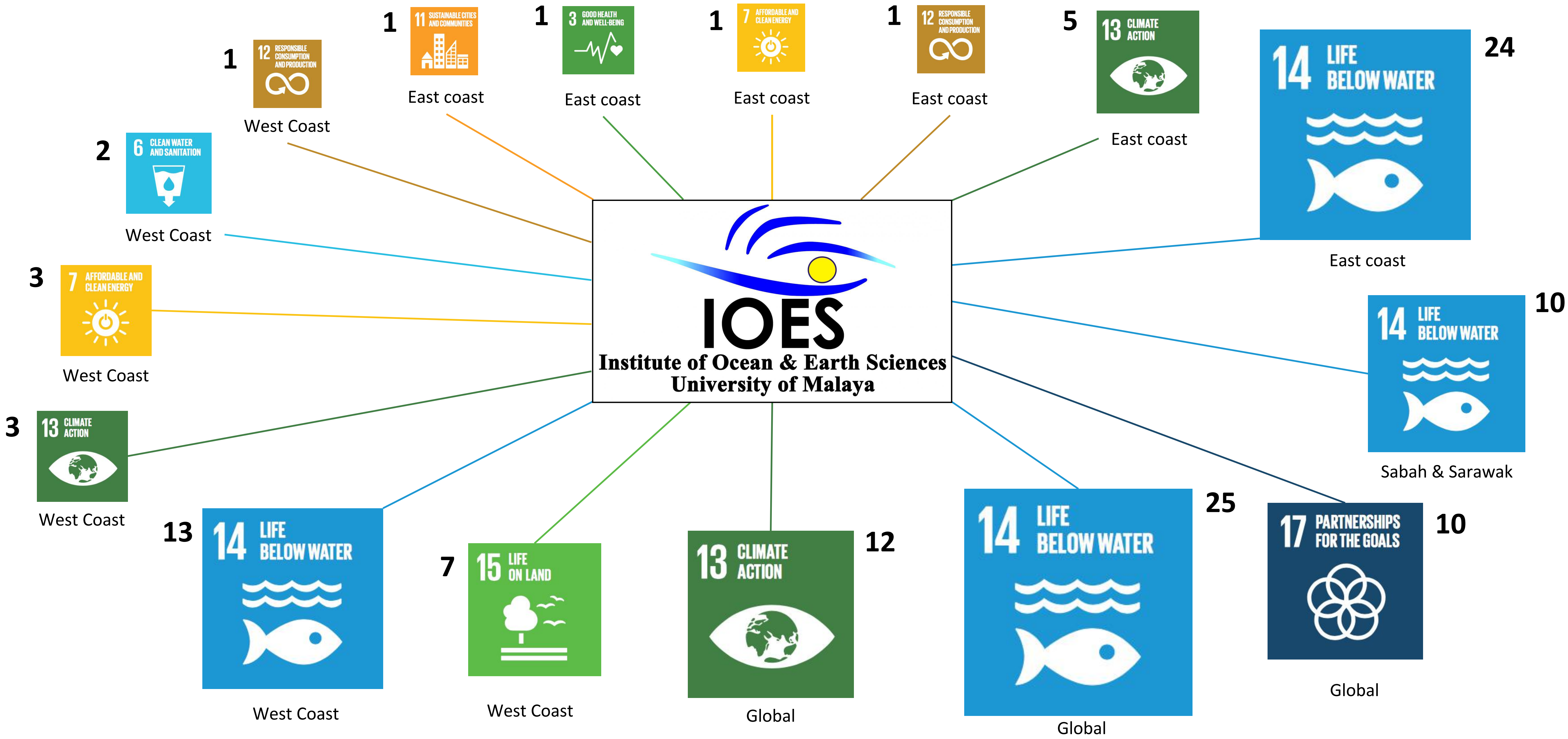
d) There is no nationwide research to understand the impact of marine plastics in the environment, identify **hotpots and sources** of these plastics.

e) Research **funding** is lacking.

3

MAPPING OF INSTITUTE OF OCEAN AND EARTH SCIENCE (IOES) PROJECTS TO UN SUSTAINABLE DEVELOPMENT GOALS

3.1 Mapping the UN Sustainable Development Goal to Research Activities in Institute of Ocean & Earth Sciences (IOES)



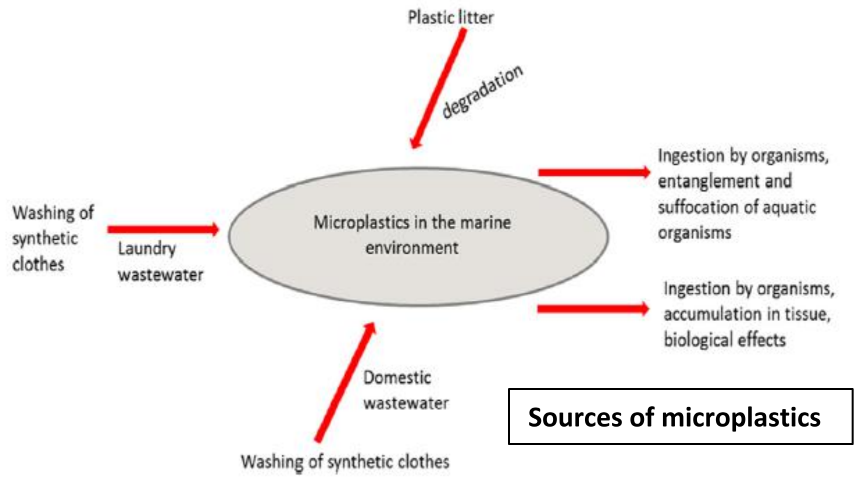
3.2 Example of Related Research related to plastic waste or microplastics by Universiti Malaya

1) Microbial degradation of microplastics
2) Survey and monitoring of plastics debris on Malaysia beaches
3) Abundance and distribution of microplastics in marine and freshwater ecosystems.
4) Distribution and Fate of Microplastics in the marine living organism.
5) Development of bioplastics from untreated seaweed and oil palm empty fruit brunches

IOES
Institute of Ocean & Earth Sciences
University of Malaya

DISTRIBUTION AND IMPORTANCE OF MICROPLASTICS IN THE MARINE ENVIRONMENT: A REVIEW OF THE SOURCES, FATE, EFFECTS AND POTENTIAL SOLUTIONS

This review describes the sources and global distribution of microplastics in the environment, the fate and impact on marine biota, especially the food chain.



Sources of microplastics

Microplastics in different size and color from mangrove sediments in Peninsular Malaysia

Potential Application:
Waste management, Exploiting microbes for remediation of contaminated environment

Authors affiliation:
Sumiani Yusoff, Institute of Ocean and Earth Science
C308, Institute of Graduate Studies Building, Universiti Malaya, Kuala Lumpur

Discussion

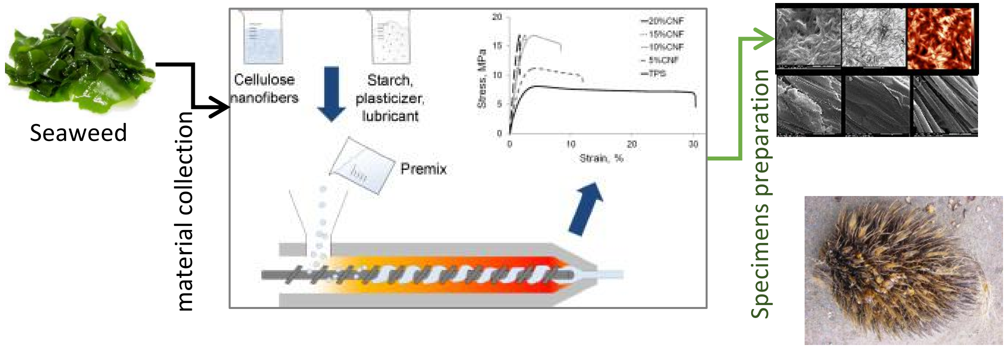
•Microplastics are very small particles of plastics that enters the marine environment through two main sources; cosmetic products and generally when larger plastic debris is weathered into smaller pieces.
•Microplastics are easily ingested by marine organisms and found to accumulate in tissues, circulatory system, and brain.
•Reducing the problem cannot occur without involving the general public, the socio-economic sectors, tourism and companies specializing in waste management.

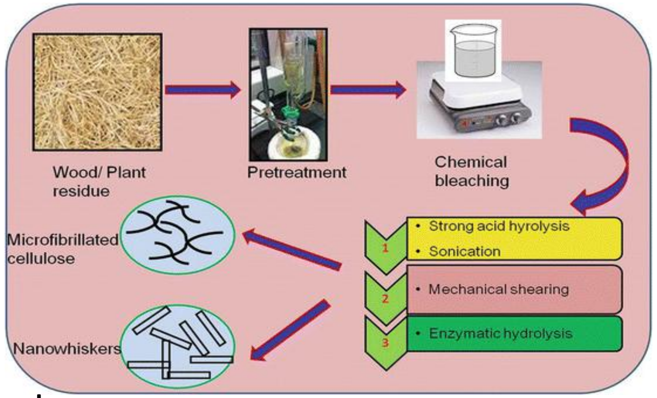
CONCLUSION

Harnessing microbes for the degradation of microplastics is a promising and environmentally safe action plan

BIONANOCOMPOSITE FROM UNTREATED SEAWEED WASTE AND EMPTY FRUIT BRUNCHES FOR BIOPLASTICS.

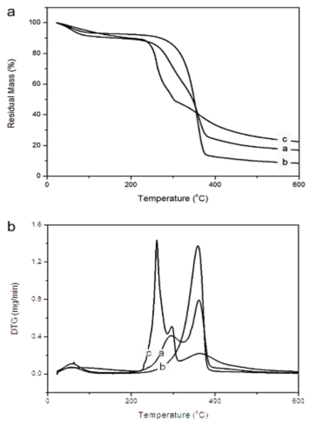
i. To produce the nanocellulose fibers from OPEFB
ii. To study the extrusion processing of bionanocomposites of seaweed starch and cellulose nanofibers produced as well as the nanofibers' dispersion in the composites.
iii. To study the effect on the mechanical, optical and moisture absorption properties of the composites.





Oil Palm Empty Fruit Brunch

Characterization:
i. optical
ii. mechanical,
iii. microscopy
iv. moisture absoprtion
.



Potential Application:
Production of biodegradable plastics, recycling of palm oil waste, circular economy

Impact

Reduction of plastic waste generation & reduction of marine pollution

Authors affiliation:
Sumiani Yusoff, Institute of Ocean and Earth Science
C308, Institute of Graduate Studies Building, Universiti Malaya, Kuala Lumpur

GROWTH KINETICS AND BIODETERIORATION OF POLYPROPYLENE MICROPLASTICS BY BACILLUS sp. AND RHODOCOCCUS sp. ISOLATED FROM MANGROVE SEDIMENT

UNIVERSITY OF MALAYA

This study aims to identify a remedial option for the disturbing accumulation of microplastics in the marine environment, thus demonstrating the growth and biodegradation ability of bacterial isolates from marine sediments in the degradation of synthetic polypropylene (pp) microplastic.

Identification of isolates

Screening of bacterial isolates

Microbial inoculum preparation & assay for PP microplastic biodegradation

Determination of weight loss of residual PP microplastics

FTIR and SEM analysis

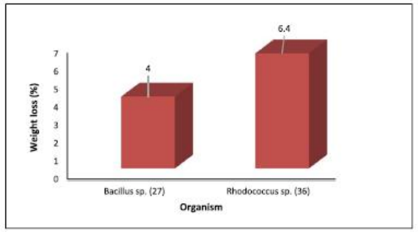


Fig. 2. Weight loss of microbially treated PP microplastics after incubation for 40 day Maximum weight loss (6.4%) was obtained for PP microplastic inoculated wit *Rhodococcus* sp. strain 36.

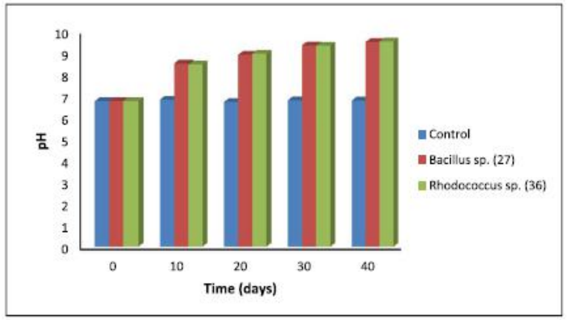


Fig. 5. pH changes of PP culture media inoculated with *Bacillus* sp. strain 27 and *Rhodococcus* sp. strain 36 during the 40 days of incubation.

RESULTS

1. Microbes adapted to the culture conditions of the PP microplastic media and utilizes it as carbon source for growth.
2. Growth of the isolates in the media causes changes in pH, resulted from the microbial degradation activities.
3. The biodegradation was confirmed by the structural, morphological and chemical changes observed on the PP microplastics using Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) analyses.

Potential Application:

Potential of microbes isolated from mangrove environment in PP microplastics degradation

Conclusion/Impact

Environmental application of the isolates in the degradation of PP microplastics

Authors affiliation:

SH Fauziah, Institute of Biological Science

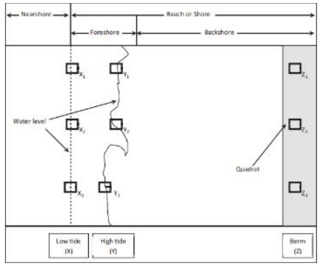
Faculty of Science, Universiti Malaya, Kuala Lumpur

PLASTIC DEBRIS IN THE COASTAL ENVIRONMENT: THE INVINCIBLE THREAT? ABUNDANCE OF BURIED PLASTIC DEBRIS ON MALAYSIAN BEACHES

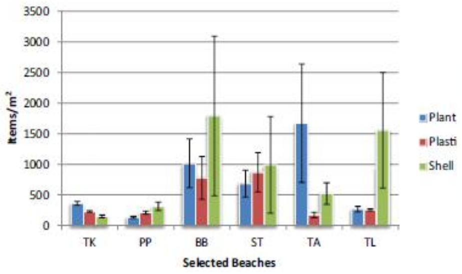
UNIVERSITY OF MALAYA

This study was designed to investigate the abundance of small plastic debris buried in the sands at six sampling sites on Malaysian beaches representing both recreational and fishing areas.

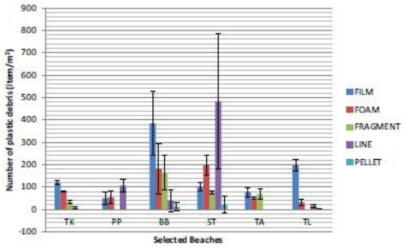
Sampling design
↓
Sieving of samples
↓
Sorting of samples
↓
Classification and quantification



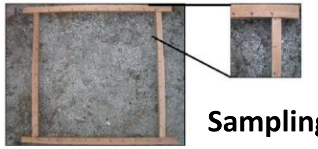
Nine points of sample per beach site (three replicates within each water level and berm area)



Number of items according to types in sand from selected beaches



Types of plastic items



Sampling quadrat

RESULTS

1. A total of 2542 pieces (265.30 g/m2) of small plastic debris were collected from all six beaches.
2. The abundance of plastic debris within different types of classification are different depending on the functions of the beach

Potential Application:

Solid waste management practices (3 R's), Public awareness programmes, Beach clean-up activities

IMPACT

Clearer understanding on the presence of plastic debris which could cause adverse environmental impact.

Authors affiliation:

SH Fauziah, Institute of Biological Science
Faculty of Science, Universiti Malaya, Kuala Lumpur

UNIVERSITY OF MALAYA

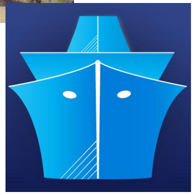
WORLDWIDE DISTRIBUTION AND ABUNDANCE OF MICROPLASTIC: HOW DIRE IS THE SITUATION?

This paper reviews the global abundance and distribution of microplastics in marine and freshwater ecosystems. The various sources, impacts, challenges and issues pertaining to microplastics monitoring and management are addressed. Recommendation to reduce the impact of microplastic via its appropriate management were provided for better findings in future microplastics studies.

SOURCES

Tourism

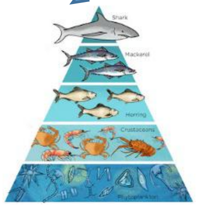
Fishery activities



Marine traffic

IMPACTS

Decrease in marine population



Affects ecosystem equilibrium

Potential Application:

Appropriate laws and regulations, standard methods to understand the severity of the situation related to global microplastic management

Authors affiliation:

SH Fauziah, Institute of Biological Science

Faculty of Science, Universiti Malaya, Kuala Lumpur

DISCUSSION

- Accumulation of microplastics varies geographically, with locations, hydrodynamic conditions, environmental pressure, and time.
- The majority of the microplastic recorded in the marine environment of Asia were secondary microplastics.
- The source of this microplastic pollution is anthropogenic activities like tourism, fishery activities, marine traffic, etc.
- Microplastic contamination reduces population size which causes imbalance in the equilibrium of the ecosystem and makes it vulnerable if any additional pressure imposed.

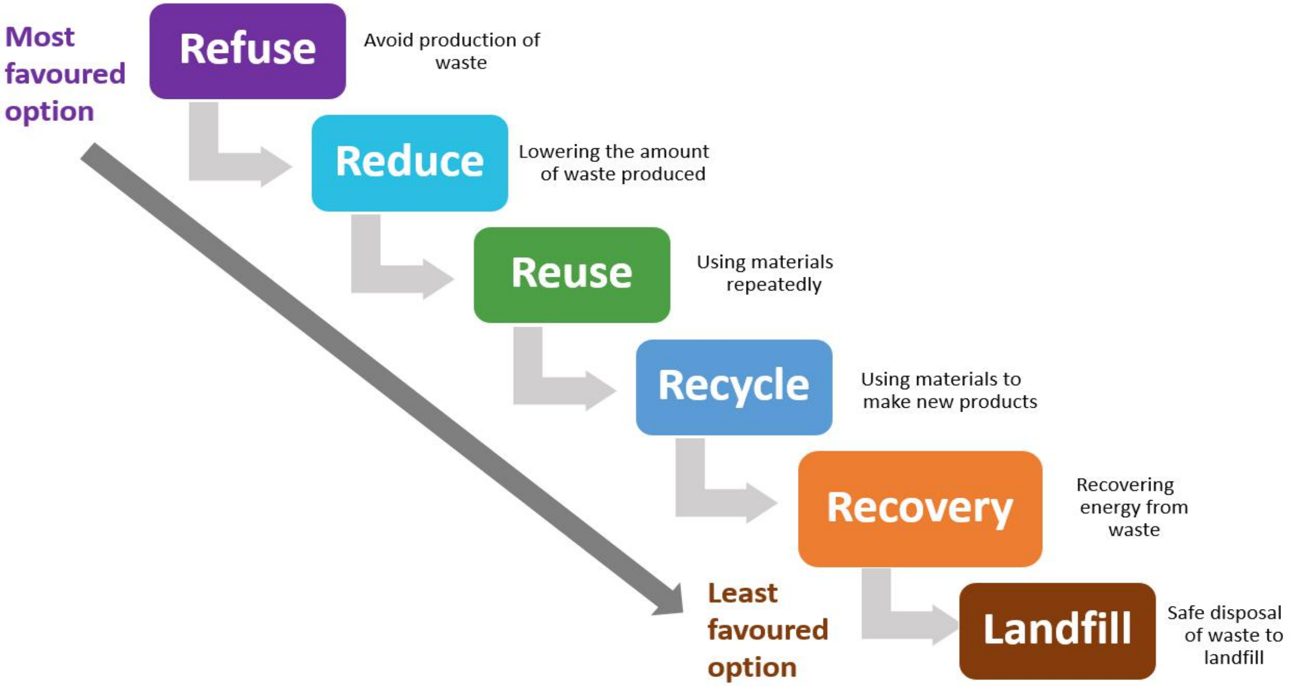
CONCLUSION

A standard guideline is necessary to collate accurate findings for future planning and strategies in the management of microplastic pollution.

4 PLASTIC WASTE MANAGEMENT HIERARCHY

4. Plastic Waste Management Hierarchy

Example of different types of Plastics



4.1 Recycle Plastic Waste to Materials

4.2 Recycle Plastics Waste to Bitumen Road

Plastic waste collection segregation and storage

Cleaning and drying of plastic waste

Shredding plastic waste into required size

Stone aggregate heated to around 160-170°C

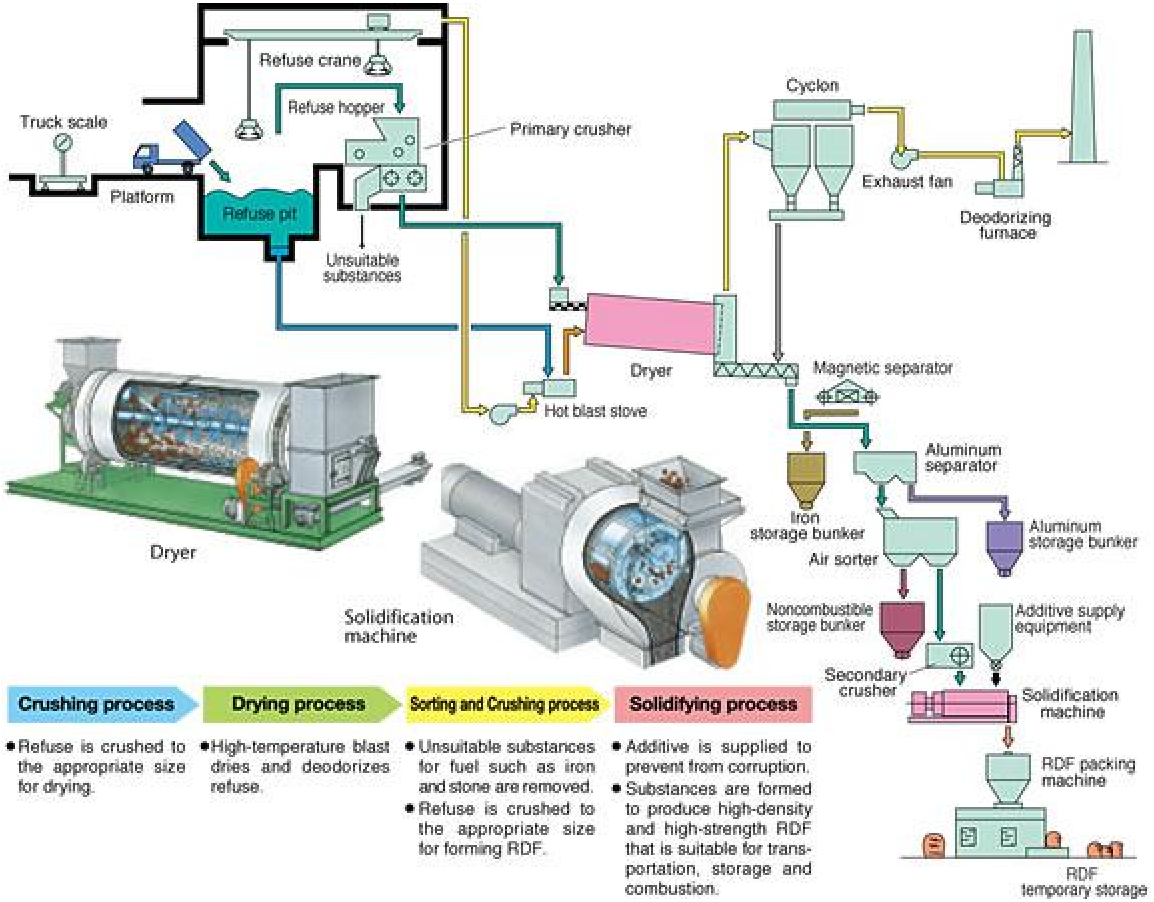
Shredded polymer waste is added to heated stone aggregate for 30-40 sec and mixed for uniform coating

The Coated aggregate is mixed with hot bitumen at temp 155-163°C

The mix known as waste plastic-aggregate bitumen mix can be used for road laying at 110-120°

4.3 Recycle Plastic Waste to Pavement

4.4 Recycle Plastic Waste to Refuse Derieved Fuel

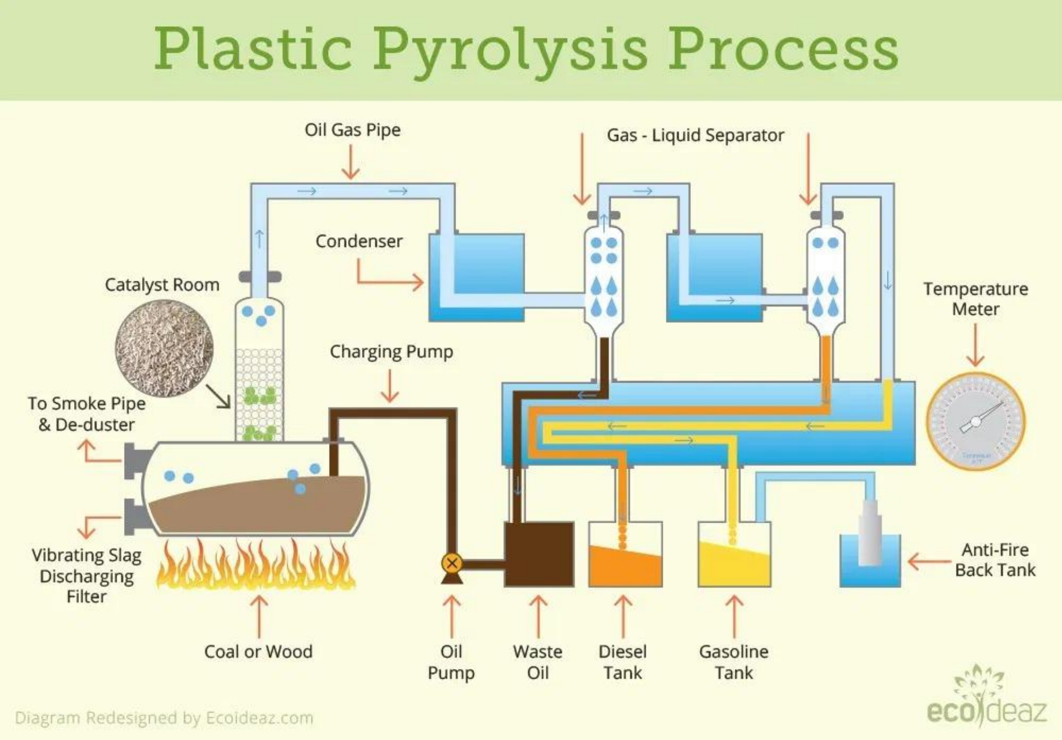


4.5 Recycle Plastics waste to Energy

FEEDSTOCKS AND OUTPUT WITH THERMAL DEPOLYMERIZATION
(Note: Paper/cellulose contains at least 1% minerals, which was probably grouped under carbon solids.)

Average Thermal Depolymerisation (TDP) Feedstock Outputs

Feedstock	Oils	Gases	Solids (mostly carbon based)	Water (Steam)
Plastic bottles	70%	16%	6%	8%
Medical waste	65%	10%	5%	
Tires	44%	10%	42%	
Sewage sludge	26%	9%	8%	
Paper (cellulose)	8%	48%	24%	



4.6 Challenges in Plastics Waste Recycling

Recycling and re-utilization of waste plastics have several advantages. It leads to a reduction of the use of virgin materials and of the use of energy, thus also a reduction of carbon dioxide emissions.

Benefits of Recycling:

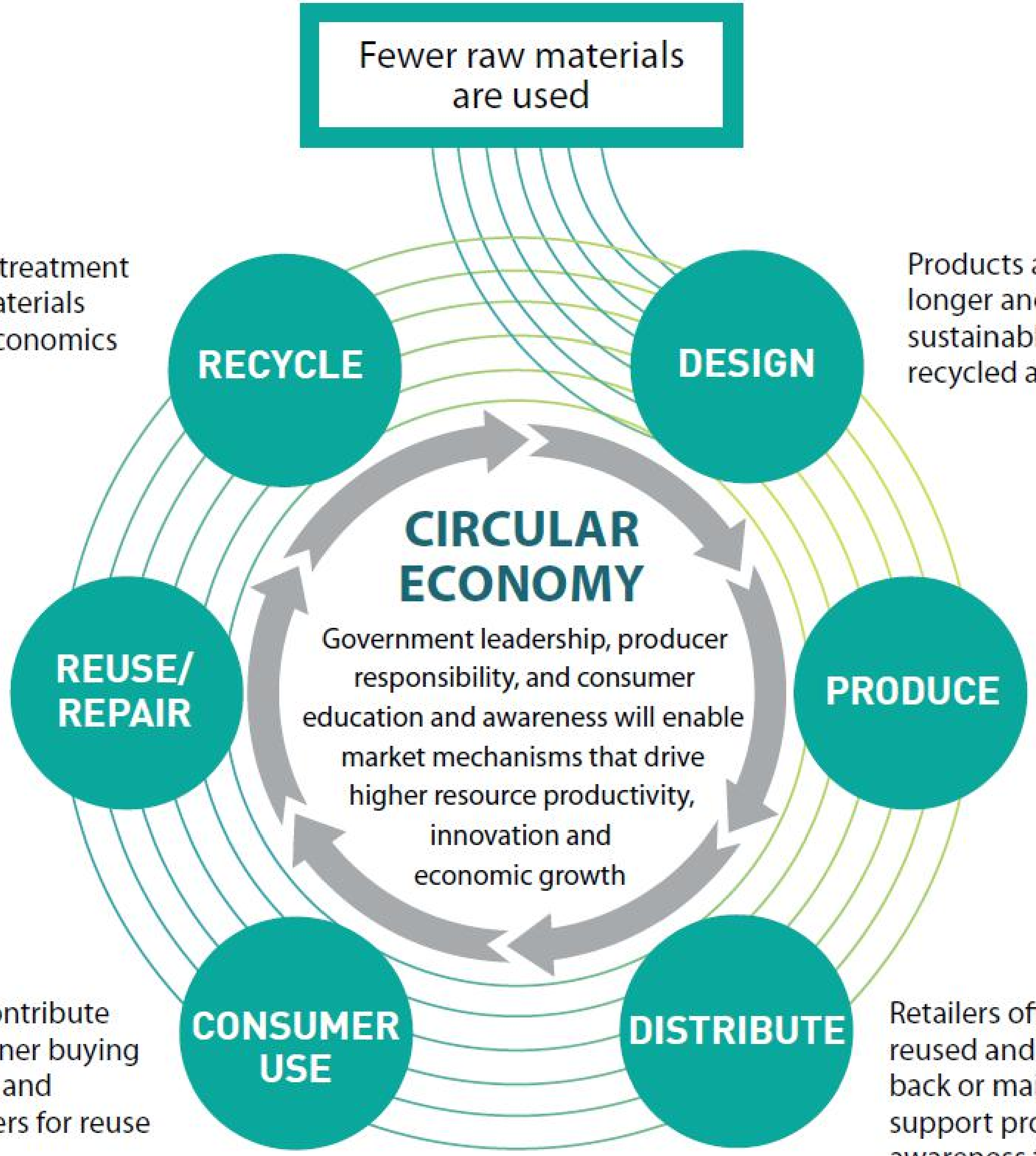
- Reduces Environmental Pollution
- Energy savings : 40 - 100 MJ/kg (depends on the polymer)
- Economic Benefits
- Reduces demand for virgin polymer
- Preferred to Landfilling
- Generates Employment
- Reduces depletion of Fossil fuel reserves

Difficulties in Recycling:

- Hard to separate from non-plastics (no 'magnet' equivalent)
- Differing composition of plastic resins
- Degradation of polymer chains on recycling
- Recycled polymer is of lower quality than virgin polymer
- Most waste plastics films specially thin plastics films have limited market value
- Identification of reuse and recycling opportunities
- Lack of Markets for recycled Plastics
- Lack of Infrastructure (collection)
- Low value of recovered Plastics
- Lack of Subsidies for recycling program

5 NATIONAL INTEGRATED PLASTIC WASTE MANAGEMENT FRAMEWORK

5.1 Plastic Circular Economy Framework



Recycle: Improved, cost-efficient collection and treatment systems will lead to fewer and fewer materials ending up in landfill and support the economics of circular design

Design: Products and packaging are designed to last longer and be more durable, using more sustainable materials that can be easily recycled at end-of-life

Reuse/Repair: Producers are fully responsible for recovering materials from their products and packaging throughout their lifecycle

Produce: Businesses collaborate and coordinate across sectors to reduce greenhouse gas production and fossil fuel use

Consumer Use: There are many ways consumers can contribute to a circular economy, like making greener buying choices, sharing assets (e.g., cars, tools) and repairing them or offering them to others for reuse and refurbishing

Distribute: Retailers offer products that can be easily reused and refurbished, offer end-of-life take back or maintenance and repair services, and support producers in providing education anc awareness to consumers

5.2 Targets and Interventions by Stakeholders

TARGET	Innovative Materials and Product Design	Cleaner Production	Reduce waste generation	Improve plastics waste collection	Improve material recycling and energy recovery	Economic of circular design
CIRCULAR ECONOMY	DESIGN	PRODUCE	DISTRIBUTE	CONSUMER USE	REUSE & REPAIR	RECYCLE
INTERVENTION	• Sustainable Materials • Bioplastics production • Incentives • R&D	• Import taxes • Reduce greenhouse gases production • Reduce fossil fuel use	• End-of-life take back • Repair service • Education and awareness	• Green procurement • Education and awareness	• Extended Producers Responsibility	• Cost-effective collection system • Waste-to-Energy • Safe disposal
AGENCIES	✓ MESTECC ✓ NRE ✓ Unversities ✓ Research centers	✓ MoF ✓ MITI ✓ MESTECC	✓ KPDNHEP ✓ KPKT ✓ MoE	✓ MoF ✓ KPDNHEP ✓ MoE ✓ KPKT	✓ MESTECC ✓ NRE ✓ MoF ✓ MITI	✓ SWCorp ✓ Local Governemnt ✓ Waste Contractors

5.3 Monitoring Framework: Proposed 9 Indicators

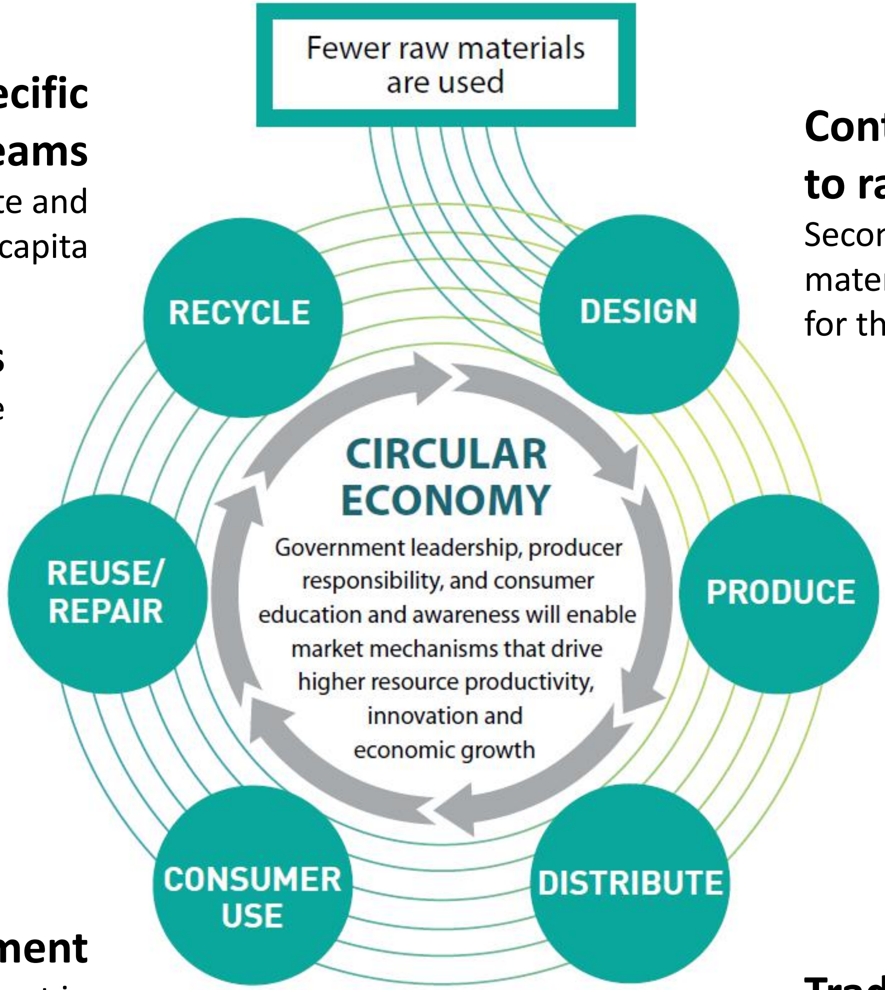
Recycling rates for specific plastics waste streams
Recycling rate of overall plastics waste and plastic packaging per capita

Overall recycling rates
Recycling rate of municipal waste

Plastic Waste
Amount of plastic waste generated

Waste generation
Generation of municipal waste per capita, total waste generation per GDP unit and in relation to domestic material consumption

Green Public Procurement
The share of major public procurement in Malaysia that include environmental requirements



Contribution of recycled plastics to raw material demand
Secondary raw materials' share of overall materials demand for specific materials and for the whole economy

Private investments, jobs and gross value added
Private investments, number of persons employed and gross value added in the circular economy sectors

Patents
Number of patents related to plastics waste management and recycling

Trade in recyclable plastics
Imports and exports of selected plastics recycled materials.

5.4 National Integrated Plastic Waste Management

Aims:

1. To promote **circular economy** of plastic wastes.
2. To implement **Extended Producers' Responsibility** (EPR) policy.
3. To ensure sustainability in product design
4. To ensure continued **public participation**
5. To strengthen **R&D** in development of bioplastics

Relevant stakeholders:

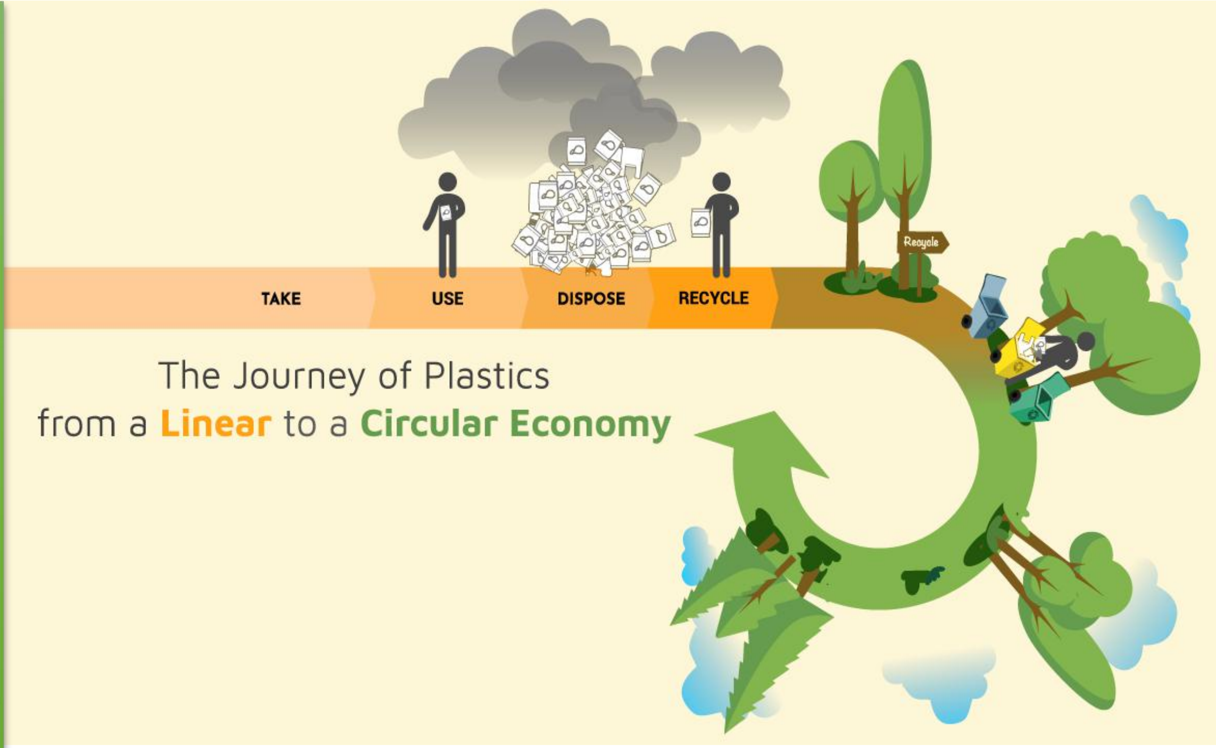
- Ministry of Housing and Local Government (KPKT),
- Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC)
- Ministry of Education (MOE)
- Ministry of International Trade and Industry (MITI)
- Ministry of Water, Land and Natural Resources (NRE)
- Ministry of Domestic Trade (KPDNHEP)
- Local Government
- Waste concessionaires (Alam Flora, E-idaman, SWM etc)
- Environmental NGOs
- Universities

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

A circular economy goes beyond recycling. The goal is not just to design for better end-of-life recovery, but to minimize the use of raw materials and energy through a restorative system.

A circular economy for plastics offers a promising vision for stemming the tide of plastic waste, but converting this aspiration into a fully functioning, closed-loop system will require greater cooperation from all key actors in the value chain.



6.2 Recommendations & Key Considerations

1) Conduct a **baseline assessment** to identify the most problematic single-use plastics.
2) Assess the potential **social, economic and environmental impacts**
3) Consider **alternative technologies** to tackle problems.
4) Identify and engage **key stakeholder groups**
5) Raise **public awareness** about the harm caused by single-used plastics
6) Provide **collection facilities**
7) Adoption of **circular economy**
8) Provide **incentives** to industry (e.g. tax rebate)
9) Embrace **holistic approach** and collaborate to innovate
10) Strengthen **enforcement** on illegal dumping


THANK YOU