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A critical analysis of technological interventions towards the national action plan for marine litter management 2018-2025: recommendations for addressing marine plastic litter in the 'new balis' of Indonesia sustainably

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A CRITICAL ANALYSIS OF TECHNOLOGICAL INTERVENTIONS TOWARDS THE NATIONAL ACTION PLAN FOR MARINE LITTER MANAGEMENT 2018-2025:
Recommendations for Addressing Marine Plastic Litter in the 'New Balis' of Indonesia Sustainably

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature:

Date: 11. 10. 2018

Supervised by: Associate Professor Mary S. Wisz, PhD

Supervisor's affiliation: World Maritime University

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ABSTRACT

Title of Dissertation: **A Critical Analysis of Technological Interventions towards the National Action Plan for Marine Litter Management 2018-2025: Recommendations for addressing marine plastic litter in the 'New Balis' of Indonesia sustainably**

Degree: **Master of Science**

This dissertation aims to provide recommendations for addressing marine plastic litter in the 'New Balis' of Indonesia sustainably through technological interventions in the framework of the National Action Plan for Marine Litter Management 2018-2025. 'New Balis' are the 10 prioritized tourism destinations in Indonesia to be developed and promoted. The 'New Balis' development is a national strategic project to boost national income from tourism sector which have been directed by Indonesian President since 2015. This is because tourism is a rapidly growing economic sector in Indonesia. However, 'New Balis' are also facing a global challenge called marine plastic litter. Marine plastic litter is a threat to 'New Balis' due to has potential impacts on the reduction of marine environment sustainability, health of tourists and local communities as well as tourism business income.

Since 2018, Indonesian government has established and promulgated the National Plan of Action on Marine Litter Management 2018-2025. This national plan consists of three important key aspects of interventions (i.e. societal effort, technological application and institutional coordination) and five strategies for addressing marine litter in Indonesia, in particular to manage 70% of marine plastic litter by 2025. The strategies include 1) National movement for raising awareness of stakeholders, 2) Land-based litter management, 3) Litter management at sea and coasts, 4) Funding mechanism, institutional strengthening, monitoring and law enforcement, and 5) Research and development. In this dissertation research, technological interventions around the world and in Indonesia are reviewed and analyzed on their relevance to the national action plan as well as the strengths, weaknesses, opportunities and threats (SWOT) of potential impacts after intervening the technologies in the 'New Balis'. In order to ensure technological interventions will be sustainable for addressing marine plastic litter in the 'New Balis', the aspects of sustainable tourism and international partnerships are also recommended to be considered by Indonesian government and related stakeholders.

Keywords: marine litter management, marine plastic litter, New Balis, sustainability, technological interventions

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List of Abbreviations

ABS	Acrylonitrile butadiene styrene
AGATOR	Automatic Garbage Collector
ALDFG	Abandoned, Lost or Otherwise Discarded Fishing Gear
BAPPENAS	Indonesian Agency for National Development Planning
BPA	Bisphenol-A
CA	Cellulose Acetate
CE Delft	Committed to the Environment Delft
CMMA	Coordinating Ministry for Maritime Affairs
DBP	dibutyl phthalate
DEHP	di-(2-ethylhexyl)phthalate
DEP	diethyl phthalate
ECHA	European Chemicals Agency
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GIS	Geographic Information System
GPS	Global Positioning System
HBCD	Hexabromocyclododecane
HSV	Hue, Saturation and Value
ICES	International Council for the Exploration of the Sea
IDR	Indonesian Rupiah
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
IOT	Internet of Things
LMEs	Large Marine Ecosystems
LPG	Liquefied Petroleum Gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environmental Protection Committee
mV	Millivolt
MW	Megawatt
NAFTA	North American Free Trade Agreement
NFC	Near Field Communication
NGOs	National Governmental Organizations
NOAA	National Oceanic and Atmospheric Administration
NP	Nonylphenol

OBABAS	Online Waste Banking
ORP	Oxidation-reduction potential
PA	Polyamides
PBDEs	Polybrominated diphenyl ethers
PC	Polycarbonate
PCA	Plastic Coated Aggregate
PCBs	Polychlorinated biphenyls
PCCPs	Personal Care And Cosmetics Products
PCL	Polycaprolactone
PE	Polyethylene
PET	Polyethylene Terephthalate
PIC	Person in charge
pH	Power of hydrogen
PLA	Polylactic acid
PLN	Indonesian National Power Enterprise
PMMA	Polymethyl methacrylate
PP	Polypropylene
PPID MEF	Information management and documentation officer of Ministry of Environment and Forestry
PS	Polystyrene
PS-E	Expanded polystyrene
PSU	Polyarylsulfone
PUR	Polyurethane
PVC	Polyvinyl chloride
RFID	Radio Frequency Identification
SDGs	Sustainable Development Goals
SDK	Software Development Kit
SURF	Speeded Up Robust Feature
SWOT	Strengths, Weaknesses, Opportunities and Threats
TDS	Total dissolved solids
TPE	Thermoplastic elastomers
UK	United Kingdom
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNWTO	United Nations World Tourism Organization
USA	United States of America
USD	United States Dollar
UV	Ultraviolet
WMU	World Maritime University

WTTC	World Travel and Tourism Council
WWW	World Wide Web

1 Introduction

Due to the reliable properties of plastic for many applications because of containing the additive chemicals and its molecular characteristics, plastic substitutes other materials and is leading to the new products development in great demand (Reisser, 2015; Hahladakis et al., 2018). In result, the global plastic production has been exponentially increasing and the plastic litter has been polluting the marine environment since 1950s (PlasticsEurope, 2017; Law 2017).

Nowadays many countries are addressing marine plastic litter. Indonesia is one of them and has developed a national action plan to address it (CMMA, 2017). This dissertation addresses marine plastic litter issues globally and in Indonesia with respect to its expanding tourism sector, particularly in the 'New Balis'. The technological interventions around the world and in Indonesia are reviewed and analyzed to be formulated as recommendations for addressing marine plastic litter in the 'New Balis' in consideration of the strategies of national action plan, sustainable tourism aspects and international partnerships for a sustainable implementation.

Chapter 1 covers the discussion on marine plastic litter as the global challenge, its challenges in Indonesia including in the 'New Balis', the National Action Plan for addressing the marine plastic litter, also aims, objectives and methodology of research.

1.1 The global challenge of marine plastic litter

In Subchapter 1.1, the discussion consists of a global overview of plastic and the supply chain of marine plastic litter.

1.1.1 A global overview of plastic

The focus of discussion in Section 1.1.1 on global plastic production, plastic classification and additive chemicals in plastic.

1.1.1.1 Global plastic production

The term 'plastic' is used here to define a sub-category of class of materials called polymers. ECHA (2012) has defined a polymer is an organic macromolecular substance characterized by the sequence of monomer unit. Polymers have long chain-like structure, heavy molecular weights and structured of repeating carbon compounds that develop naturally or can be synthesized (Kratochvíl, 2009; UNEP, 2016).

Globally, large-scale plastic production started in the 1950s (PlasticsEurope, 2012). Figure 1 shows world plastic production was approximately 1.5 million metric tons in 1950 but rapidly increased over 6 decades up to 335 million metric tons in 2016. The productions include thermoplastics, polyurethanes, thermosets, adhesives, coatings and sealants materials (PlasticsEurope, 2015). Andrady (2017) noted that global plastic production grew rapidly responding to an increasing world population (Figure 2).

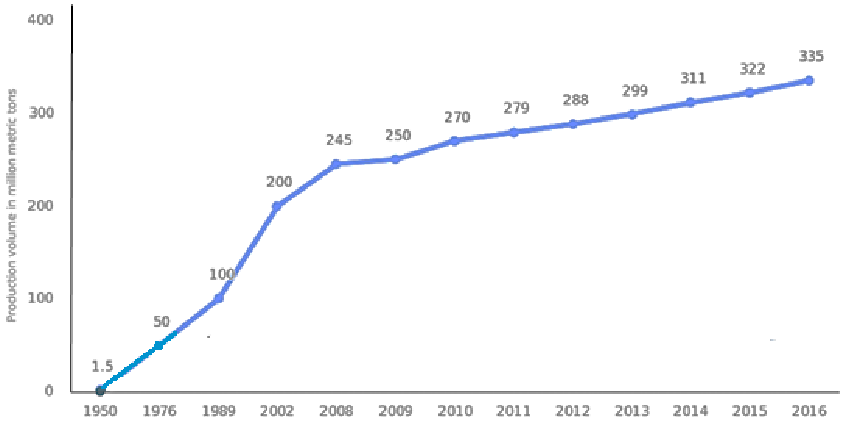

Figure 1 Plastic production in the world and Europe from 1950 to 2016. Data sources: PlasticsEurope (2017), PlasticsEurope (2015) and PlasticsEurope (2013)

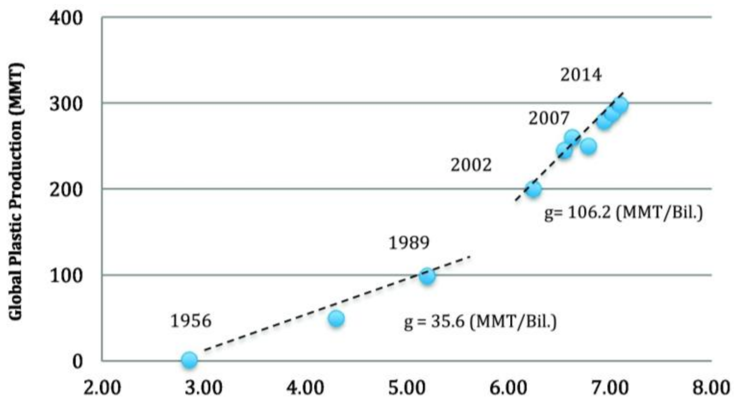

Figure 2 The change in global plastic production with the world population. Source: Andrady (2017)

In the world, China is the largest producer of plastic materials (26%), followed by European countries (20%) and NAFTA (North American Free Trade Agreement) countries (19%) in 2014 (PlasticsEurope, 2015). Figure 3 shows the share of world plastic materials production in 2006 and 2014.

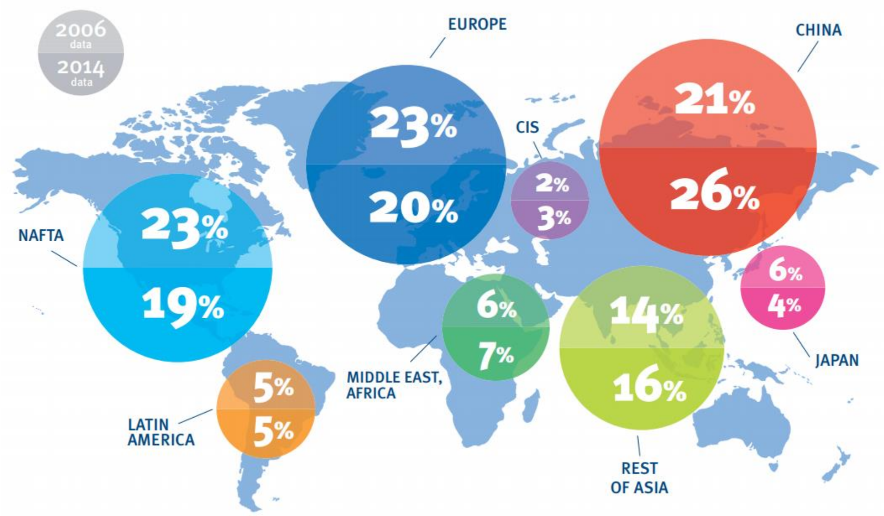

Figure 3 Global production share of plastic materials in 2014 and 2016. Source: PlasticsEurope (2015)

1.1.1.2 Classification of plastics

Plastic can be classified based on its materials types and size.

<u>**Type classification: thermosets and thermoplastics**</u>

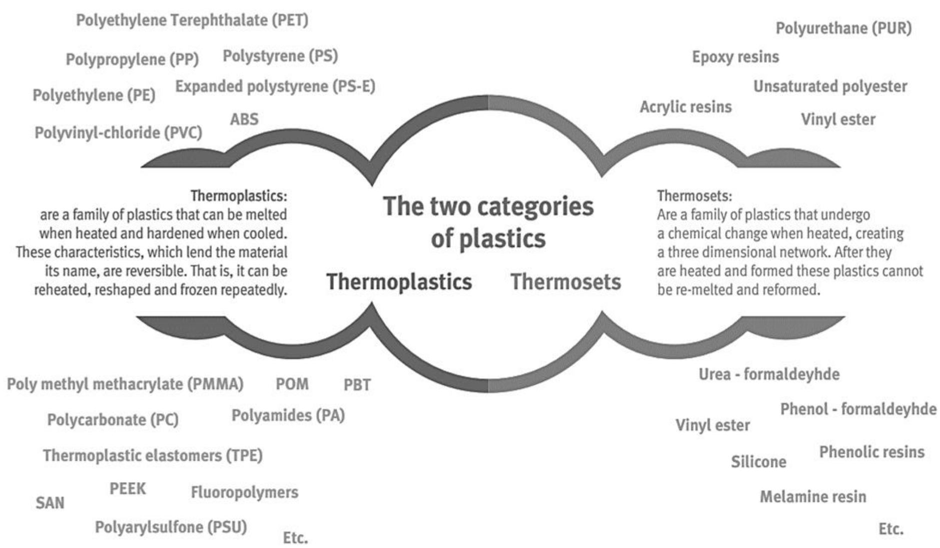

Figure 4 Definition and resin types of thermoplastics and thermosets. Sources: PlasticsEurope (2017)

Plastic commonly refers to a group of synthetic polymers which can be classified as thermoplastics and thermosets (Elshabini et al., 2017). Figure 4 defines and lists a number of plastic materials (resins) of thermosets and thermoplastics. According to Lee et al. (2014), polyethylene, polypropylene and polystyrene are the main resins of plastic litter found in the marine environment.

Size classification: macroplastics and microplastics

In general, plastics can be classified based on their size as macroplastics or microplastics (Lachmann et al., 2017). Some studies have defined various diameter of macroplastics of >20 mm (Ryan et al., 2009) and >200 mm (Eriksen et al., 2014). Microplastics are defined as plastic fragments or particles with diameter of <2 mm (Ryan *et al.*, 2009) and 0.33–4.75 mm (Eriksen *et al.*, 2014). The size classification of plastic used here is based on GESAMP (2015) which defines microplastics diameter of <5 mm and macroplastics diameter of $\geq$5 mm. Van Cauwenberghe *et al*. (2015) suggest a classification of plastic nomenclature based on size to be nanoplastic, microplastic, mesoplastic and macroplastic as shown in Figure 5.

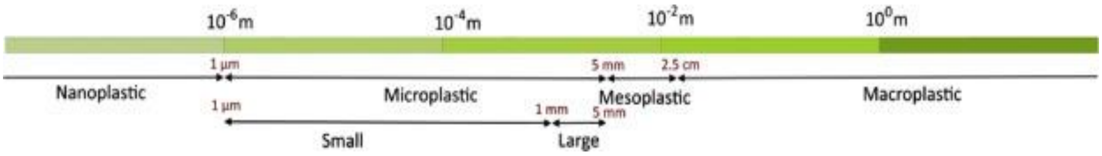

Figure 5 Nomenclature of plastic based on size. Source: Van Cauwenberghe et al. (2015)

Microplastics can be differentiated as the primary and secondary microplastics. Primary microplastics were originally manufactured for industrial or domestic applications to be of a microscopic size (Auta et al., 2017) while secondary microplastics have been generated by exposure to ultraviolet irradiation, weathering and mechanical fragmentation of larger plastics in the environment (Cole et al., 2011; Lee et al., 2014; Andrady, 2015).

1.1.1.3 Additive chemicals in plastics

Plenty plastics frequently contain a wide variety of additive chemicals which are added to revamp the properties of plastic products (Hahladakis et al., 2018). Table 1 lists of common additive chemicals with some functions in plastic.

Table 1 Common additive chemicals in plastic

Short form	Full name	Functions in plastic
DBP	dibutyl phthalate	anti-cracking agents in nail varnish
DEP	diethyl phthalate	skin softeners, colour and fragrance fixers
DEHP	di-(2-ethylhexyl)phthalate	plasticizer in PVC
HBCD	hexabromocyclododecane	flame retardant
NP	Nonylphenol	stabilizer in food packaging and PVC
PBDEs	Polybrominated diphenyl ethers (penta, octa & deca forms)	flame retardants
phthalates	Phthalate esters	improve flexibility and durability

Source: GESAMP (2016)

1.1.2 Supply chain of marine plastic litter

Plastic litters pass through the sequence of production and distribution processes called supply chain, to the ocean (Campbell et al., 2017; Hahladakis et al., 2018). In Section 1.1.2, the supply chain of marine plastic litter is discussed by defining marine plastic litter, investigating the types, sources and pathways of plastic litter to the ocean as well as describing the behaviours of plastic litter in the ocean.

1.1.2.1 Marine plastic litter definition and types

Defining ‘marine plastic litter’

Marine litter is defined as any persistent solid material in the marine and coastal environment due to accidental inputs, littering, illegal dumping, insufficient treatment capacity through drainage and sewage systems, as well as natural transport of these materials to the ocean by wind or rivers (Galgani et al., 2010; Gall & Thompson, 2015, Jambeck et al., 2015). Marine plastic litter is a persistent solid material which makes up most marine litter, contains polymers and fragments into microplastics, that are potentially hazardous to marine biota and human beings (Lachmann *et al*., 2017; Presidential Decree of Republic of Indonesia No. 83 of 2018 on Marine Litter Management).

<u>Types of marine plastic litter</u>

Marine plastic litter types can be classified by its location and size. By location, it can be categorized as beach/harbour litter, shoreline litter, surface waters litter, seafloor litter and deep sea floor litter (Derraik, 2002). By its size, marine plastic litter consist of microplastics and macroplastics (GESAMP, 2016). To collect marine microplastics, microfilters <1 μm separation or nanofilters are required and to see them should use optical or electron microscope (Andrady, 2017).

In the marine and coastal environment, a wide variety of macroplastic litter found. Table 2 lists the examples of marine macroplastics litter based on the plastic resin type. Microplastics which directly released into the environment include micro-beads in personal care and cosmetics products (PCCPs), plastic powders used in moulding, industrial ‘scrubbers’ used to blast clean surfaces, as well as plastic resin pellets and plastic nanoparticles used in a variety of industrial processes (Lei et al., 2017; Anderson et al., 2016).

Table 2 Marine macroplastic litter types

Plastic resin type	Marine macroplastic litter item
Polyethylene (PE)	Plastic bags, storage containers, straws, stirrers
Polypropylene (PP)	Food containers, rope, bottle caps and strapping
Expanded polystyrene (PS-E)	Cool boxes, floats and cups
Polystyrene (PS)	Food utensils and containers
Polyvinyl chloride (PVC)	Film, pipe and containers
Polyamide (PA) or Nylon	Fishing nets and rope
Polyethylene Terephthalate (PET)	Bottles, strapping and textiles
Polyester resin + glass fibre	Textiles and boats
Cellulose Acetate (CA)	Cigarette filters

Adapted from Andrady (2015) and UNEP (2016)

1.1.2.2 Land-based sources and pathways of plastics to the ocean

It is estimated that 4.8−12.7 million metric tons of plastic litter entered oceans from land-based sources in 192 coastal countries in 2010 (Jambeck et al., 2015). Figure 6 demonstrates the portion of plastic litter produced and mismanaged globally. Pathways of plastic litter from land to the ocean pass through the entry points include rivers, coastline and atmosphere (GESAMP, 2016). Lebreton et al. (2017) estimate that between 1.15 million tons and 2.41 million tons of plastic litter enters the ocean from rivers annually. The potential source sectors of plastic litter entering the ocean via those entry points are listed in Figure 7, Figure 8 and Figure 9.

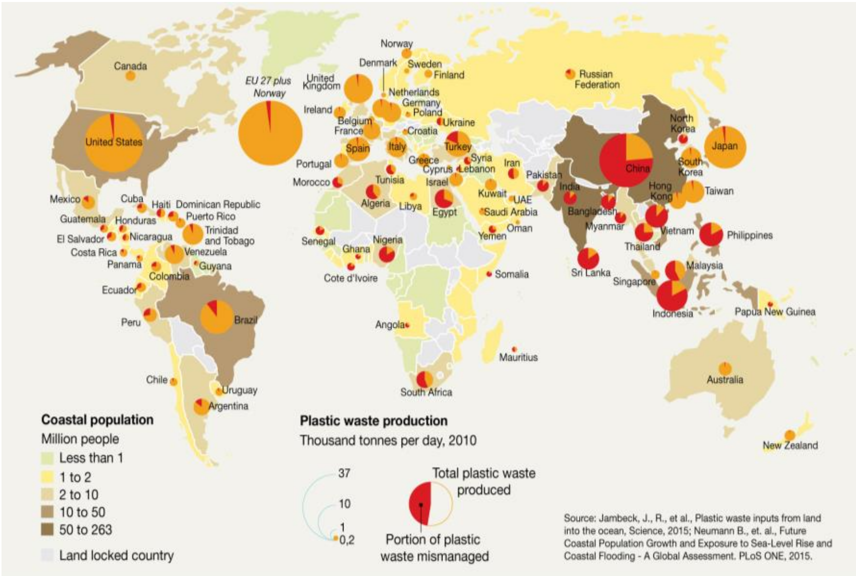

Figure 6 Plastic litter produced and mismanaged from land-based sources. Source: UNEP & GRID-Arendal (2016).

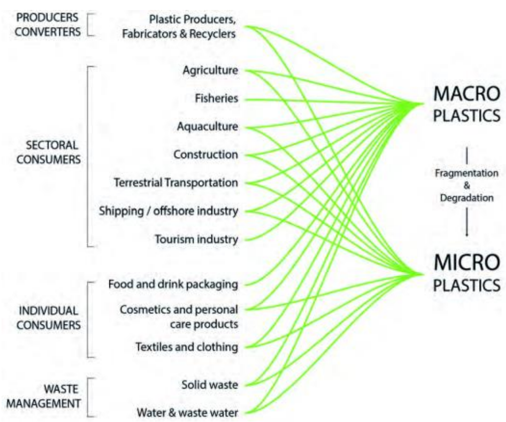

Figure 7 Potential source sectors of plastic litter entering the ocean via rivers. Source: GESAMP (2016).

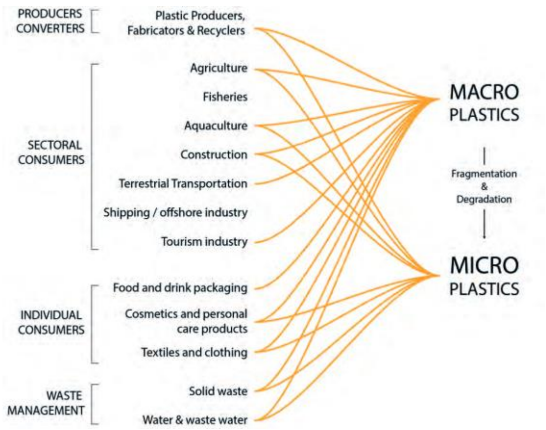

Figure 8 Potential source sectors of plastic litter enteing the ocean via coastline. Source: GESAMP (2016).

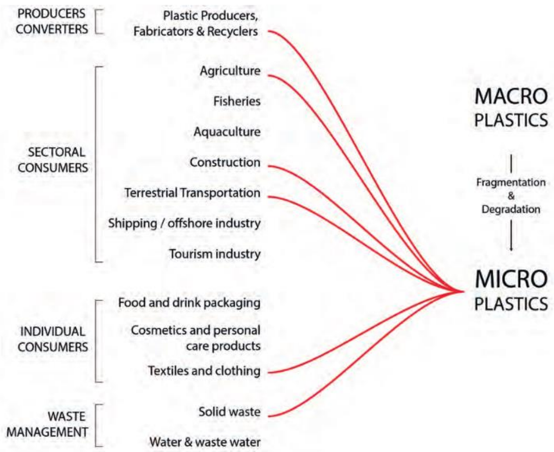

Figure 9 Potential source sectors of plastic litter enterting the ocean via atmosphere. Source: GESAMP (2016)

Land-based sectors generating macroplastics to the ocean

Macroplastics entering the ocean can come from a wide variety of land-based sources. Table 3 provides a number of main sectors identified as the sources of macroplastic litter from land and the typical entry points to the ocean.

Table 3 Source sectors of macroplastics from land to the ocean

Source sector	Macroplastic litter category	Entry points	Relative importance
Retail	Packaging, household goods and consumer goods	Rivers, coastline and Atmosphere	High
Food and drink	Single-use packaging	Rivers, coastline and Atmosphere	High

Source sector	Macroplastic litter category	Entry points	Relative importance
Households	Packaging, household goods and consumer goods	Rivers, coastline and atmosphere	High
Tourism industry	Packaging, household goods and consumer good	Rivers, coastline and atmosphere	High
Plastic recyclers	Packaging, household goods and consumer goods	Rivers, coastline and atmosphere	Medium
Construction	EPS and packaging	Rivers, coastline and atmosphere	Low
Agriculture	Films/sheets, pots and pipes	Rivers, coastline and atmosphere	Low
Terrestrial Transportation	End-of-life vehicles and tyres	Rivers and coastline	Low

Adapted from UNEP (2016) and GESAMP (2016)

Land-based sectors generating microplastics to the ocean

Microplastics entering the ocean can come from a wide variety of land-based sources. Table 4 provides a number of main sectors identified as the sources of microplastic litter from land and the typical entry points to the ocean.

Table 4 Source sectors of microplastics from land to the ocean

Source sector	Primary microplastics	Secondary microplastics	Entry points	Relative importance
Tourism industry		Fragmented packaging, household goods, consumer goods,	Rivers, coastline (incl. waste water), atmosphere	High
Food and drink		Fragmented single-use packaging	Rivers, coastline (incl. waste water), atmosphere	High
Plastic producers	Plastic resin pellets		Rivers, coastline (incl. waste water)	Medium
Terrestrial Transportation		Tyres wear dust	Rivers, coastline (incl. waste water)	Medium
Retail		Fragmented packaging, household goods, consumer goods	Rivers, coastline (incl. waste water)	Medium

Source sector	Primary microplastics	Secondary microplastics	Entry points	Relative importance
Households		Fragmented packaging, household goods, consumer goods	Rivers, coastline (incl. waste water)	Medium
	Personal care and cosmetic products (PCCPs)		Coastline (inc. waste water)	Medium
Cleaning ships' hulls, buildings	Abrasive powders		Rivers, coastline (incl. waste water)	Medium
Manufacturing	Powders for injection moulds, powders for 3D printing		Rivers, coastline (incl. waste water)	Low
Plastic recyclers		Fragmented packaging, household goods, consumer goods	Rivers, coastline (incl. waste water)	Low
Construction		Fragmented EPS, packaging,	Rivers, coastline (incl. waste water)	Low
Agriculture		Fragmented films/sheets, pots, pipes	Rivers, coastline, atmosphere	Low

Adapted from UNEP (2016) and GESAMP (2016)

Land-based pathways of macroplastics to the ocean

Macroplastics entering the ocean pass trough a wide variety of pathways. Figure 10 illustrates a simulation of pathways of some macroplastics from land to the ocean.

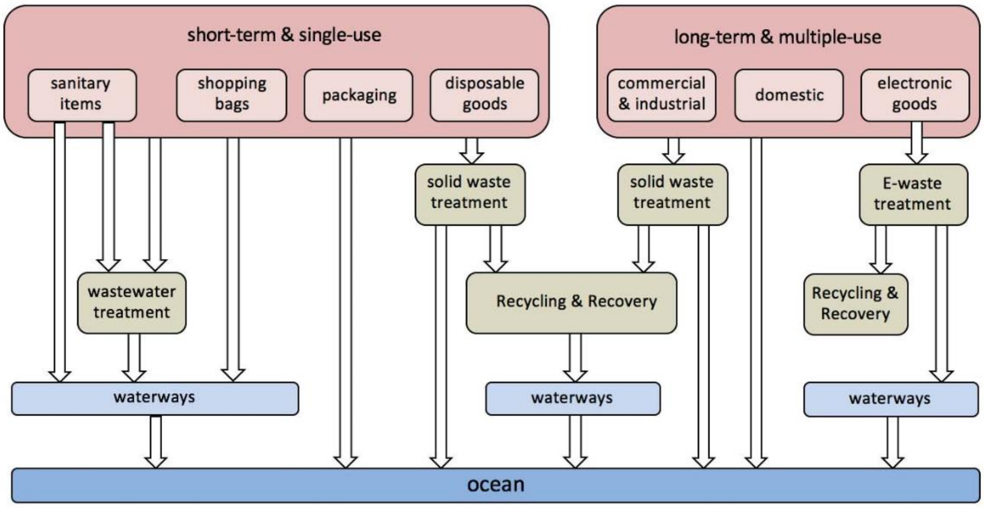

Figure 10 Pathways of macroplastics from land to the ocean. Source: UNEP (2016)

Land-based pathways of microplastics to the ocean

Microplastics entering the ocean pass trough a wide variety of pathways. Figure 11 illustrates a simulation of pathways of some microplastics from land to the ocean.

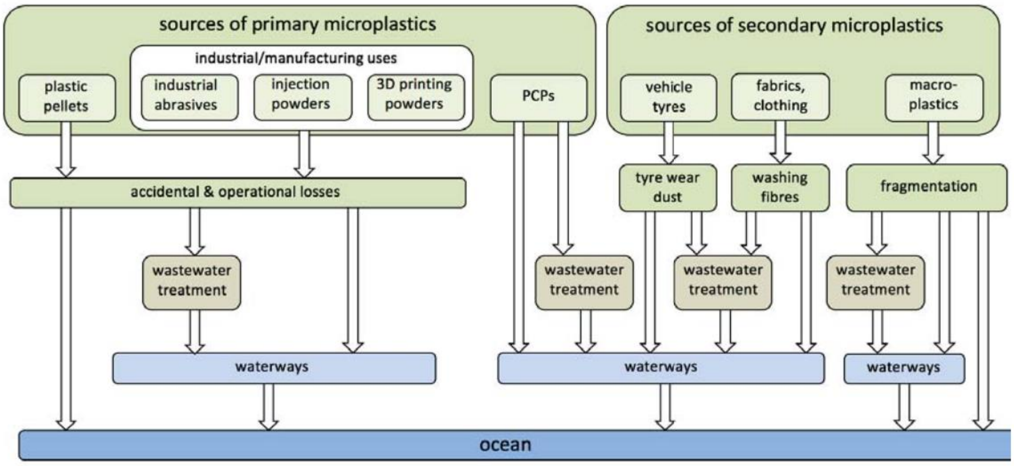

Figure 11 Pathways of microplastics from land to the ocean. Source: UNEP (2016)

1.1.2.3 Sea-based sources and pathways of plastics to the ocean

Plastic litter are not only possible from land into ocean but also from sea-based sources (GESAMP, 2016). The potential source sectors of plastic litter entering the ocean in the sea are listed in Figure 12.

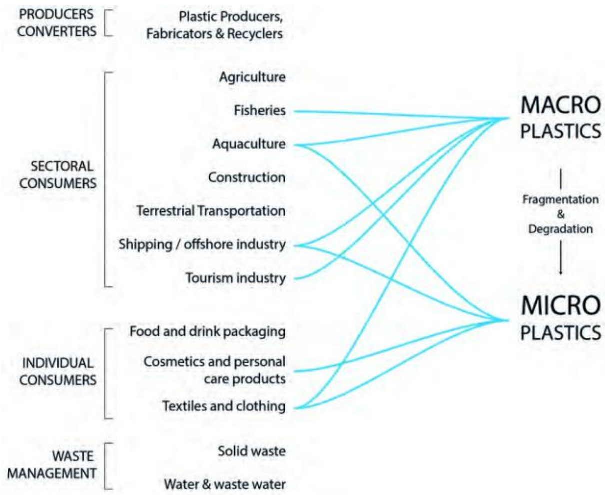

Figure 12 Potential source sectors of plastic litter entering the ocean in the sea. Source: GESAMP (2016)

Sea-based sectors generating macroplastics to the ocean

Macroplastics entering the ocean also come from a wide variety of sea-based sources. Table 5 provides a number of main sectors identified as the sea-based sources of macroplastic litter and the typical entry points to the ocean.

Table 5 Source sectors of macroplastics from sea to the ocean

Source sector	Description	Entry points	Relative importance
Marine Fisheries	Fishing gear, strapping bands, storage boxes, packaging, personal goods	Coastal, Marine	High
Aquaculture	Buoys, lines, nets, structures, storage boxes, packaging, personal goods	Coastal, Marine	Medium
Shipping/ offshore industry	Cargo, packaging, personal goods	Coastal, Marine	Medium
Ship-based tourism	Packaging, personal goods	Coastal, Marine	Medium

Adapted from UNEP (2016) and GESAMP (2016)

An estimate 640,000 tons of fishing gear lost to the marine environment every year globally (Richardson et al., 2018). The types of abandoned, lost or otherwise discarded fishing gear (ALDFG) which most often documented for 'ghost fishing' are gill nets, pots/traps, trawl nets and longlines (NOAA Marine Debris Program, 2015; Kim et al., 2014). It is estimated that ALDFG contributes 10 percent of total marine litter by volume globally (Macfadyen as cited in FAO, 2016). Pham et al. (2014) found that ALDFG (derelict fishing gear) accounted for 34 percent of the total marine litter in European seas.

Sea-based sectors generating microplastics to the ocean

Microplastics entering the ocean also come from a wide variety of sea-based sources. Table 6 provides a number of main sectors identified as the sea-based sources of microplastic litter and the typical entry points to the ocean.

Table 6 Source sectors of macroplastics from sea to the ocean

Source sector	Primary microplastics	Secondary microplastics	Entry points	Relative importance
Fisheries		Fragments and fibres from operational use of fishing gear, ropes	Coastline, Sea	High
Aquaculture		Fragments and fibres from operational use of nets, ropes and (EPS) buoys	Coastline, Sea	Medium
Shipping	Accidental loss of palstic resin pellets		Coastline, Sea	Medium
Ship-based tourism	PCCPs		Coastline, Sea	Low

Adapted from UNEP (2016) and GESAMP (2016)

Sea-based pathways of macroplastics to the ocean

Macroplastics are also possible entering the ocean pass trough the sea-based pathways. Figure 13 illustrates a simulation of pathways of some macroplastics from sea to the ocean.

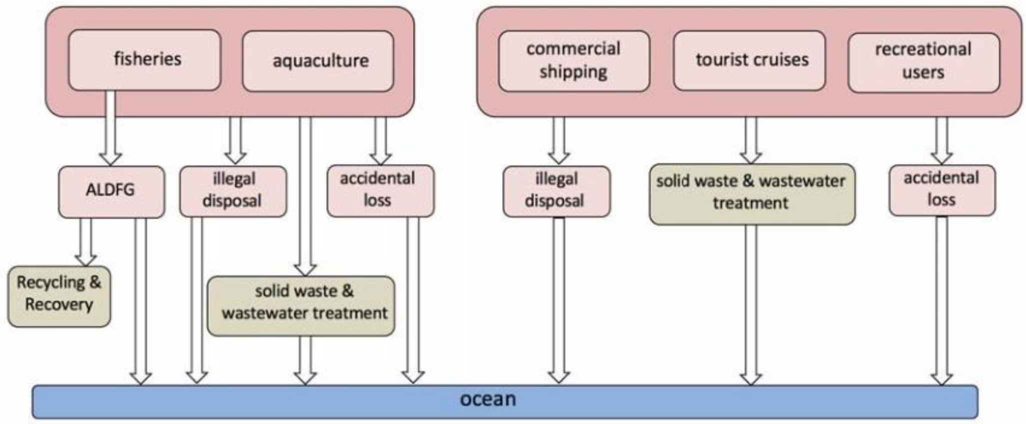

Figure 13 Pathways of microplastics from sea-based sources to the ocean. Source: UNEP (2016).

<u>Sea-based pathways of microplastics to the ocean</u>

Microplastics are also possible entering the ocean pass trough the sea-based pathways. Figure 14 illustrates a simulation of pathways of some macroplastics from sea to the ocean.

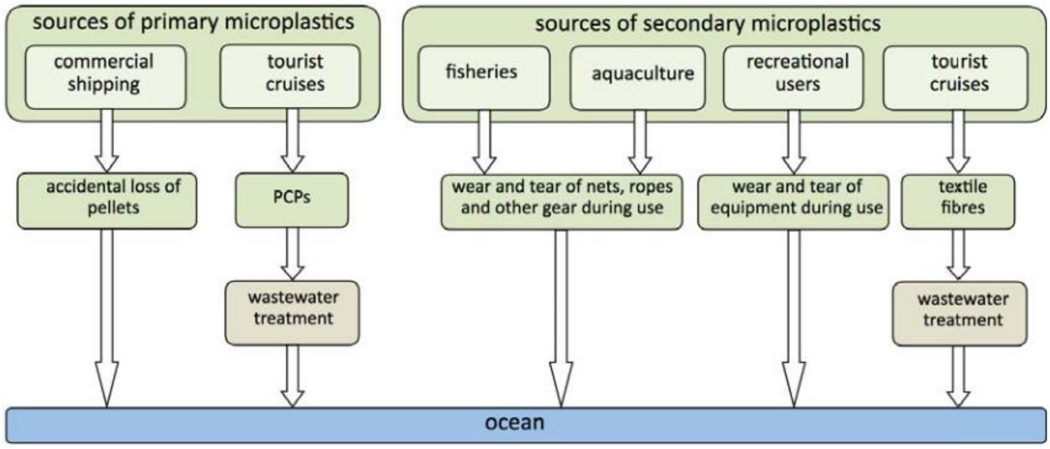

Figure 14 Pathways of microplastics from seab-based sources to the ocean. Source: UNEP (2016)

1.1.2.4 Behaviours of plastic litter in the ocean

Plastic litter particles can float on the sea surface, accumulate on the seafloor or on the shorelines (Pham et al., 2014). In the ocean, the particles also can be fragmented, degraded and ingested by marine biota as illustrated in Figure 15.

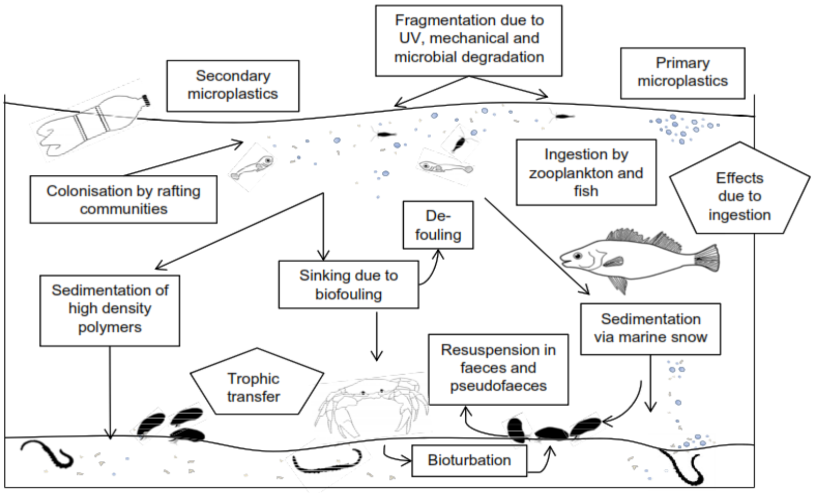

Figure 15 Marine plastic litter behaviours. Source: Wright et al. (2013)

Floating or sinking

Different densities of plastic resins determine they will be floating or sinking in the ocean relative to seawater densities (Reisser, 2015). The densities of common plastics range from 830 to 1380 kg m-3 (Bag et al., 2003; Andrady, 2015). The density of pure water is 1000 kg m-3 and for surface oceanic density vary from 1020 to 1030 kg m-3 depending on the temperature, salinity and ocean depth (Brown, 2016). Plastics with higher density than sea surface density such as those composed of polyvinyl chloride (PVC) and polyethylene (PET) are more likely to sink (GESAMP, 2016). However, the buoyancy of a plastic particle will be dependent on other factors like entrapped air, water currents, turbulence and biofouling (UNEP, 2016; Ryan, 2015).

Fragmentation and degradation

Fragmentation is a physical and mechanical process which breaks larger pieces of plastic litters into numerous smaller plastic fragments due to UV photodegradation, mechanical forces, oxidation, hydrolysis, microbial biodegradation (Ter Halle et al., 2016; Mendoza et al., 2018; Andrady, 2015; Song et al., 2017) or fish bites (Kühn et al. 2015). Fragmentation refers to a process of breaking down size of plastic particles instead of altering densities of the particles (GESAMP, 2016). In contrast, degradation (e.g. photodegradation and biodegradation) alters the properties of plastic particles to be decreased in molecular weight and particle densities, lost in tensile and compression properties, lost in surface properties (e.g. discoloration and cracking) and changed in spectral characteristics (Andrady, 2015; Biber et al., 2018). Biber et al. (2018) noted that degradation of plastics occurred much more slowly in seawater than air.

Retention in biota and sediment

Plastic retention in marine biota and sediment initiated since the plastic floated in the sea. Buoyant plastics may be transported to seabed by biofouling (Ryan, 2015; Fazey & Ryan, 2016), ingestion by vertically migrating species (Choy & Drazen, 2013), or sinking within phytoplankton marine aggregates (Long et al. 2015) or zooplankton fecal pellets (Cole et al. 2016). Martin et al. (2017) state that bioturbation, trawling and tidal forcing can influence the distribution of plastic debris within marine sediments and water column.

1.1.3 Distribution and impacts of marine plastic litter in a global perspective

Marine plastic litter have become a global challenge today. It can be found in the coastal and marine environment around the world, either macroplastics or microplastics (Law, 2017).

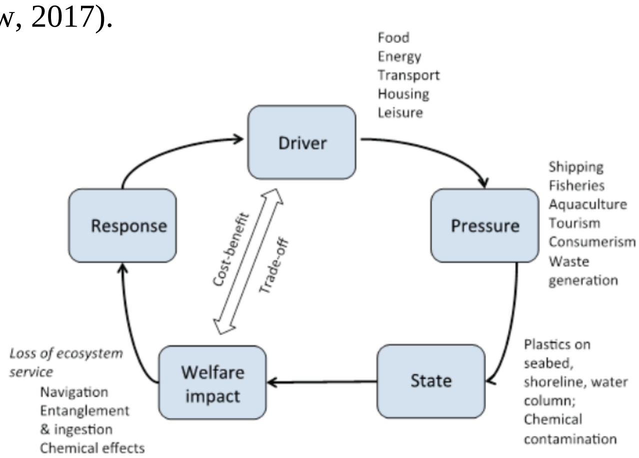

Figure 16 DPSIR/DPSWR model as applied to the generation and potential impacts of marine plastic litter. Source: GESAMP (2016).

The basic need of human beings such as food, energy, transport, housing and leisure drive anthropogenic activities include shipping, fisheries, tourism, consumerism and waste generation sectors (UNEP, 2016). These sectors are the pressures since releasing plastic litter to the marine ecosystems, includine shoreline, water column, seabed and biota. Therefore, lost of ecosystem services, pollution and hazardous impacts to biota happen in the marine environment as illustrated in Figure 16 (GESAMP, 2016). In Section 1.1.3, global distribution and impacts of marine plastic litter are discussed.

1.1.3.1 Global distribution of marine plastic litter

Nowadays, the ocean has been polluted by plastic litter globally. Eriksen *et al.* (2014) estimate there are at least 5.25 trillion floating plastic particles in the world's ocean weighing 268,940 tons. The floating plastic particles transported by ocean currents to flow back along shorelines and flow towards the subtropical convergence zones called garbage patches or oceanic gyres where the particles accumulate (Cozar et al., 2014; Lachmann et al., 2017). The gyres include South Pacific Ocean Gyre, North Atlantic Ocean Gyre, North Pacific Ocean Gyre, South Atlantic Ocean Gyre and Indian Ocean Gyre (Cozar et al., 2014). Figure 17 shows the buoyant plastic concentration in the global ocean, particularly in the oceanic gyres. Ellen MacArthur Foundation’s (2016) study forecasts that there could be more plastic than fish in the ocean, by weight, in 2050 unless notable actions are taken.

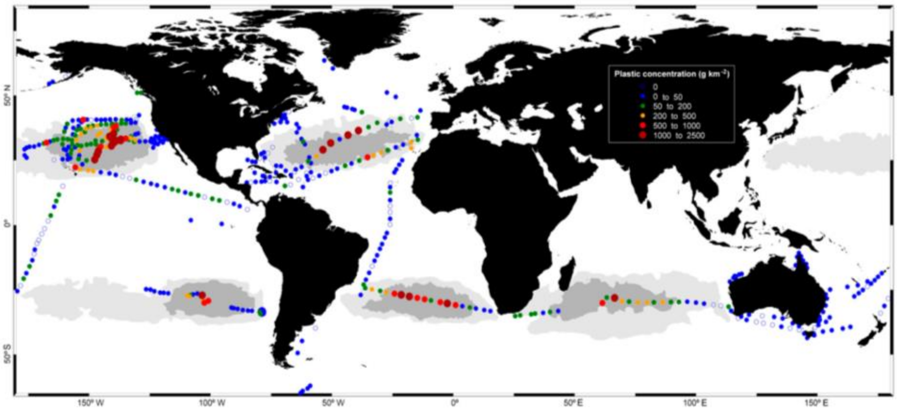

Figure 17 Concentration of plastic litter in surface waters of the global ocean. Source: Cozar et al. (2014)

Global plastic marine litter distribution, by density, in the Large Marine Ecosystems (LMEs) also have been illustrated by UNEP (2016) as shown in the Figure 18.

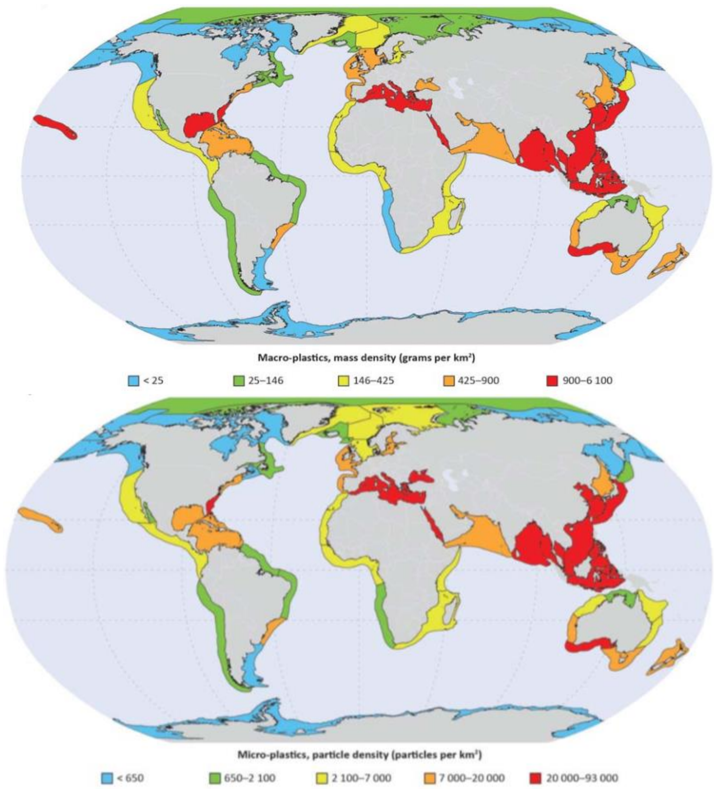

Figure 18 Distribution of plastic litter abundance on the ocean surface. Source: UNEP (2016).

Plastic pollution on the sea surface dominated by particles smaller than 1 centimeter in diameter (Hidalgo-Ruz et al., 2012). Beside floating on the sea surface, plastic particles also found in the ocean sediments. Van Cauwenberghe et al. (2015) found the abundance of up to 1 microplastic per 25 cubic centimeters in deep-sea sediments collected at four locations representing different deep-sea habitats ranging in depth from 1,100 meters to 5,000 meters.

1.1.3.2 Ecological impacts of marine plastic litter

The ecological impacts of marine plastic litter are reviewed in Subsection 1.1.3.2 include marine habitat damage, ingestion of plastic by animals, marine biota entanglement, provision of transport substrate for marine organisms and global warming.

Habitat damage

Studies have reported that plastic litters in the marine environment can damage many habitats, for instance, coral reefs (Sheehan et al., 2017), mangroves (Smith, 2012), seagrasses (Clark et al., 2012) and sandy beaches (Carson et al., 2011).

Lamb et al. (2018) indicate that exposure to plastic intensifies the risk of diseases in corals from 4% to 89%. This is supported by researches that found corals ingest microplastics in the seawaters (Ter Halle et al., 2016; Allen et al., 2017). Derelict fishing gears are causing tissue loss and fragmentation of coral reefs in Gulf of Thailand (Valderrama Ballesteros et al., 2018). At the Goiana Estuary, Brazil and Mumbai, India, plastic litters entering the mangrove creeks get entangled among the roots and retained for long periods, in result, blocking the tidal flow, contaminating the feeding sites of many animals and disrupting the larval development of associated fauna (Ivar do Sul et al., 2014; Kantharajan et al., 2018). Uhrin et al. (2014) explain that plastic litter can damage seagrasses by breaking and corroding stems or denuding whole parts of seagrass beds. Amounts of plastic litter found on sandy beaches affect the physical properties alterations (i.e. increased permeability and lowered subsurface temperature) of sediments at Hawaiian beaches which lead to the changes of beach biota community structure (Carson et al., 2011).

Ingestion

Ingestion of plastic litter may be accidental, intentional or indirect (from lower trophic organisms that have ingested plastic) by seabirds and marine biota ranging in size from microorganism (such as planktonic invertebrates and corals) to megafauna (such as marine mammals and sea turtles) (Law et al., 2017; Allen et al., 2017). Chemical signature (odours) of plastic particles in the sea can induce foraging behaviour in achovy schools (Savoca et al., 2017) and procellariiform seabirds (Savoca et al., 2016). Table 7 lists some impacts of marine plastic litter ingestion on marine animals.

Table 7 Impacts of marine plastic litter ingestion on marine animals

Animal species	Location	Predominant plastic litter type	Impact	Study
Spheniscus magellanicus (Penguins)	Beaches in Lagos, Brazil	Plastic sheets, fishing nets	Perforated gut, death	Brandão et al. (2011)
Arenicola marine (Lugworms)	*Laboratory*	Microplastics	Reduced biochemical functions, death	Browne et al. (2013)
Physeter macrocephalus (Sperm whales)	Mediterranean sea	Plastic materials from greenhouse (e.g. cover material, plastic burlap, mulch)	Gastric rupture, death	de Stephanis et al. (2013)
Tigriopus japonicus (Copepods)	*Laboratory*	Microplastics and nanoplastics	Death	Lee et al. (2013)
Pomatoschistus microps (Fish)	Minho River estuary, Portugal	Microplastics	Reduced biochemical functions	Oliveira et al. (2013)
Daphnia magna (Fish)	*Laboratory*	Nanoplastics	Brain damage and behavioural disorders	Mattsson et al. (2017)
Caretta caretta (Sea turtles)	Azores, North Atlantic subtropical gyre	Microplastics, plastic sheets, plastic pellets	Plastic accumulation in gut, starvation, reduced population size	Pham et al. (2017)
Calonectris borealis (Seabirds)	Catalan coast, western Mediterranean sea	Plastic fragments and filaments	Plastic accumulation in stomach, starvation	Codina-García et al. (2013)

Entanglement

Entanglement refers to litter twining, constricting, ensnaring and ghost fishing a marine fauna, in particular, by ALDFG, balloons and plastic bags (Law, 2017; FAO, 2016; Wilcox et al., 2016). Some studies have identified that marine animals, for instance, grey seals (Allen et al., 2012); invertebrates, fish, seabirds (Good et al., 2010); gorgonians (Pham et al., 2013); sea turtles (Duncan et al., 2017); and whales (Meÿer et al., 2011) entangled by ALDFG. Entanglement affecting marine animals to suffer constriction, dermal wound and death (Law, 2017). He & Suuronen (2018) identified that ALDFG does not only waste valuable marine resources but also harms some of the most endangered marine species.

Provision of transport substrate for marine organisms

Several studies have identified that marine plastic litters provide substrates for marine organisms, including invertebrates and bacteria (Widmer & Hennemann, 2010; Goldstein et al., 2012, Oberbeckmann et al., 2016). Marine plastic fragments can host diverse communities and some of them are alien and infectious species (Zettler et al. 2013; Baker-Austin et al., 2013). This is because of the creation of new habitats which may drift long distances and transport invasive species and bacteria in the ocean (Barnes et al. 2009; Oberbeckmann et al., 2018). In the smaller size range, microplastic in seawater develops a thin biofilm that includes a diverse microbe communities which encourages the attachment of larger organisms that use chemical and/or physical properties as a signal to settle (Zardus et al. 2008; Hadfield et al. 2014).

Global warming

In addition to impacts of plastics to the environment, Royer et al. (2018) noted that plastics in seawater produce hydrocarbon gases, namely methane (CH_4), ethylene (C_2H_4), ethane (C_2H_6) and propylene (C_3H_6). Although the production of hydrocarbon gases in air is much higher than in water, the production continues in the dark and may continue throughout the lifetime of plastic in the ocean (Royer et al., 2018). Methane is one of the most potent greenhouse gases which causes global warming (Saunois et al. 2016).

1.1.3.3 Social impacts

The social impacts of marine plastic litter are reviewed in Subsection 1.1.3.3 include human health and food safety reduction, loss of income and loss of intrinsic value.

Human health and food safety reduction

Plastics contain many chemical additives and monomers such as Bisphenol-A (BPA), DBP, DEP, DEHP, HBCD, pthalates and PBDEs which are a serious risk factor for human health (Proshad et al., 2018). Plastics are being used by human with the potential impacts to health, such as oxidative stress, immune response, endocrine disruption, changes to the reproductive systems, hepatotoxicity and neurotoxicity (Hannon et al., 2015). Several health problems can be suffered by human if there is a plastic content enter body (via food and drinks) or contact to skin (via contaminated water during washing), for instance, irritation in the eye, skin irritation, respiratory problems, liver dysfunction and cancers (Proshad et al., 2018; Revel et al., 2018).

Wright & Kelly (2017) noted that plastics have contaminated seafood such as bivalves in China and mussels in Canada and Belgium with plastic types of PET, PS, PP and PE. Other studies also have identified some food commodities are contaminated by plastic, for instance, blue mussel in North Sea (Van Cauwenberghe & Jansen, 2014) and salts in China (Yang et al., 2015). Therefore, the food safety is reduced.

Loss of income

UNEP (2016) considers that loss of income as a social cost which directly affects individuals and communities. For example, in the fisheries sector, it is assumed that the value of fish contaminated or damaged by plastics will be lower which may reduce fishermen's income (UNEP, 2016). In the tourism sector, the presence of marine litter can discourage tourists to visit beach, which in turn leads to lost income and jobs in the tourism businesses (UNEP, 2016). For example, because of the large amount of marine litter on the beaches of Geoje Island in South Korea, following a period of heavy rainfall, the visitor number decreased from 890,435 in 2010 to 330,207 in 2011 caused the tourism revenue loss of the island was estimated to be US$29-37 million (Jang et al., 2014).

Loss of intrinsic value

The loss of intrinsic value comprises people's behaviour which is not responsive to a degradation of the environment (UNEP, 2016). For example, Keizer et al. (2008) noted that people are more probable to litter if the environment setting is littered and/or if they watch someone litter.

1.1.3.4 Impacts on maritime economic sectors

The impacts on maritime economic sectors are reviewed in Subsection 1.1.3.4 include fisheries and aquaculture, marine tourism and commercial shipping sectors.

Fisheries and aquaculture

The impacts of marine plastic litter on fisheries and aquaculture include the damage to fishing vessels and equipment and the reduction of potential catches or sales resulting from plastics (GESAMP, 2016). McIlgorm et al. (2011) have noted that floating plastics frequently affecting engine cooling systems and becoming entangled in propellers. Scheld et al. (2016) estimated that the yearly loss due to derelict fishing gears for nine species of crustacea amounted to US$ 2.5 billion in Chesapeake Bay. Van der Meulen et al. (2014) estimated that an annual loss of up to 0.7 % of the income for aquaculture sector in the UK due to microplastics.

Marine Tourism

The presence of marine plastic litter has an impact on the aesthetic value of coastal tourism areas. This visual inconvenience can decrease some personal benefits from coastal environments, for instance, physical health enhancement, stress reduction and concentration improvement as well as might be a reason not to visit certain beaches (White et al. 2013). Van der Meulen et al. (2014) projected that total regional beach cleaning costs ranging between $188,735 and $2.5 million (GBP 100,000 and 1.5 million) every year in Devon and Norfolk, UK.

Commercial shipping

The impacts on this sector include the damage to vessels like propellers and cooling systems which causes potential loss of productivity and revenues from delays or accidents affecting supply chains (GESAMP, 2016).

1.2 Marine plastic litter challenges in Indonesia

In 2010, Indonesia had a coastal population of 187.2 million who live within 50 km of the coast and generating 3.22 million tons of mismanaged litter yearly and leaking 0.48-1.29 million metric tons plastic litter per year to the ocean which come from industry, household waste and tourism activities (Jambeck et al., 2015). Subchapter 1.2 discusses marine plastic litter concentration and its impacts in Indonesia including in the 'New Balis'.

1.2.1 Marine plastic litter concentration in Indonesia

Marine plastic litter in Indonesian marine areas is very high in concentration. The micro-plastic density is estimated of 20,000-93,000 particles per square kilometer and macro-plastic density of 900-6,100 gram/km^2 (UNEP, 2016). World Bank Technical Team (2018) has assessed the marine litter leakage of the 15 target cities in Indonesia, which were selected based on urbanization trends, proximity to the coast, population size and presence of container ports and/or tourism activities. Table 8 shows the litter composition found in waterway waste streams of 15 cities in Indonesia. Lebreton et al. (2017) estimate that an annual emission of 200,000 tonnes of plastics (14.2% of global total) to the ocean from Indonesian rivers and streams, mainly coming from the Islands of Java and Sumatra.

Table 8 Litter composition in waterway waste streams of 15 cities in Indonesia

Categories/ Cities	Jakarta	Makassar	Manado	Balikpapan	Surabaya	Semarang	Medan	Yogyakarta	Bitung	Batam	Denpasar	Padang	Mataram	Pontinanak	Bandar Lampung	Average
Diapers	12.9	23.7	26.4	7.7	31.1	10.2	14.9	0.4	16.3	15.9	11.9	0.8	8.7	12.8	9.5	13.5
Other organic waste	52.1	29.9	50.4	55.4	33.3	54.2	57.9	60.9	45.4	49.5	59.4	83.0	55.2	64.1	50.6	53.4
Glass, metals, inert	5.39	1.7	4.7	2.9	2.1	0.2	4.6	4.4	13.0	7.8	4.6	2.6	3.5	2.6	1.7	4.1
Plastic bottles	2.4	0.3	3.1	1.0	0.4	0.6	0.4	0.0	2.3	0.6	1.2	0.6	0.4	0.6	0.1	0.9
Plastic cups	0.6	2.6	1.6	0.5	0.6	1.3	0.7	0.0	1.4	2.2	0.93	1.1	0.3	0.7	0.1	1.0
Plastic bags	21.6	25.4	7.6	14.1	17.9	14.0	6.3	7.2	9.4	15.2	13.4	4.1	12.4	10.8	22.5	13.5
Plastic Packaging	4.1	14.4	3.3	10.7	14.2	17.1	12.4	3.3	7.4	6.4	7.1	6.3	13.5	6.3	2.3	8.6
Other plastics	0.9	2.1	3.2	7.8	0.5	2.4	2.9	23.8	4.8	2.5	1.7	1.6	6.0	2.2	22.9	5.7
% Plastics	**29.5**	**44.7**	**18.5**	**38.8**	**33.5**	**35.3**	**22.7**	**39.3**	**25.3**	**26.7**	**24.2**	**13.6**	**32.6**	**20.6**	**29.4**	**29.0**

Source: World Bank Technical Team (2018)

A report of Ocean Concervancy (2018) based on the International Coastal Cleanup 2017 event recorded that 95,051 litter items weighing 2,155 kilograms collected from 80 kilometres of beach in Indonesia, with the top 3 litter types are cigarette buts, food wrappers and straws. Syakti et al. (2017) observed that plastic material made up more than 75% of 2,313 litter items collected during a three-year survey in Cilacap Bay, Indonesia. The most abundant plastic materials were found namely PP (68%) and PE (11%) with microplastic concentration of 2.5 mg/m^3 in seasurface of the coastal waters (Syakti et al., 2017).

1.2.2 Impacts of marine plastic litter in Indonesia

The marine plastic litters presence has been identified in Indonesian seawaters. However, researches on the marine plastic impacts are limited. Some studies show that marine fish ingested plastic litter. Tahir & Rochman (2014) found that 4 of 10 fish collected at Paotere Fish Market in Makassar, contained plastic particles in their digestive tract (gut). In another study, Plastic debris was found in 28% of individual fish and in 55% of all observed species (11 species) in Makassar fish market (Rochman et al., 2015).

Plastics in Indonesian seawaters also affect the habitat damage. The plastic impacts on seagrass and its associated biota have been observed such as broken leaves, tissue abrasion and organism assemblage on stranded marine plastic litter (Hermawan et al., 2017). Hoeksema & Hermanto (2018) found various discarded plastic nets have become the substrate for corals in Lembeh Strait, however, these nets are not unstable and unnatural substrate, so it was found that some corals had dropped down on the net which attached to the net.

1.2.3 Marine plastic litter issues in the 'New Balis'

Marine plastic litter issues in the 'New Balis' are described in Section 1.2.3 by explaining the 'New Balis' definition and tourism sector's contribution in Subsection 1.2.3.1 to argument these areas should be protected from marine plastic pollution. Then, Subsection 1.2.3.2 documenting current marine plastic litter management in the 'New Balis' with a study case in Labuan Bajo.

1.2.3.1 The ‘New Balis’ and tourism sector

The President of Republic of Indonesia, Mr. Joko Widodo instructed the Minister of Tourism, other Ministers related to tourism affairs, and the Heads of Local Governments where the 10 national tourism destinations located, to focus on the reparation and to ensure the actual progress in these prioritized tourism destinations development in November 2015 (Ratman, 2016). In February 2016, the Ministry of Tourism proposed these 10 national tourism destinations to be promoted as the ‘New Balis’ with the expectation that the new destinations would attract as many tourists as those visting Bali Island, Indonesia (Purwanto, 2016).

In the Indonesian Government Work Plan 2017, these tourism destinations have been defined to consist of three terrestrial tourism destinations, namely Lake Toba (North Sumatra); Borobudur Temple (Cetral Java); also Bromo, Tengger and Semeru (East Java); as well as seven marine tourism destinations, namely Labuan Bajo (East Nusa Tenggara), Tanjung Kelayang (Bangka Belitung), Wakatobi (Southeast Sulawesi), Seribu Islands (Jakarta), Tanjung Lesung (Banten), Mandalika (West Nusa Tenggara) and Morotai Island (North Moluccas). Figure 19 shows the locations of ‘New Balis’.

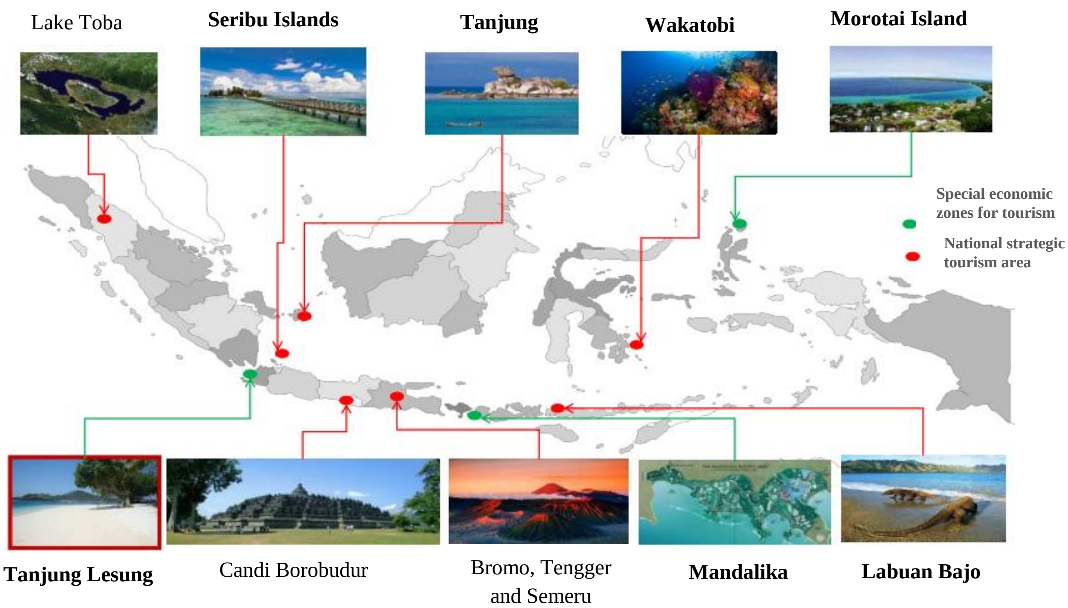

Figure 19 Locations of the ‘New Balis’. Source: BAPPENAS (2017)

The 'New Balis' development is a national strategic project to boost national income from tourism sector (Purwanto, 2016). This is because tourim is a rapidly growing economic sector in Indonesia indicated by its total contribution along with travel to gross domestic product (GDP) which increased significantly over the last decade and is predicted to reach more than 1,400 trillion IDR or equal to 101.78 billion USD in 2027 as shown in Figure 20 (WTTC, 2017).

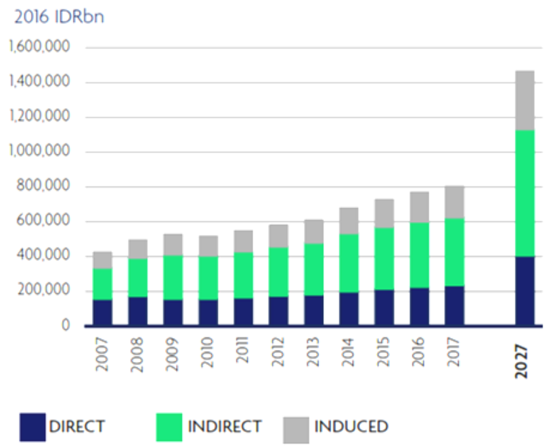

Figure 20 Total contribution of travel and tourism to Indonesia GDP over the last decade. Source: WTTC (2017)

1.2.3.2 Current marine plastic litter management in the 'New Balis'

The description of current marine plastic litter management in the 'New Balis' on this subsection based on the interviews to some stakeholders in Labuan Bajo, one of the 'New Balis'. It is located in the Province of East Nusa Tenggara.

It is indicated that the main sources of marine plastic litter in Labuan Bajo are household waste, single-use food and drinks packaging (e.g. styrofoam and water bottles) and plastic bags. The recommended interventions which are easiest to do include use and bring the reusable drinking bottles when going to the office and reusable shopping bags when going to shop, also avoid to use styrofoam and plastic for food packaging.

There are some promising methods to address marine plastic litter which are suggested, include society empowerment and involvement, waste bank, single-use plastic reduction, also litter sorting, pressing (by machinary) and recycling. To reduce the dependency of communities on plastics, some methods are proposed, encompassing education to people, bring own reusable drinking bottle and shopping bags. The major challenges are happened such as public awareness and the ease of getting plastic bags from markets and restaurants.

Some efforts are suggested to be done by organizations and institutions in addressing marine plastic litter, mainly implementation of the role to avoid plastic usage during meetings and at cafetaria, collaboration in managing litter and socialization to families and fishermen about litter management. To measure effectively the progress of plastic litter reduction, some methods are suggested, including no litter found in the public places, no litter found after meeting and public events also many village and household sorting the litter. The next plans that will be done by stakeholders in Labuan Bajo include socialization to communities, integrated litter management and empowerment of 'community cares litter'.

1.3 An overview of the National Action Plan for Marine Litter Management 2018-2025

Indonesian government stated that had put in place a robust National Plan of Action on Marine Plastic Debris as the road map to address 70% of marine plastic litter by 2025 during the Session of Our Ocean Leadership at Our Ocean Conference 2017 in Malta. This plan experienced a revision and finalization process over time. Since September 2018, the National Action Plan for Marine Litter Management 2018-2025 has been established and promulgated. This National Action Plan is designed as an annex to the Presidential Decree Number 83 of 2018 on Marine Litter Management. It contains three key aspects of interventions and five strategies of actions which explained in Subchapter 1.3.

1.3.1 Key aspects of interventions

There are three key aspects of interventions have been identified on the National Action Plan, namely societal effort, technological application and institutional coordination (CMMA, 2017). The significant societal efforts are important to reduce, recycle and reuse plastic litter to be done since an early age, whereas technological interventions are necessary to control plastic litter, including the application of science-based management (CMMA, 2017).

The Presidential Decree regulates the National Action Plan should be also implemented by institutional coordination which involves human resources from various sectors and institutions. The national coordination for implementing the National Action Plan is led by a Coordinating Minister for Maritime Affairs whom assisted by a Minister for Environment and Forestry as the Person in Charge (PIC) of the National Coordinating Team. The National Coordination Team involves 14 Ministers, the Head of Maritime Security Agency and the Cabinet Secretary. The coordinating team is responsible to the Indonesian President.

1.3.2 Strategies, programs and goals

The National Action Plan for Marine Litter Management 2018-2025 consists of five strategies of actions, namely 1) National Movement to raise awareness among stakeholders, 2) Land-based litter management, 3) Litter management at sea and coasts, 4) Funding mechanism, institutional strengthening, monitoring and law enforcement, and 5) Research and development. Each strategy contains programs and goals to be implemented. In total, this plan contains 13 programs and 56 goals of actions.

1.3.2.1 Strategy 1: National Movement for raising awareness of stakeholders

Stakeholder awareness is important to the acceptance of and involvement in the National Action Plan (CMMA, 2017). This strategy consists of 2 programs and 12 goals as described in Sub-Chapter 4.1.

1.3.2.2 Strategy 2: Land-based litter management

Land-based litter management is important to early anticipate plastic litters entering the ocean. The focus areas of management include watersheds areas, upstream industry and downstream industry. This strategy consists of 3 programs and 18 goals as described in Sub-Chapter 4.1.

1.3.2.3 Strategy 3: Litter management at sea and coastal areas

Litter management at sea and coastal areas include sea transport, marine tourism, marine fisheries and aquaculture, as well as coast and small islands activities. This strategy consists of 3 programs and 15 goals as described in Sub-Chapter 4.1.

1.3.2.4 Strategy 4: Funding mechanism, institutional strengthening, monitoring and law enforcement

This strategy includes diversification of funding schemes outside the state and regional budget for income and expenditure, strengthen institutions and effectiveness improvement of supervision and implementation of law enforcement. This strategy consists of 3 programs and 7 goals as described in Sub-Chapter 4.1.

1.3.2.5 Strategy 5: Research and development

Research and development strategy aims to encourage management innovation and solution for marine litter pollution. This strategy consists of 1 program and 4 goals as described in Sub-Chapter 4.1.

1.4 Aims and objectives of research

1.4.1 Aims

This research aims to to provide recommendations for addressing marine plastic litter in the 'New Balis' of Indonesia sustainably through technological interventions in the framework of the National Action Plan for Marine Litter Management 2018-2025.

1.4.2 Objectives

The objectives of this research are:

a. to review marine plastic litter issues globally and in Indonesia,
b. to review technological interventions from around the world and Indonesia for marine plastic litter management,
c. to map the relevant technological interventions towards the National Action Plan for Marine Litter Management 2018-2025,

d. to identify strengths, weaknesses, opportunities and threats (SWOT) of the potential impacts of technological interventions for managing marine plastic litter in the ‘New Balis’,
e. to document the current status of marine plastic litter management in the ‘New Balis’ of Indonesia, focused on Labuan Bajo,
f. to formulate recommendations for implementing the National Action Plan in the ‘New Balis’ sustainably

1.5 Methodology

1.5.1 Literature review

A systematic literature review was conducted, focussing on peer reviewed publications and reports in grey literature mostly from 2010 to 2018. Electronic key word searches were performed using ScienceDirect, Google Scholar, WMU Library and Google websites. Key words used for marine plastic debris, including marine plastics, marine litter, plastic production, additive chemicals in plastic, plastic impacts, plastic entanglement, plastic ingestion, habitat damage, derilict fishing gears and gyres; for technological interventions, including plastic into fuel, plastic into electricity, plastic vehicles, microbe enzymes for plastic, technology innovation, plastics into roads, marine plastic mobile games. After that, looking at the abstract or conclusion of published journal articles and reports. The reference list refers only to those references mentioned within this text and is not a full list of all reviewed papers. In addition, official website of the organizations and companies, as well as trusted and actual online news articles are also reviewed.

1.5.2 Semi-structured interview

Semi-structured review conducted to document current marine plastic litter management in the ‘New Balis’ with Labuan Bajo as a sample and there were 6 people whom interviewed with 10 questions. They were selected based on their expertise or experience in managing marine plastic litter.

1.5.3 Formulation of recommendations

The proposed recommendations for addressing marine plastic litter in the 'New Balis' formulated based on the results of technological interventions review, technological interventions mapping towards the national action plan, as well as identification of strengths, weaknesses, opportunities and threats (SWOT) of potential impact after intervening technologies in the 'New Balis'. The aspects of sustainable tourism and international partnerships are also recommended to be considered by Indonesian government and related stakeholders.

2 Technological interventions to address marine plastic litter: Lessons from around the world

Chapter 2 discusses the technological interventions to address marine plastic litter around the world as the lessons to formulate the recommendations for addressing marine plastic litter in the 'New Balis'. This chapter is divided into three Subchapters following the three first strategies of the National Action Plan, which discusses the technological interventions to raise awareness among stakeholders, to address land-based litter and to address litter at sea and coastal areas.

2.1 Technological interventions to raise awareness among stakeholders

2.1.1 Educating through websites and social networks

World wide web (WWW) is defined as a techno-social system to interact humans based on technological networks (Aghaei et al., 2012). Fuchs et al. (2010) state the goals of this system to enhances human cognition, communication, and co-operation (Fuchs et al., 2010). Website is a location connected to the internet that maintains one or more pages on the WWW. Website aims to publish the information for anyone at any time and establish an online presence (Aghaei et al., 2012). Social networks have an important role in changing the way humans communicate. Now, humans can interact, consume news information, and various other things from all over the world from one application of social networks.

2.1.1.1 The most popular social networks around the world

There are top six sites which have minimum of 1 billion active users, namely Facebook, YouTube, WhatsApp, Facebook Messenger, WeChat and Instagram (We Are Social, 2018). Figure 21 shows a number of most popular social network sites globally.

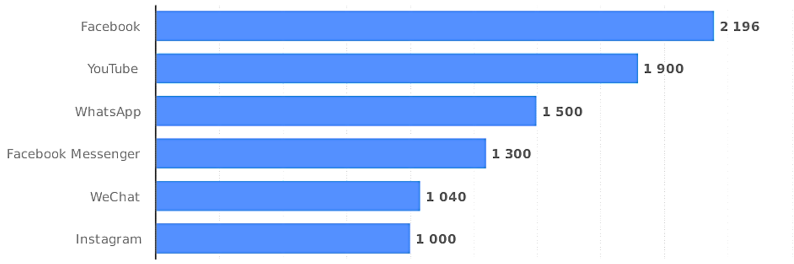

Figure 21 Most popular social network sites worldwide as of July 2018, ranked by number of active users (in millions). Adapted from We Are Social (2018).

2.1.1.2 Websites and social networks usage to educate people in addressing marine plastic litter around the world

Websites and social networks have been used by international NGOs to campaign of plastic reduction, reuse and recycling; to do not litter at beaches rivers and the sea; to clean rivers, seas and beaches from plastic litter; to share knowledge of the importance of marine and coastal ecosystems; and to share the knowledge of the plastic litter impacts to marine environment and human health. Some global organizations have been identified that have been doing these educational efforts through their websites and social networks, such as Plastic Change, Plastic Oceans International, Greenpeace International, Surfrider Foundation, Oceana, 5 Gyres, Algalita and WWF International. Among intergovernmental organizations, there are some UN specialized agencies and partnerships which actively online campaign and share knowledge related to marine plastic litter, namely FAO, UNEP, IMO and IOC-UNESCO.

Social media has been widely used to increase awareness about reducing marine litter out. Plastic Change is a Danish organization working globally. They raise awareness about the consequences of the increasing plastic pollution in the oceans and the environment in general (Plastic Change, 2018). Website and social networks are their tools to spread message to solve marine plastics. From 70 videos uploaded in YouTube, Plastic Change already got more than 232 thousand views in August 2018. Different to Plastic Change, Oceana has more 1.7 million views from their uploaded 121 videos on their YouTube Channel in August 2018. So, it is suggested that updating the content is very important. Social networks are used by Oceana to achieve their mission of campaigning our oceans to be more bio diverse and abundant, including protection from plastic pollution (Oceana, 2018).

2.1.2 Digital literature usage to provide information related to marine plastic litter

Today, with the presence of various types of smartphones, tablets, laptops, and computers, people prefer to consume information from the digital world and connected to internet. It is estimated that there are 2.53 billion smartphone users (eMarketer, 2018) and 4.18 billion active internet users (We Are Social, 2018).

Digital literature or electronic literature is defined as a digital literary work was developed/written/coded and can be read on an electronic device or computer (Hayles, 2008; Heckman & O'Sullivan, 2018). Digital literature includes e-book, digital document (e.g. letter, report and legal document), blog, e-magazine and hypertext. Many intergovernmental organizations and programs such as FAO, IMO, UNEP and UNESCO use digital literature to disseminate updated knowledge and meeting reports related to marine litter and pollution to people globally. Besides non-governmental organizations (NGOs) also use digital literature.

The Plastic Oceans International from California focuses on campaigning to protect the sea from litter. They use blogs and various social programs to convey information related to the impact of litter in the marine ecosystem, also use documentary films as a way of campaigning (Plastic Oceans International, 2018).

2.1.3 Mobile applications, electronic games and board games on marine plastic litter

2.1.3.1 Mobile applications and electronic games

A wide of variety applications have been created by developers. The use of mobile applications and games for marine plastic litter management has been implemented.

Dive Against Debris application has been used by 50,000 divers from 114 countries. Launched in 2011, Diver Against Debris managed to have a positive impact on the health of marine ecosystems, especially coral reefs. Divers will collect marine waste and record it in the application. The results can be shared with all users of this application. As many as 1 million marine litter have been collected. This is one example of the successful use of mobile applications for marine litter management in the world (Project Aware, 2018).

UNESCO has created a mobile game that focus on sustainable development goals (SDGs) Agenda 2030, especially on six goals. The mobile game is called the World Rescue. World Rescue is a narrative, research-based video-game inspired by the SDGs. Through fast-paced gameplay set in Kenya, Norway, Brazil, India, and China, the player will meet other characters to solve problems including pollution and plastic litter recycling education is also simulated in this game (ZU Digital, 2015).

Ocean Generation provides game based on web. They called it The Big Catch. Ocean Generation aims to educate people especially kids to be aware with plastic litter issue. The game is simple. Play as a mammal, swim and try to catch all plastic. There are three stages. Each stages will give different information depend on type of the plastic (Ocean Generation, 2018).

Beside Ocean Generation's website, in the KoiKiwi website, there is a set of online games which focused on the ecological education. There are 3 games on the website related to plastic litter, namely Rubbish Cleaner Game, Catch The Rubbish and Shoot Down Plastic Bottles (KoiKiwi, n.d.).

2.1.3.2 Board games

Board games can be used as the tools to raise public awareness on marine plastic litter. Scramble, crossing word and puzzle are the board common games which also has been developed into digital. Not only for have fun, but board games can be used to educate people.

Ocean Crusaders (2018) provides free education games product which is able to be downloaded and printed, such as puzzles, crossword and scramble on their website. The games aim to help teachers and parents around the world to educate their students or children. It educates student and children about the oceans, the marine creatures and the hazards in the ocean.

2.2 Technological interventions to address land-based plastic litter

2.2.1 Application of information technology in collecting plastic litter from the urban areas

The IOT (Internet of Things) and GIS (Geographic Information System) are being combined in the city of Copenhagen, Denmark. Sensor will be installed in trash cans in the city of Copenhagen. When bins become full, the sensor provides notification to the cleaning department. In real time, the sanitation department can find out which trash cans have been fully charged and must be transported (Gutierrez, 2015).

Cavdar et al. (2016) have designed and implemented a smart solid waste collection system which is efficient in cost, healthy, hygienic and fits in with modern city design. This system consists of litter containers, robotic litter collection vehicles and web portal. The communication system placed in the container consists of an ultrasonic sensor, a SIM card (M2M), two lithium polymer batteries (5000 mAh), the main circuit board, an antenna and a system mounting protection box (IP67). The amount of litter collected in the containers and measured by an ultrasonic sensor. Using this digital identity, a smart system is arranged to determine which containers are full, which ones have been emptied, how many kilograms of waste is in the containers and how much waste is being generated in different districts (Cavdar et al., 2016). Cavdar et al. (2016) state that the system would cost 50–80 % less than the current system.

2.2.2 Robotic technology to collect plastic litter in the river

Nowadays, robotic technologies have been used to intervene in collecting plastic litter in the river in many cities around the world. The cleanliness of river is important to prevent plastic litter entering the ocean. Lebreton et al. (2017) estimate that 1.15-2.41 million tons of plastic litter recently enters the ocean every from rivers globally.

<u>Trash Robot</u>

Trash Robot is a technological intenvention device which is developed by Urban Rivers to clean up litter, including plastics, in the Chicago River, United States (Urban Rivers, 2018). This robot can be operated by anyone from anywhere around the world voluntary because it connects to internet. The players can donate for the maintenance cost. Anybody can just log on to get a couple minutes for cleaning up trash from the river by controlling this robot in real life directly from their computer. So the device will fill its hopper dump at one of provided collection points. One of Urban Rivers team members will come sort and remove this litter. Users will be able to see through the robot’s camera during trash collection. The camera make it is safer for the wildlife which live in that area. After there will be no more trash left to clean, next plan is wild life monitoring, including fish, birds and ducks geeses.

The WasteShark

The WasteShark is an aquatic drone which is designed by RanMarine Technology to collect litter in rivers, canals and harbours initially in Rotterdam, Netherlands (RanMarine Technology, 2018). It is capable to work for 16 hours a day and to carry 200 litres of litter before it need to be cleared and sent out to work again. There are two models of the WasteShark, namely Class A operated by remote control and Class B which is autonomous. The WasteShark is able to measure water quality parameters including pH, ORP, conductivity, dissolved oxygen, turbidity, ammonium, chloride, nitrate, salinity, mV, TDS and resistivity as well as depth and temperature. These data are trasmitted to central command by this robot. It can collect floating litter includes macroplastics, microplastics and debris.

Ro-Boat

Ro-Boat is an autonomous river cleaning robot incorporating mechanical design and computer vision algorithm (Sinha, et al., 2014). Ro-boat is designed to clean great Indian rivers, for example, the Ganges. It is built with a gimballed camera with two axis rotation, stable mechanical system of air and water propulsion, robotic arms and solar energy conversion. There are two pollutant tracking algorithms to detect and recognize pollutant, namely HSV Color Space and SURF (Speeded Up Robust Feature) in the real time. To track the pollutant and generate command for the controller to maneuver the Robot, Kalmar Filter is developed using those algorithms. Ro-Boat has been successfully tested in Yamuna River, New Delhi. It is able to work for 24 hours on 7 days.

2.2.3 Eco-bricks

Eco-bricks aim to recover the plastics, and any inorganic materials, from the litter pathways, for recycling or energy generation or to develop new constructive materials (Gaggino & Arguello, 2010; Antico et al., 2017). Eco-bricks are the name for PET bottles filled with inorganic litter materials that could be used as building blocks (Antico et al., 2017). Table 9 lists the example of eco-bricks building projects around the world.

Table 9 Examples of eco-bricks building projects around the world

Project	Year of Construction	Country	Description	Reference
A Village: Plastic Bottle Vilage	2016	Panama	An entire village made of Eco-bricks. The village includes 120 houses, a boutique and an eco-lodge. One of the added eco-friendly benefits is the cool temperatures maintained inside the structures that reduces need for air conditioning.	Plastic Bottle Village (2018)
A School: Hug It Forward	2014	Guatemala	School made of Eco-bricks have been built in Guatemala. The advantages of using ecobricks are cheaper than conventional way, reduce litter, serve as a hands-on lesson in ecology and involve the entire community in the construction	Hug It Forward (2018)
A House	2016	Bangladesh	Rashedul Alam and Asma Khatun constructed a house made of Eco-bricks that consist a total of 80,000 plastic bottles	Rab (2017)

Societies and NGOs in many places recognize Eco-bricks as a valid bottle plastic recycling method (Antico et al., 2017). Antico et al. (2017) state that Eco-bricks have become an accessible or low-cost construction materials for social projects in areas where litter and dump sites are a social problem and recycling industry might not be yet available.

Eco-bricks building projects have been implemented in many states in South Asia, Latin America and Africa (Taaffe et al., 2014; Antico et al., 2017). The implementation of this project usually is based on social project where communities work together, for example in building an educational center or a chair in the recreational spaces (Antico et al., 2017). Voids within the Eco-bricks are reduced to strengthen physical and mechanical properties like volume stability, elastic modulus and elastic-plastic recovery behavior of Eco-bricks (Antico et al., 2017).

2.2.4 Conversion of plastic litter into fuel

Plastic litter is a promising source of cheap and abundant feedstock for fuel synthesis through thermochemical conversion, assuming the produced fuels meet the technical specifications prescribed by regulations (Faussone, 2018). According to UNEP (2009), plastic is one of the most promising resources for fuel production because it has not only high heat of combustion and but also increasing availability in local communities beside for resource conservation. Table 10 lists the oil ratio of plastic litter types.

Pyrolysis is the thermochemical decomposition of organic material at high temperature and in the absence of oxygen (Scholz, 2015; Mandal et al., 2015). Compared to combustion, pyrolysis has a lower process temperature and lower emissions of air pollutants such as polybrominated diphenyl ethers (PBDEs) (Czajczyńska et.al, 2017). It has become a common technique for conversion of plastic waste into fuel. Faussone (2017) notes that the produced pyro-oil, which is in a liquid state, can substitute fossil fuel or a crude oil. In order to improve awareness on plastic separation from household waste, an education and public outreach activities have been initiated by involving the development of pyrolysis technology for producing oil. The technology is an integrated system of pyrolysis machine and shredding machine (Biddinka et.al, 2017).

Table 10 Oil ratio of different plastic litter types

Raw material	Oil ratio
PP (microwave oven food box/yogurt bottles etc)	50%-75%
PE(plastic film /plastic wrap)	50%-75%
PS (smack-box/blister box)	50%-75%
ABS (engineering plastics)	40%
Leftovers of paper	Wet 15-20%, dry 60%
House garbage	35-50%
Plastic cable	80%
Plastic bag	50%
PVC (raincoat/building materials)	Not suitable
PET (water bottles/sodas beverage)	Not suitable

Source: Huayin Group (2018)

In the world, there are many companies have produced fuel oil from plastic litter. For example, Sustane Technologies in Canada, Recycling Technologies in UK, Huayin Group in China, Blest in Japan and Neste in Finland.

2.2.5 Conversion of plastic litter into electricity

Incineration of litter is a mass burning technology, performing with a controlled combustion to generate electricity (Peerapong & Limmeechokchai, 2016). The process of incineration encompasses (Peerapong & Limmeechokchai, 2016): waste laced on a grate which transverse the combustor with excess air supplying to typically combust up to 1,000 metric tons a day; the air is controlled at a certain range, the high level is lower than the burn temperature and reaction rate, while the low level allows hydrocarbons to quit without burn unburned; finally, the combustion process generates electricity and steam. Abaka et al. (2017) note that the total quantity of litter gets reduced approximately 67% to 90% due to incineration for generating electricity, which is conditional on the adopted technology and waste composition.

Incineration in Sweden

Sweden is a country which has long experience in the incineration of waste, including plastic, since the first incineration plant was established in 1904, and recently there are 32 plants (Avfall Sverige, 2016). In 2016, almost 2.3 million tons of household waste was turned into energy through incineration, it is approximately 50% of total household waste in Sweden (Avfall Sverige, 2016). Sweden imported 2.3 million tons of waste from, among others, UK, Ireland and Norway in 2015 (Avfall Sevrige, 2016).

Sysav is a cleantech company located in Sweden. It has generated 1,477,700 MWh of heating and 168,250 MWh of electricity for E-on and Nordpool, the Nordic electricity grid points (Sysav, 2018). All recovered energy was used; what was not sold was used in the Sysav Group's own facilities. The waste-to-energy plant provides Malmö and Burlöv with 60 percent of their district heating need (Sysav, 2018).

Incineration in Netherlands

Plastic incineration also has been carried out in the Netherlands. The Dutch incineration facilities are amongst the most efficient in the world, with high energy recovery and competitive gate fees (Gradus et al., 2017). The incineration of plastic litter is beneficial due to produces more than three times of energy compared to other materials which the cost of doing incineration is still very expensive (Morris as cited in Gradus et. al, 2017).

2.2.6 Conversion of plastic litter into road construction materials

Currently, several studies have identified that plastic is a potential material to be mixed for roads construction.

Plastic road in India

Sharma et al. (2017) indicated that plastic usage in the construction materials lead to the better strength, longer durability and delayed deterioration of roads as well as the voids also reduced in the case of plastic coated aggregate (PCA) pavement. Tiwari et al. (2018) also have proved that bitumen modified by plastic litter (PE type) which is used for road construction, its pavement durability was increased. Trimbakwala (2017) recommends that 8% is the optimum plastic proportion for blending the bitumen in the construction of plastic roads and informs that a kilometer long of test-track has been tested in Karnataka, India.

Plastic road in Netherlands and Canada

In Netherlands, three companies (i.e. Wavin, KWS and Total) are joining forces to construct a 30-meter-long cycle path as the pilot project called PlasticRoad (Wavin, 2018). The road will be made of 100% recycled plastic from the ocean (Wavin, 2018). Beside Netherlands, Canada also tested a construction of plastic road in Vancouver in 2012 (CBC News, 2012). Judd stated in CBC News (2012) that the plastic usage in road construction materials can save 20 per cent of fuel at the asphalt plant.

2.2.7 Conversion of plastic litter into public transportation tickets

Plastic litter collection efforts also have been done in the city public transportation.

Public transportation tickets in China

Since 2012, the conversion of bottle plastics into credits reimbursement for metro trips via reverse vending machines has been started at stations in Beijing, China, initiated by a company named Incom (Martinko, 2014). The subway passengers deposit plastic bottles into the bottle slot and simply tap their card to receive a 5-cent to 15-cent reimbursement per bottle that goes toward the reduction of the price of a trip (Martinko, 2014).

Public transportation tickets in Turkey

In Istanbul, Turkey, the municipality has started installing automated "Smart Mobile Waste Transfer Machines" up to 100 locations by the end 2018. Commuters will receive refund credits for their "Istanbulkart" cards which can be used in the city's public transport systems and several other municipal services (Daily Sabah, 2018).

2.2.8 Production of bio-based and biodegradable plastics

Definition and classification of bio-based and biodegradable plastics

Bio-based plastic is a different kind of biodegradable plastic. Bio-based plastics are defined as polymers which are wholly or partly derived from biomass either biodegradable or not biodegradable (van den Oever et al., 2017; Scherer 2018). It can be produced from different biomaterials such as sugarcane, starch from potatoes and corns, or cellulose from plant oil (Scherer et al., 2018). Biodegradable plastics are made of polymers that can be broken down by microorganisms (bacteria or fungi) into water and naturally occurring gases (e.g. carbon dioxide and methane), and is recognized by enzymes in natural environment (Rujnić-Sokele & Pilipović, 2017; van den Oever et al., 2017). Figure 22 demonstrates classification among bio-based, biodegradable, fossil-based and not biodegradable plastics.

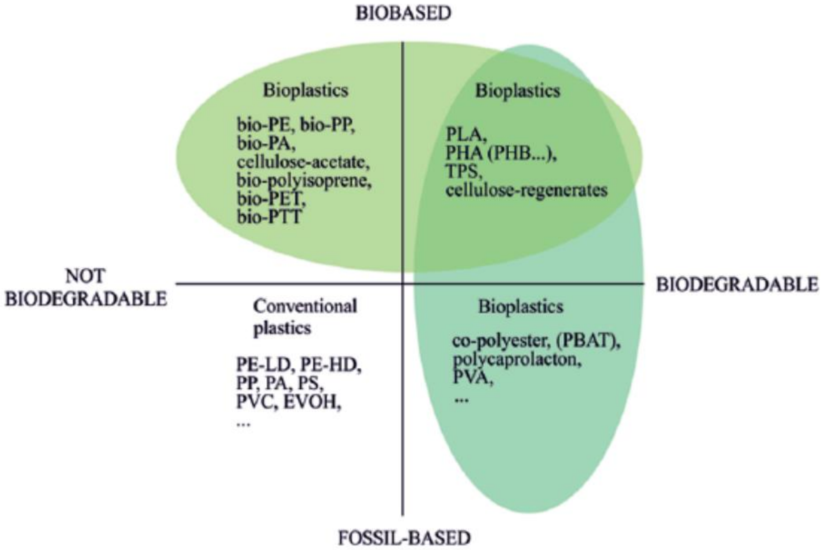

Figure 22 Classification of bio-based, fossil-based, biodegradable and not biodegradable plastics. Source: Rujnić-Sokele & Pilipović (2017).

<u>Bio-based plastic as an alternative</u>

The replacement of fossil-based plastics with bio-based plastics is considered as a promising alternative because it will decrease the dependency of plastics on petroleum and the pressure on landfills from plastic litter (Álvarez-Chávez, 2012). Bio-based plastics could potentially save 241 to 316 Mio. t of CO2-eq annually by substituting 65.8% of all conventional plastics (Spierling et al., 2018).

<u>Biodegradability</u>

It is indicated that biodegradable plastics take shorter time than not biodegradable plastic to be degraded in the environment even though in several decades (Rujnić-Sokele & Pilipović, 2017). Figure 23 illustrates the degradation periods of bio-based plastic products. Biodegradability depends strongly on the environmental conditions like temperature, presence of microorganisms, presence of oxygen and water, so may be different on the soil, in the soil, in dry or humid climate, in surface water, in marine water, or in human made systems in composting (van den Oever, et al., 2017).

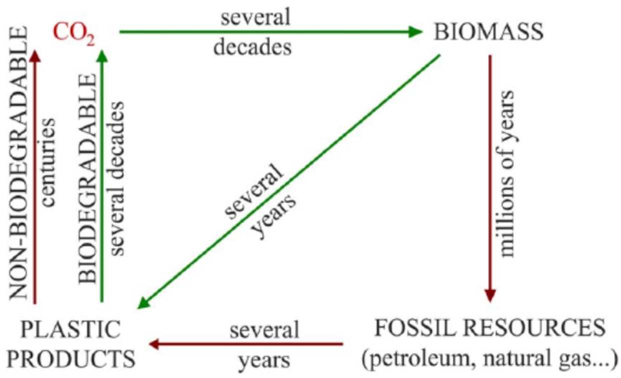

Figure 23 Degradation period of bio-based plastic products. Source: Šprajcar et al. (2012).

Bio-based and biodegradable plastic products in general

Bio-based plastics and biodegradable plastics have been commercialized in the manufacturing of various products, for instance, shopping bags, bio-fibers, garbage bags, compost bags, poly bags, food packaging and agricultural mulch films (van den Oever, et al., 2017). Van den Oever et al., (2017) state that the three most commonly used bio-based plastics are PLA (polylactic acid), starch based plastics and Cellophane. Biodegradable end-product does not directly degrade once released to the environment because additive chemicals used to enhance their longevity (Lambert & Wagner, 2017). Nowadays, many companies have produced bio-based plastic and biodegradable plastic products.

Bee’s Wrap products

In Vermont, USA, a company named Bee’s Wrap produces ‘Bee's Wrap’ which is a bio-wrap made of organic cotton, beeswax, organic jojoba oil, and tree resin (Bee’s Wrap, 2018). This combination of ingredients creates a malleable food wrap which is washable, reusable, and compostable (Bee’s Wrap, 2018).

EnviGreen products

EnviGreen is a company in Bangalore, India which provides various products are made from natural starch & vegetable oil derivatives which are claimed that softens in water & dissolves in hot water also contains no conventional plastic and non-toxic to the environment, animals and plants (EnviGreen, 2016). Its products include carry bags, trash bags, oil and grease sachets, bin liners, packaging films, aprons, wrapping covers and laundry bags (EnviGreen, 2016).

Ooho

Ooho is a spherical drinking water product which is packed by edible packaging. The packaging material is 100% made of plants & seaweed, biodegradable in 4-6 weeks like a piece of fruit, fresh, can be flavoured and colored, five times less CO_2 and nine times less energy consumption than PET (bottle plastics) during production (Skipping Rocks Lab, 2018).

2.2.9 Production of food containers and fashion products made from recycled plastic litter

Currently, some companies have developed food containers and clothes made of recycled plastic litter. Table 11 shows the list of examples of products made of recycled plastic litter. Figure 24 demonstrates the process of making a food container made from recycled bottles.

Table 11 The examples of food containers and fashion products made from recycled plastic litter

Product	Plastic litter type	Company	Information source
Sunglasses	shopping bags, detergent bottles and plastic milk jugs from the ocean (HDPE)	Norton Point (USA)	www.nortonpoint.com
Food box	bottles (PET)	Direct Pack (USA & Canada)	www.thebottlebox.com
Apparel, footwear, bags and luggage	PET, HDPE, PP	Return Textiles (USA)	www.bionic.is
Swimwear and running shoes	fishing nets (nylon), food packaging (PS), bottles and garments (PES)	Adidas (Germany)	www.adidas-group.com
Food packaging	bottles (PET), PP	Placon (USA)	www.placon.com

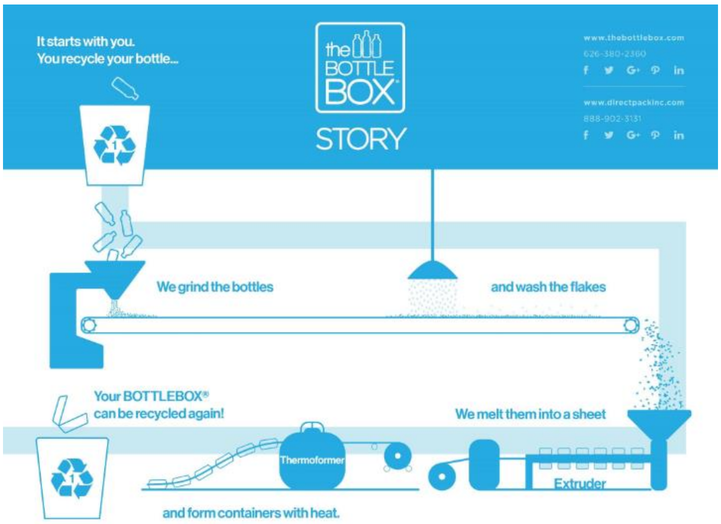

Figure 24 Recycling process of plastic bottles to be food containes. Source: Direct Pack (2018).

2.2.10 Provision of water dispenser in public places

The provision of water dispenser in public places has been assumed that will reduce a number of plastic bottles litter. Uehara & Ynacay-Nye (2018) observed that 58.82% of 363 students at Ritsumeikan University are willing to use water bottle refill stations, so it is estimated that 45,191 disposable plastic bottles would be saved and 10,846 kg of related CO_2 emissions would be reduced annually.

Dorfman (2016) has designed the advanced water dispenser system and method which is able to provide information of water volumes which users consume and their impact on the environment. The data may be shared on the user's social media accounts or used as inputs for games (Dorfman, 2016). It is also featured by user authentication by way of biometrics or an RFID/NFC tag (Dorfman, 2016). This authentication technology will be useful to limit a water consumption per person.

2.3 Technological interventions to address plastic litter at sea and coastal areas

The technological interventions to address plastic litter at sea nad coastal areas are also impotant and have been conducted in many countries around the world. This subchapter will discuss the intervention on beaches and at sea.

2.3.1 Modified vehicles to collect plastic litter on beaches

On beaches in many countries, modified vehicles to collect plastic litter have been produced. This technology is used to clean up the coastal area, particularly in the tourism areas with sandy beaches.

The Surf Rake

The Surf Rake is a vehicle which is designed to clean beach that featured by hundreds of tines mounted in offset rows rake through the sand every second, removing the unwanted litter up to the smallest objects from the sand such as glass, cigarette butts and pop-tops, then depositing them in the hopper (Barber, 2018a). Its maximum capacity is 16 gallons and hydraulic flow is 12 gallons per minute (Barber, 2018a).

The Sand Man

Another example is the Sand Man. It is able to elevate the sand and utilize a sifting screen to sieve the beach litter, then deposit them into the collector (Barber, 2018b). There are three interchangeable screens with mesh sizes of 3/16 inches, 3/8 inches and 1/2 inches (Barber, 2018b). The sand sifter's smaller mesh is used for fine cleaning while the larger mesh allows for deeper cleaning and rapid sifting speed in wet sand (Barber, 2018b).

2.3.2 Autonomous plastic litter collection at sea

Nowadays, some autonomous technological systems have been used to intervene in collecting plastic litter at sea. There are two types of autonomous system are discussed in this subchapter, namely The Ocean Cleanup System and Seabin Project.

The Ocean Cleanup system

The Ocean Cleanup system consists of a 600-meter-long floater that put at the ocean surface and a tapered 3-meter-deep skirt attached below. The floater allows buoyancy to the system and anticipates plastic to flow over it, while the skirt stops marine plastic litter to drift underneath. Both the litter and system are being carried by the current, whereas wind and waves drive the system only. The system thus moves faster than the litter, allowing the litter to be captured. Due to its U-shape and the screen below, the plastic litter are collected in the center of system (The Ocean Cleanup, 2018).

The system is designed to capture plastics ranging from microplastics (mm) to macroplastics, including discarded great fishing nets. It is estimated that the system could clean 50% of the Great Pacific Garbage Patch in five years. After fleets of systems are deployed into every oceanic gyre, combined with source reduction, approximately 90% of plastic in the ocean can be reduced by 2040 globally (The Ocean Cleanup, 2018). Algorithms in the system create a real-time telemetry to monitor the location, condition, performance and trajectory of the entire system. The system fully depend on the ocean forces to catch and concentrate the plastic. All electronic devices include lights and AIS powered by solar energy (The Ocean Cleanup, 2018).

Seabin technology

Seabin is an automatic floating debris interception device to be installed in the calm seawater environment, for instance, marinas and ports (Seabin Project, 2016). The Seabin can catch an estimated 1.5 kilograms of floating litter per day (depending on weather and litter volumes) including microplastics of 2 mm in dimeter (Seabin Project, 2016). Water is sucked in from the surface and passes through a catch bag inside the Seabin, with a submersible water pump capable of displacing 25.000 liters per hour, plugged directly into 110/220 V outlet. The water is then pumped back into the marina leaving litter and litter trapped in the catch bag (Seabin Project, 2016)

2.3.3 Incineration of plastic litter on-board ships

Plastic litter on-board usually includes sheets, bottles, drums, wrapping, synthetic ropes, fishing nets, garbage bags and empty chemical cans (CE Delft, 2016; Čulin & Bielić, 2016). There are two ways to manage plastics on-board, either they are kept separately (compacted or otherwise) and delivered to PRF or they can be incinerated, the ashes being treated as incinerator ashes (CE Delft, 2016). Incineration is constrained by MARPOL VI, Regulation 16 which prohibits on-board incineration of PVC except in a shipboard incinerator for which an IMO Type Approval Certificates has been issued in accordance with MEPC.244(66) and incineration of plastics with PCBs is always prohibited (MEPC, 2014).

2.3.4 Fishing gear marking

Several technologies have been developed to reduce the loss of fishing gear. Depending on the number of purposes, the type of technology applied to the fishing gear will also be different. One of the easiest and most effective technologies is radio frequency identification (RFID), which refers to technologies that automatically identify objects through radio waves (He & Suuronen, 2018). In general, RFID tags can only be read within a short distance that low-frequency tags can be read from 30 cm or less, high-frequency tags can be read from about 1 m, and ultra-high frequency tags can be read for up to 6 m (Theiss et al. as cited in He & Suuronen, 2018).

Pingers (also called beacons) continuously emit acoustic signals at certain frequencies once in the water. A hydrophone is used to listen to the acoustic signals from the pinger to home in its position. A transponder listens to the acoustic signal from a command unit via a hydrophone. Once it has detected a certain signal, the transponder sends an acoustic signal back to the hydrophone, so that the location of the transponder can be determined. These pingers and the detectors can be used for locating gillnets (or any other gear with a pinger) if they become lost. German researchers tested a long-range pinger detector which could detect both analog and digital pingers between 10 and 160 kHz, and with the help of an onboard GPS, to calculate the distance between the pingers installed in gillnets (ICES as cited in He & Suuronen, 2018).

2.3.5 Microbes enzyme

The microbe *Ideonella sakaiensis* is being used to digest plastic waste. Yoshida et al. (2016) reported a novel discovered bacterium, *Ideonella sakaiensis* 201-F6, with the unique ability to use Poly(ethylene terephthalate) (PET) as its major carbon and energy source for growth. This strain produces two enzymes which is capable to hydrolyze PET and the reaction intermediate, mono(2-hydroxyethyl) terephthalic acid. Both enzymes are requisite to enzymatically convert PET efficiently into its two environmentally benign monomers, ethylene glycol and terephthalic acid

(Yoshida et al., 2016). Austin et al. (2018) observed that PETase (PET-digesting enzyme) produced by *Ideonella sakaiensis* 201-F6 degrades another semi aromatic polyester, polyethylene-2,5-furandicarboxylate (PEF), which is an emerging, bioderived PET replacement with improved barrier properties.

Other studies also have been identified some microorganisms which took from deep sea environment are able to degrade plastics. For example, *Zalerion maritimum* which is able to degrade PE (Paco et al, 2017) and *Pseudomonas* sp., *Clanostachys rosea*, *Trichoderma* sp. and *Rhodoccus* sp. which are able to degrade PCL and bio-based plastics made from potato and corn starch (Urbanek et al., 2017).

2.3.6 Ship recycling

Ships are typically disposed of after a lifespan of 22–30 years (Mikelis, 2008; Du et al., 2018). Ship recycling refers to breaking up a ship and recycling its constituent materials and generally is considered as the best choice for sustainable development (Du et al., 2018). End-of-life ships sent to the breaking yards for recycling are often encumbered with hazardous materials and chemicals, such as polychlorinated biphenyls (PCBs), fiber and solid foam, asbestos, which can have several negative implications on the marine environment and human health (Du et al., 2018).

In China, for example, there are five stages in recycling ships (Du et al., 2017). First, preparations are made such as complete vessel information, the opening of gas lines on ships, installing warning signs, and preparing security equipment. Second, do the cleaning of the waste of the ship such as removing all furniture, pumping the remnants of ship oil, cleaning up hazardous materials (PCB, asbestos, freon, and lead batteries). Third, removing parts of the ship such as removing the ship's engine, deck, and the bottom of the ship. Fourth, cutting parts of the ship into smaller pieces such as cutting the ship's pipes. Fifth, classify the remnants of the ship.

3 Technological interventions to address marine plastic litter in Indonesia

Indonesia is a country also pay attention and do efforts seriously to address marine plastic litter by doing management from land to the ocean. Some technological interventions have been started and done over time. This chapter discusses what Indonesia has done with technological approach in managing marine plastic litter.

3.1 Technological interventions to raise awareness among stakeholders

3.1.1 Educating through websites and social networks

3.1.1.1 The most popular social networks in Indonesia

There are top five sites which have used by more than 30% of Indonesian population, namely YouTube, Facebook, WhatsApp, Instagram and LINE (We Are Social, 2017). Figure 25 shows the list of most popular social network sites in Indonesia.

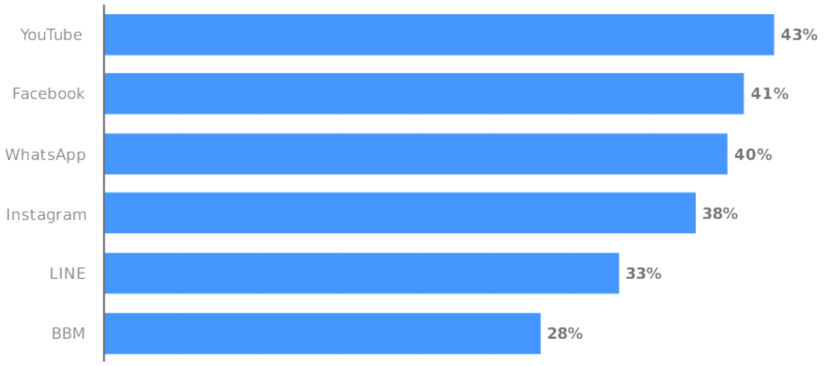

Figure 25 Most popular social networks in Indonesia, by share of population in 2017. Source: We Are Social (2017).

3.1.1.2 Websites and social networks usage to educate people in addressing marine plastic litter in Indonesia

Websites and social networks have been used by governments, local communities and NGOs to campaign of plastic reduction, reuse and recycling; to do not litter at beaches rivers and the sea; to clean rivers, seas and beaches from plastic litter; to share knowledge of the importance of marine and coastal ecosystems; and to share the knowledge of the plastic litter impacts to marine environment and human health. Some local and national organizations have been identified that have been doing this educational efforts through their websites and social networks, namely Greeneration, Young Waste, Green Moluccas, Indonesian Movement on Plastic Bag Diet, Divers Clean Action, Indonesian Waste Platform and Indonesian Maritime Youth Association. Among Indonesian ministries, there are three ministries which actively campaign and share knowledge related to marine plastic litter, namely Ministry of Environment and Forestry, Ministry of Fisheries and Marine Affairs and Coordinating Ministry for Maritime Affairs.

On Young Waste's website (www.sampahmuda.com), visitors are able to sell their litter to pay mobile credits, pre-paid voucher for electricity and online taxi services (Go-Jek) (Sampah Muda, 2018). However, web visitors should create an account first to access these services.

3.1.2 Digital literature usage to provide information related to marine plastic litter

In Indonesia, some ministries have published many digital documents like magazines, books, posters, statistical data, regulations and infographic information related to marine litter and environment on their websites. Coordinating Ministry for Maritime Affairs and Minister of Environment and Forestry, for instance, use digital literature to disseminate updated knowledge, events and meeting reports related to marine litter and environment to Indonesian people (PPID MEF, 2018; CMMA, 2018). Besides non-governmental organizations (NGOs) also have published digital literature on their websites, such as Clean Jasmine Waste Bank (*Bank Sampah Melati Bersih*).

3.1.3 Mobile applications, electronic games and board games on marine plastic litter

3.1.3.1 Mobile applications and electronic games

Several electronic games related to marine litter education have been developed and are ready to be played. There are 3 games found and reviewed in this Subsection.

Combating Marine Debris

Combating Marine Debris is a game developed on an Android platform. This game aims to educate the users to protect marine biota from marine debris for all ages. The players should click marine debris before they touch marine biota. This game was sponsored by the Coordinating Ministry for Maritime Affairs. This game is available to be downloaded on Google Play Store.

Combating Marine Debris 2

Combating Marine Debris 2 is a game developed on an Android platform. This game aims to educate the users to sort litter from the river and throw them to trash bin in order to protect ocean will be polluted. This game for all ages. This game was sponsored by the Coordinating Ministry for Maritime Affairs. This game is available to be downloaded on Google Play Store.

Trash Grabber

Trash Grabber is an educational game application to get to know the types of litter which found in the environment for all ages. It is played on smartphones and made on an Android platform with Corona SDK application. It was developed by Sudiatmika et al. (2014).

3.1.3.2 Board games

Board games are discussed in this subsection including Ecofunopoly also Snake and Ladder with theme of litter. Both of them are kind of board games which developed by Indonesian people.

Ecofunopoly

Ecofunopoly is an environment-based educational game that aims to change human behavior. This game was created as a tool or media to introduce children about environment and how to be someone who is environmentally friendly. There is a waste theme to learn about waste around people, including cause, effect, type, separation, and how to reduce your waste, also stimulate positive action towards waste reduction (Ecofunopoly, 2018).

Snake and Ladder with theme of litter

Snake and ladder with theme of waste has been produced and designed by *Melati Bersih* Waste Bank. The way in playing this board game, in general, is the same with the conventional snake and ladder but there are essential information such as the impotance of clean lifestyle and natural sustainability, as well as about litter handling (Melati Bersih, 2014).

3.2 Technological interventions to manage land-based plastic litter

3.2.1 Application of information technology in collecting plastic litter from the urban areas

This kind of technological intervention has been implemented based on the website and mobile application of online waste bank such as Young Waste (*Sampah Muda*), OBABAS and *Lestari Hijau*. In Young Waste system, customer can order the provider to collect and buy the litter from the customer's location (Sampah Muda, 2018). Those online waste bank allows the customers to have the online records and transactions

3.2.2 Robotic technology to collect plastic litter in the river

In Indonesia, the development of robotic technology to clean the rivers from litter has been done. Many robots have been being developed, such as AGATOR (Nurlansa, et al., 2014), Rinerbot (Insantama, 2016), Riverboat (Zubaidah, 2015) and Underwater (Rafsanjani, 2016).

AGATOR (Automatic Garbage Collector) is a robot model to pick up the litter in the river which is calm. This robot is able to carry litter receptacle up to 5 kilograms and its average speed when take out the litter is 0.26 m/s (Nurlansa et al., 2014).

3.2.3 Eco-bricks

In Indonesia, Eco-bricks have become popular in the society and schools. Many projects involve students, local communities and teachers. For example, in Bali, a teacher had mobilized her entire school of 1,600 students to make eco-bricks, so, the school had 900 of 1.5 liter bottles and 1,400 of 600 ml bottles of eco-bricks. The school will use eco-bricks to build furniture and a food forest play garden (Ecobricks, 2015).

3.2.4 Conversion of plastic litter into fuel

The development of conversion technology to produce fuel from plastics has been being processed by some researchers and students in Indonesia. The production still has small scale unit but the fuel have been tried on motorcycle. For example, Surono & Ismanto (2016) examined and produced fuel from three types of plastics, encompasses plastic bags (PE), plastic cups (PP) and plastic bottles (PET). From their study, it is concluded that PP was the most potential feedstock to produce fuel with the least LPG (liquefied petroleum gas) requirement and the fastest processing time. Nurdianto et al. (2016) caharacterized their fuel products from plastic bottles (PET) and indicated that PET fuel properties close to gasoline propertis, then, they tried the fuel to operate motorcycle with the proportion to gasoline 5:95 and 20:80. The emission examination indicated that the mixed fuel (20:80) had the least gas emission in CO, CO_2 and hydrocarbon.

3.2.5 Conversion of plastic litter to electricity

In Indonesia, electricity provision and management at local and state level is hold by a state-owned enterprise called PLN. PLN plans to develop a waste power plant with a total capacity of 195 megawatts (MW) in the Java and Bali regions (Meilanova, 2018). Currently, there are two waste power plant implemented in Indonesia, located in Bekasi operated by Navigat Organic with capacity of 12 MW and in Surabaya operated by Sumber Organik company with capacity of 1.6 MW (Meilanova, 2016).

3.2.6 Conversion of plastic litter into road construction materials

The interventions in roads construction using plastics as the materials are carried out seriously by Indonesian government. In 2017, Indonesian government constructed 700-m long plastic roads in Bali (Chered, 2017), 2 kilometers in Bekasi (Widya, 2017), 100 meter in Makassar (Cahyu, 2017) and 100 meter in the rest area at Highway of Tangerang-Merak (Anjungroso, 2017). Sumadilaga as cited in Chered (2017) states that construction of 1-kilometer long and 7-meter wide road requires 2.5 tons – 5 tons of plastic bags. The composition of plastic in the road materials is approximately from 10 percent to 20 percent (Sumadilaga as cited in Murdaningsih, 2018).

3.2.7 Conversion of plastic litter into bus tickets

In Indonesia, this kind of technology has not been implemented. However, there is a policy intervention by the municipality to provide city bus tickets for the passengers with the role of changing as 5 medium size bottles, 3 big bottles, 10 cups, 1 plastic bag and packaging of plastic litter for 1 bus ticket in Surabaya (Ulum, 2018). The changing process is at the waste bank and drop box of Purbaya Terminal.

3.2.8 Production of bio-based and biodegradable plastics

Kamsiati et al. (2017) recorded that bio-plastics which are biodegradable have been made from cassava starch, chitosan, gelatin, tapioca and glycerol in Indonesia. Production of bio-based plastic products which are biodegradable has been industrialized, for instance, by AVANI company in Indonesia. AVANI has produced various plastic products as shown in Table 12.

Table 12 Bio-based plastic products

Product	Biomass
Bio-cassava bag	cassava
Bio-poncho	corn, soy, sunflower seeds
PLA products	corn starch
Bio-paper products (coffee cup, straw, bowl and coffee cup lid)	corn starch
Bio-box (plate, bowl, food box)	bagasse
Bio-wooden cutlery	birchwood

Source: AVANI (2018)

3.2.9 Production of food containers and fashion products made from recycled plastic litter

Related to this kind of intervention, there is a company have produced bracelets from recycled materials, comprising recycled glass for the beads and recycled water bottles for the cord (4Ocean, 2018). The glass and bottle litter are from marine litter which collected in Bali, Indonesia where the its international headquarters located. It is claimed that one bracelet represents 1 pound of trash (4Ocean, 2018).

3.2.10 Provision of water dispenser in public places

It is a fact that the tap water in Indonesia has not been drink directly yet. This condition leads to the high consumption of bottled water in many places. In Indonesia, the average volume per person in the market for bottled water amounts to 146.6L in 2018 (Statista, 2018). Therefore, the provision of water dispenser is essential to reduce the water bottles litter in public places. In some universities, there are public water dispensers are available. For example, University of Gadjah Mada (Fahrianto et al., 2018) and Bogor Agricultural Univerity (Aditama, 2018).

3.3 Technological interventions to address plastic litter at sea and coastal areas

This subchapter will discuss the technological interventions to addres plastic litter at sea and coastal areas in Indonesia.

3.3.1 Modified vehicles to collect plastic litter on beaches

This kind of intervention has not been identified in Indonesia.

3.3.2 Autonomous plastic litter collection at sea

This kind of intervention has not been identified in Indonesia.

3.3.3 Incineration of plastic litter on-board ship

Plastic incineration on-board is assumed that happen in Indonesian sewaters.

3.3.4 Fishing gear marking

Implementation of fishing gear marking in Indonesia have been started in 2018. The pilot project focus on the 2 small-scale fishermen sites, Pekalongan and Sadeng. Testing of tagging gear with FibreCode technology supports the efforts to improve traceability in fishing gear supply chains, particularly in a commercial setting. Second phase focused on scoping net marking at manufacture level and a pilot scheme for reporting lost gear and a gear recovery & recycling program (Giskes, 2018).

3.3.5 Microbes enzyme

This research has not discovered the way of implementation of reducing marine plastic litter by microbes enzyme.

3.3.6 Ship recycling

There is a green ship-recycling yard in Indonesia, namely *PT Galangan Kapal Madura*, located in Madura, East Java. Akriananta & Suastika (2017) state that the ship-recycling industry provides the services of docking, cutting, de-coating and material handling.

4 Recommendations for Addressing Marine Plastic Litter in the 'New Balis' Sustainably based on Technological Interventions Analysis

Recommendations for addressing marine plastic litter in the 'New Balis' are formulated in the form of mapping the relevant technological interventions to the National Action Plan, SWOT analysis of potential impacts after intervening technologies and consideration of sustainable tourism aspect and global partnerships in this Chapter.

4.1 Mapping the relevant technological interventions towards the national plan of action

Mapping analysis of technological interventions is conducted towards the goals of the National Action Plan in each strategy. It is indicated that technological interventions are not limited to a certain strategy but can be implemented in other strategies.

4.1.1 Goals in Strategy 1

Table 13 Mapping the relevant technologies to be intervened in the goals in Strategy 1

No	Program		Goal	Technology
1.1	Public Awareness Enhancement	a.	Increased understanding of coastal cities and major rivers watersheds societies, on marine litter impacts, especially plastic litter for health and ecosystems, as well as socialization related to integrated litter management	websites, social networks, digital literature, mobile applications, electronic games and board games, plastic converter into public transportation tickets
		b.	Increased public awareness regarding the use of the types of plastics which are safe for health and the environment, easy to decompose and can be recycled	websites, digital literature
		c.	Increased litter utilization in industrial environments	websites, digital literature
		d.	Implementation of training in plastic litter sorting and utilizing	websites, digital literature
		e.	Increased coastal community awareness on coastal and marine management, as well as fostering concern for the environment	websites, social networks, digital literature, mobile applications, electronic

No	Program	Goal	Technology
			games and board games, water dispenser
		f. Implementation of technical guidance on the selection of plastic waste as raw material for plastic recycling industry	websites, digital literature
		g. Increased public awareness on marine litter issues	websites, social networks, digital literature, mobile applications, electronic games and board games
		h. The campaign for the role of the plastic industry that is safe for health and environment, easily decomposes, and can be recycled in reducing waste accumulation	websites, digital literature
		i. The formation of collaboration programs with the business world, mass media, community groups, and traditional or religious institutions	websites, digital literature
		j. Implementation of national awarding events	website and social networks
1.2	National Movement of marine litter awareness through education for civil servants, students and educators	a. The implementation of environmental and hygiene activities awareness in ministries / government institutions, schools and campuses	digital literature, mobile applications, electronic games and board games, water dispenser
		b. Material inclusion for the teaching of culture / behavior of clean and healthy living and environmentally aware in the content of the education curriculum of school-age children	digital literature, mobile applications, electronic games and board games

4.1.2 Goals in Strategy 2

Table 14 Mapping the relevant technologies to be intervened in the goals in Strategy 2

No	Program	Goal	Technology
2.1	The control of litter in watersheds areas	a. The availability of litter collection infrastructure in the river	robotic collector
		b. The availability of litter management facilities including plastic litter at the reduce-reuse-recycle litter treatment plant and recycling center	information technology, eco-bricks
		c. River estuary control from marine litter including plastic litter	website, digital literature
2.2	The control of plastic waste from	a. Increased production of plastics that are easily decomposed and recycled	eco-bricks, bio-based and biodegradable plastics

	the upstream industry sector	b.	Compilation of incentives studies for industries of easily decomposed and recycled plastics	website, digital literature
		c.	The availability of guidelines for good manufacturing process of easily decomposed and recycled plastic products	website, digital literature
		d.	The availability of prototypes of litter power plant with a capacity of up to 2000 tons per day	website, plastic convertor into electricity (incinerator)
		e.	The establishment of utilizing units for plastic litter management into fuel oil	plastic converter into fuel
		f.	The stipulation of regulations regarding plastic excise	website, digital literature
		g.	The reduction of plastic litter through the principle of circular economy	eco-bricks, bio-based and biodegradable plastics, recycled food containers, recycled fashions products, plastic converter into public transportation tickets
2.3	The control of plastic waste from the downstream industry sector	a.	The stipulation of ministerial regulation on the application of plastic litter technology for road construction	website, digital literature
		b.	Increased use of plastic waste as additional material for the construction of roads and bridges	plastic converter into road material
		c.	The availability of tools or machines for plastic litter recycling	bio-based and biodegradable plastics
		d.	The availability of information about producer and stock of chopped plastics	website, digital literature
		e.	Formulation of distribution study of the plastic recycling industry to tourist destinations	website, digital literature, technological information
		f.	Increased number of recycling industries	eco-bricks, bio-based and biodegradable plastics, recycled food containers, recycled fashions products
		g.	The stipulation of ministerial regulation on the road map of litter reduction by the producers	website, digital literature
		h.	Increased production of easily decomposed and recyclable plastics	bio-based and biodegradable plastics

4.1.3 Goals in Strategy 3

Table 15 Mapping the relevant technologies to be intervened in the goals in Strategy 3

No	Program		Goal	Technology
3.1	The management of plastic waste from Sea Transport Activities	a.	The implementation of the Minister of Transportation Regulation Number 29 of 2014	website, digital literature
		b.	The availability of facilities and infrastructure for reception facilities in each public port	water dispenser, eco-bricks, plastic converter into roads
		c.	The availability of facilities and infrastructure for handling litter in every ocean fishing port and archipelago fishing port	water dispenser, eco-bricks, plastic converter into roads
		d.	The implementation of ISO 14001 international environmental management certification for the management of waste and waste in public ports	technological information, digital literature
		e.	The implementation of ISO 14000 environmental management certification for the management of waste and waste in every ocean fishing port and archipelago fishing port	technological information, digital literature
		f.	The socialization of waste management procedures on board when sailing	digital literature, electronic games
3.2	The management of plastic waste derived from activities in the marine tourism area	a.	The issuance of regulations on operational standards for waste management procedures from activities in marine tourism destinations	website, digital literature
		b.	The implementation of Standards of Procedures for litter management in marine tourism destinations	website, digital literature
		c.	The availability of facilities and infrastructure for plastic waste management in the area of marine tourism destinations	water dispenser, eco-bricks, plastic converter into roads, plastic converter to fuel, bio-based and biodegradable plastics, technological information, recycled food container, recycled fashion products, plastic converter into public transportation tickets
3.3	The management of plastic	a.	The availability of regulations regarding the Standard of Procedures for environmentally friendly fisheries activities	website, digital literature, technological

	waste derived from marine and fisheries activities		information, fishing gear marking
		b. The availability of regulations regarding Standards of Procedures for environmentally friendly aquaculture activities	website, digital literature
3.4	The waste management derived from activities in the coast and small islands	a. The availability of litter storage and recycling processing facilities on the outer small islands	water dispenser, eco-bricks, plastic converter into roads, plastic converter to fuel, bio-based and biodegradable plastics, technological information, recycled food container, recycled fashion products
		b. The establishment of international cooperation in handling plastic waste at sea	website, digital literature, social networks
		c. The implementation of joint actions to clean plastic waste in coastal and small islands	modified collector vehicles
		d. The implementation of clean coastal and marine national movements	modified collector vehicles

4.1.4 Goals in Strategy 4

Table 16 Mapping the relevant technologies to be intervened in the goals in Strategy 4

No	Program	Goal	Technology
4.1	Diversification of funding schemes outside the state budget for income and expenditure; regional income and expenditure budget	a. Increased plastic waste management activities funded by government and private partnerships, CSR grants, community funds, and other legitimate funding sources in accordance with the provisions of the legislation	website, digital literature, social network
4.2	Strengthen institutions	a. Budget allocation priorities for plastic waste management	digital literature
		b. The implementation of general guidance (assistance, supervision, coordination, technical guidance, monitoring, and evaluation and guidance and general supervision) in the area	digital literature

		c. The establishment of a litter management unit in the area of marine tourism destinations	water dispenser, eco-bricks, plastic converter into roads, plastic converter to fuel, bio-based and biodegradable plastics, technological information, recycled food container, recycled fashion products
4.3	Effectiveness improvement of supervision and implementation of law enforcement	a. Increased coordination through enforcement operations on violations related to waste at sea	website, digital literature, information technology
		b. Increased adherence of local governments, managers and communities in maintaining the cleanliness of marine tourism destinations	digital literature, social networks, website
		c. The stipulation of a ministerial regulation concerning Indonesian national standards for plastics that are easily biodegradable and can be recycled compulsorily	website, digital literature, information technology

4.1.5 Goals on Strategy 5

Table 17 Mapping the relevant technologies to be intervened in the goals in Strategy 5

No	Program	Goal	Technology
5.1	Encouragement of management innovation and overcome waste pollution at sea through research and development	a review of the distribution of the plastic recycling industry to tourist destinations	digital literature, social networks, website
		the creation of plastic substitutes with environmentally friendly materials	bio-based and biodegradable plastics
		availability of biodegradable plastic products that can be recycled	bio-based and biodegradable plastics
		availability of integrated information systems for plastic waste in the sea for monitoring and response	Information technolo

4.2 Strengths, weaknesses, opportunities and threats (SWOT) analysis of the potential impacts after intevening technologies to address marine plastic litter in the 'New Balis'

4.2.1 SWOT analysis of potential impacts after intevening technologies in Strategy 1

Table 18 SWOT analysis of potential impacts after intervening technologies in Strategy 1

Strengths	Weaknesses
• Updated information is easy and quick to be shared • Information can be saved for a long time and opened at any time • Interactive, fun • Audio visual • Stakeholders are easy to communicate • Many people can be involved • Build an international network	• Requires electricity to use electronic devices • Requires enough space to play a giant version of the board game
Opportunities	**Threats**
• Internet access is available • Many young people are willing to be volunteers for educational activities • The method is favored by children • School support for socialization • Many internet and smartphone users	• Hacking / cyber attack • The telecommunications channel will be cut off due to a natural disaster • Hoax information • Raining when playing games • May contain hidden missions

4.2.2 SWOT analysis of potential impacts after intevening technologies in Strategy 2

Table 19 SWOT analysis of potential impacts after intervening technologies in Strategy 2

Strengths	Weaknesses
• Early litter handling • Landfilling and emission reduction • Eco-value and useful products • Circular economy enhancement • Energy recovery and resource efficiency	• Need for high initial costs • Need for industrial experts and engineers • Need for product standards and regulations • Raw material capacity requirements
Opportunities	**Threats**
• Adequate researches and technologies • Funding possibilities • Influence for improved litter management • Environmental awareness among stakeholders • Sufficient skilled human resources	• Insecure market for waste-based fashion products • The lack of emission limit values • Land use conflict • Reluctance of stakeholders • Facilities destruction due to natural disasters

4.2.3 SWOT analysis of potential impacts after intevening technologies in Strategy 3

Table 20 SWOT analysis of potential impacts after intervening technologies in Strategy 3

Strengths	Weaknesses
• Fishing gear marking as preventive solution • Blue economy enhancement • Eco-value and useful products • Unique souvenir and gift products • Energy recovery and resource efficiency	• Need for high initial costs • Need for industrial experts and engineers • Need for product standards and regulations • Raw material capacity requirements
Opportunities	**Threats**
• Adequate researches and technologies as well as science institute • Funding possibilities • Influence for improved litter management • Environmental awareness among stakeholders • Sufficient skilled human resources	• Insecure market for waste-based fashion products • The lack of emission limit values • Conflict of interest • Reluctance of stakeholders • Facilities destruction due to natural disasters • IUU fishing

4.2.4 SWOT analysis of potential impacts after intevening technologies in Strategy 4

Table 21 SWOT analysis of potential impacts after intervening technologies in Strategy 4

Strengths	Weaknesses
• Transparency • Supporting the SDGs • Attractive power in promotion	• Need for initial proof
Opportunities	**Threats**
• Sharing experience • Sharing resources	• Hack / Cyber attacks • Hoax information • Terrorism and maritime crimes

4.2.5 SWOT analysis of potential impacts after intevening technologies in Strategy 5

Table 22 SWOT analysis of potential impacts after intervening technologies in Strategy 5

Strengths	Weaknesses
• Transparency • Supporting the SDGs • Collaborative research	• Need for initial proof
Opportunities	**Threats**
• Sharing information • Sharing resources	• Facilities destruction due to natural disasters

4.3 Strategy to achieve sustainability through sustainable tourism aspects and global partnerships

In Subchapter 4.1, the technological interventions have been recommend based on the goals of the National Action Plan. The SWOT of prospective condition after intervening the technologies in the marine plastic litter management in the 'New Balis' have been analyzed in Subchapter 4.2 to be considered. In this Subchapter, the sustainable tourism aspects and global partnerships are discussed to be a part of recommendations.

4.3.1 Sustainable tourism aspects

According to UNTWO, sustainable tourism is a business that attains a balance between the socio-cultural, environmental and economic aspects of tourism development so as to assure long-term benefits to affected communities

4.3.1.1 Socio-cultural aspect

Sustainable tourism should respect socio-cultural authenticity, conserve built and living cultural heritage and contribute to cross-cultural understanding and tolerance (UNWTO as cited in Stange et al., 2013). The recommended strategies to achieve this aspect through technological intervention include:

1. Education and capacity building related to technological interventions for marine litter management should be improved.
2. Policy and regulations in link with technological-based marine litter management should be strengthened and implemented with consideration of stakeholder's interests and duties.
3. Technological interventions should be considered as a way to improve the awareness of local wisdom and culture.

4.3.1.2 Environmental aspect

Sustainable tourism should make optimal use of environmental resources, maintaining essential ecosystems and helping conserve biodiversity (UNWTO as cited in Stange et al., 2013). The recommended strategies to achieve this aspect through technological intervention include:

1. Research and development to find more effective and efficient methods and types of technology needs to be carried out over time.
2. Environmental impact assessment of the application of technology needs to be carried out thoroughly and the results need to be consulted to experts from universities and related agencies.
3. Application of clean technology to produce systems and products without waste and pollutions needs to be improved through institutional collaboration and multidisciplinary approach.

4.3.1.3 Economic aspect

Sustainable tourism should make sure long-term economic benefits for societies, fairly distributed to all community stakeholders, including stable employment and income-earning opportunities, social services and poverty alleviation (UNWTO as cited in Stange et al., 2013). The recommended strategies to achieve this aspect through technological intervention include:

1. Principles of circular economy, blue economy and Pancasila-based economy (because it is multicultural approach and social justice) should be considered and implemented simultaneously.
2. Exhibition, advertisement and competition of technology related to marine litter management should be enhanced and expanded.
3. Capability and usability of clean technology should be explored in order to support litter reduction, reuse and recycling.
4. Research and development for finding the low-cost technologies and materials should be intensified.

4.3.2 Global partnerships

In order to make some efforts to achieve the SDGs, in particular, Goal 14, Goal 15, Goal 8, Goal 9 and Goal 17, Indonesian government should pay attention in global partnerships at marine litter management. It is important that information of the current and actual practices, technological interventions and knowledge of impacts of marine litter should be considered in making the partnerships policy.

5 Conclusion and recommendations

5.1 Conclusion

It is a fact that technological interventions in marine plastic litter management are needed. It is because of marine plastic litter have influenced the all sector of life, such as economic, social and ecological aspects in a global scale. Nowadays, many countries have been making some efforts to address marine plastic litter with technological interventions. Some researches indicate that technological interventions are able to solve the problems of marine plastic litter. However multidiscipline approach should not be left behind.

Recently, Indonesia has developed a national action plan to address marine plastic litter. This dissertation addresses marine plastic litter issues globally and in Indonesia with respect to its expanding tourism sector, particularly in the 'New Balis'. The technological interventions around the world and in Indonesia are documented and analyzed to be formulated as recommendations for addressing marine plastic litter in the 'New Balis' in consideration of the strategies of national action plan, sustainable tourism aspects and international partnerships for a sustainable implementation.

5.2 Recommendations

In order to provide recommendations for addressing marine plastic litter in the 'New Balis' of Indonesia sustainably through technological interventions in the framework of the National Action Plan for Marine Litter Management 2018-2025, there are some recommendations in efforts to improve the study of technological interventions supporting the implementation of the National Action Plan, as below:

1. Paying serious attention to the need for further studies on the ability of the work of technology interventions on marine plastic waste based on the types of plastic.
2. It is necessary to conduct further studies on mapping of technological interventions to break the supply trash of plastic coming from land to sea.

3. It is necessary to strengthen intergovernmental cooperation in the formulation of policies and regulations related to marine plastic waste
4. The problem solving of marine plastic waste is necessary to use a multi-sector approach, in particular, the economic, social, cultural and environmental sectors.
5. In order to ensure technological interventions will be sustainable for addressing marine plastic litter in the 'New Balis', the aspects of sustainable tourism and international partnerships are also recommended to be considered by Indonesian government and related stakeholders.

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Appendices

List of Interview Questions

1. From your perspective, what are the most important sources of marine plastic debris that need to be addressed in the world/Indonesia?

2. From your perspective, what would be the most accessible efforts that can reduce plastic waste?

3. Some methods might require a longer time horizon to see results. From your perspective, what is the most promising method to solve marine plastic debris problems?

4. From your perspective, what is the most promising method to reduce the dependence of society on plastics?

5. From your perspective, what is the most promising method to reduce the leakage of plastic debris to the sea? Any particular technologies or strategies?

6. From your perspective, what are the main challenges in reducing marine plastic debris?

7. From your perspective, what an organizations and institutions do we need to have to solve the problem of marine plastic debris?

8. From your perspective, what are the strengths and weaknesses of existing organizations and institutions in overcoming the marine plastic debris?

9. From your perspective, what is the most useful way to measure progress reduction of plastic waste?

10. What is your organization's next plan?