Mapping the Plastic Litter Leaking into the Waterways of Mekong Countries and Providing Innovative Solutions for Efficient Waste Management

Activity B1

Reviewing the Existing Monitoring Program and Methodologies

Prepared by
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Acronyms

ACSDSD	ASEAN Centre for Sustainable Development Studies and Dialogue
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BMA	Bangkok Metropolitan Authority
CBPMP	Community-Based Plastic Monitoring Program
CCDCC	Coastal Cleanup and Data Collection Campaign
CECR	Center for Environment and Community Research
COBSEA	Coordinating Body on the Seas of East Asia
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CU	Chulalongkorn University
DEQP	Department of Environmental Quality Promotion
DMCR	Department of Marine and Coastal Resources
ERIA	Economic Research Institute for ASEAN and East Asia
FFI	Fauna and Flora International
FTI	Federation of Thai Industries
GAEA	Global Action for Environment Awareness
GGGI	Global Green Growth Institute
GIC	Geoinformatics Center
GPML	Global Partnership on Marine Litter
HDPE	High Density Polyethylene
IETC	International Environmental Technology Centre
IGES	Institute for Global Environmental Strategies
IGO	Intergovernmental organisations
INGO	International Non-Governmental Organisation
ISWA	International Solid Waste Association
ITC	Institute of Technology of Cambodia
IUCN	International Union for Conservation of Nature
LAOs	Local Administration Organisation
Lao PDR	Lao People's Democratic Republic.
LDPE	Low-Density Polyethylene
LMC	Lower Mekong Country
MAFF	Ministry of Agriculture and Forestry
MCC	Marine Conservation Cambodia
MCD	Marine Conservation and Community Development
MFA	Material Flow Analysis
MIND	Ministry of Industry

MoE	Ministry of Environment
MOH	Ministry of Health
MoI	Ministry of Interior
MonRE	Ministry of Natural Resources and Environment
MOPH	Ministry of Public health
MPW	Mismanaged Plastic Waste
MRC	Mekong River Commission
MRF	Material Recovery Facility
MRPMP	Mekong River Plastic Monitoring Project
MSW	Municipal solid waste
NCPMP	National Coastal Plastic Monitoring Program
NGO	Non-Governmental Organisation
NPO	Non-Profit Organisation
NUOL	National University of Laos
PCD	Pollution Control Department
PET	Polyethylene Terephthalate
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PPC	Plastic Pollution Calculator
PPP	Thailand Public Private Partnership
RC3S	Regional Capacity Centre for Clean Seas
RUA	Royal University of Agriculture
RUPP	Royal University of Phnom Penh
SCG	Siam Cement Group
SUN	Sustainable University Network
SUP	Single Used Plastic
SWM	Solid Waste Management
TAF	The Asia Foundation
TBCSD	Thailand Business Council for Sustainable Development
TEI	Thailand Environment Institute
TPIA	Thai Plastic Industry Association
UAV	Unmanned aerial vehicle
UPWMI	Urban Plastic Waste Monitoring Initiative
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
VCOMs	Vientiane City Office for Management and Service
WWF	World Wildlife Fund

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1. Introduction

1.1 Overview of Plastic Pollution

The issue of plastic pollution in oceans, rivers, and coastlines has escalated significantly over the years, with plastic waste now visible on shores across every continent, especially near tourist hubs and densely populated areas. Plastics enter the environment through various pathways throughout their lifecycle, including urban and stormwater runoff, sewer overflows, littering, improper waste disposal, industrial processes, tire abrasion, and wind dispersal.

In 2019, approximately 22 million tons of macro plastics and microplastics entered the environment, causing harm to both terrestrial and aquatic ecosystems, including rivers and oceans (OECD, 2022). The largest share of this leakage (82%) stemmed from improper waste management, reflecting insufficient disposal practices. Additional sources of plastic pollution included abrasion and loss of microplastics (12%), littering (5%), and marine activities (1%). Importantly, rivers are significant contributors, carrying a substantial amount of plastic debris into the ocean.

1.2 Riverine Plastic Leakage

Among the primary sources of marine plastic pollution are land-based plastics, with rivers playing a crucial role in transporting plastics to the oceans. Approximately 80% of plastic waste reaching the ocean originates from managed land-based sources, with the remaining 20% coming from direct littering and other activities in water bodies. Studies indicate that eight of the top ten rivers worldwide contribute 88–95% of the global plastic load to the sea, predominantly located in Asia (Schmidt et al., 2017). The Mekong River stands out as a major contributor, identified among the top 15 rivers globally for plastic waste emissions, releasing between 18.8 to 37.6 kt annually.

The leakage of plastic waste into the Mekong River from land-based sources is closely linked to the management of plastic throughout its value chain, particularly downstream. The Lower Mekong Basin (LMB), spanning several countries (Cambodia, Laos, Thailand and Vietnam), faces challenges due to inadequate waste management systems, characterized by numerous disposal sites, poorly designed landfills, and open dumpsites. This ineffective waste management system in lower-income countries significantly contributes to high volumes of plastic leakage into water environments.

1.3 Plastic's Impact on Health and Environment

Plastic contamination in aquatic environments has become a widespread issue, affecting previously pristine landscapes such as oceans, rivers, and lakes. Plastic persists in these ecosystems for long periods due to human activities, natural movement, and slow degradation rates. As plastics break down, they form microplastics, which are present in our food, water, and air, and carry harmful substances that pose health risks.

The ongoing presence of plastics threatens ecosystems and aquatic life, causing harm and environmental damage. Birds, marine animals, and aquatic species are increasingly affected by

plastic, either through ingestion or entanglement. Additionally, the long-term presence of plastics leads to their gradual breakdown into microplastics, which can infiltrate the food chain and potentially endanger human health (UNEP & UNDP, 2024).

1.4 Importance of Assessing and Monitoring Riverine Plastic monitoring

1.4.1 Plastic Pollution Monitoring

Plastic litter can be categorized as macroplastics, microplastics, and mesolitter. Macroplastics, defined as plastic debris exceeding 5 mm in diameter, are primarily associated with illegal dumping sites, unregulated open dumpsites, and littering by citizens. Macroplastics include plastic bottles, bags, containers, and other substantial plastic objects that have entered the environment and are often found in terrestrial and aquatic settings. Microplastics are small plastic pieces less than five millimetres long which can be harmful to our ocean and aquatic life. Mesoplastics fall into the category in between microplastics and macroplastics (US Department of Commerce, n.d.).

A plastic monitoring program systematically tracks and evaluates plastic pollution across various environments, such as terrestrial and aquatic systems. It involves collecting data on the types, quantities, and locations of plastic waste through methods like physical sampling, remote sensing, and surveys. This data collection is crucial for understanding the extent and composition of plastic pollution and involves analyzing samples to identify plastic types, sizes, and concentrations. Monitoring also gives information on plastic consumption levels, reuse rates, and environmental discharge. By assessing how plastics enter and move through ecosystems, monitoring provides insights into sources of pollution and pathways of plastic debris.

1.4.2 Need for Plastic Monitoring

Given the vast discharge volumes of plastic loadings into the Mekong River, from Lower Mekong Countries (LMCs) which increase plastic emissions into the ocean. Addressing plastic waste management issues in LMCs is crucial to mitigating plastic loading into the Mekong River and, consequently, reducing global marine plastic pollution (RRC.AP, 2020).

The monitoring and assessment of plastic pollution and leakage helps to understand (i) the state, sources, use and fate of plastic pollution and (ii) leakages into various compartments of the environment be it land or water. Information obtained from the monitoring and assessment of plastic litter can support the collection of objective information necessary for mitigation design and adaptive measures.

1.4.3 Monitoring Points

Plastic pollution is a multifaceted and widespread problem that demands a thorough understanding of its dynamics throughout the entire value chain. Effective monitoring is essential for pinpointing the sources, pathways, and effects of plastic leakage into the environment. This information is crucial for developing and implementing effective strategies to reduce and manage plastic pollution. While understanding the key monitoring entry points it is crucial to know:

- Who monitors what: To identify role of diverse stakeholders in monitoring value chain

- What type of plastic: To understand whether microplastic, macroplastic or nanoplastic shall be monitored
- Where to monitor: To know the area of focus (terrestrial, coastal, waterways, plastic production value chain, plastic waste management chain)
- How to monitor: To follow specific monitoring methodologies (surveys,analysis, remote sensing)
- Whom: To understand whom to report, data management

1.5 Objectives of the Review

The objective of this report include:

I. Identifying key elements of riverine plastic monitoring
II. Mapping of the current state of plastic pollution and the capacity and implementation of various methodologies to assess and monitor plastic pollution in the river basin
III. Identifying the remaining gaps in the capacity, tools, and protocols and developing recommendations for improvement of these methodologies

1.6 Framework of the Report

The report is divided into six chapters. The general structure of each chapter is:

I. Chapter 1 Introduction: general overview of plastic pollution, riverine plastic leakage, plastic's impact on health and environment, importance of riverine plastic monitoring along with the objectives of the review has been discussed.
II. Chapter 2 Policy framework: Various policies/laws/regulations frameworks concerning plastic monitoring for Cambodia, Laos, Thailand and Vietnam as well as regional frameworks have been elaborated.
III. Chapter 3 Stakeholder mapping: Various regional and country-specific stakeholders in the plastic monitoring sector have been identified.
IV. Chapter 4 Technology: consists of a technical review of global guidelines, regional protocols for plastic monitoring and existing monitoring tools and methods in each of the four countries.
V. Chapter 5 Challenges for plastic pollution monitoring in the LMCs: both regional and country-specific, have been identified.
VI. Chapter 6 Recommendations: both regional and country-specific, have been compiled.

2. Policy Framework

2.1 Regional Framework

Table 1 outlines two of the agreements/conferences related to marine and river pollution by the Mekong River Commission (MRC) and IOC-WESTPAC. In Table 2, various regional frameworks related to marine debris have been listed. These are ASEAN (Association of Southeast Asian Nations) Framework of Action on Marine Debris, ASEAN Regional Action Plan for Combating Marine Debris（2021-2025, Manila Plan of Action to Advance the Phnom Penh Declaration on the EAS Development Initiative 2018-2022, Bangkok Declaration on Combating Marine Debris (June 2019), APEC Roadmap on marine debris (2019). A brief objective and overview of each of these frameworks has been included in the table.

Table 1: Agreements and Meetings related to Marine and River Pollution

Name of Agreement/Conference	Objectives and Overview
Agreement on Cooperation for the Sustainable Development of the Mekong River Basin (April 5, 1995)	● The Governments of Cambodia, Lao PDR, Thailand and Vietnam agreed to continue to cooperate in a constructive and mutually beneficial manner for the sustainable development, utilization, conservation and management of water and related resources in the Mekong River Basin, and to protect the environmental and ecological balance of the Mekong River Basin from pollution or other harmful effects. They agreed to protect the environmental and ecological balance of the Mekong River Basin from pollution or other harmful effects. ● It is currently developing protocols for monitoring macroplastics in rivers, microplastics in rivers, and microplastics in the digestive tracts of fish.
IOC-WESTPAC (IOC Sub-Commission for the Western Pacific)	● Established in 1989 by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the IOC promotes international cooperation and coordinates programs in ocean research, ocean observation, ocean services and capacity building to increase knowledge of the nature and resources of the oceans and coastal areas, and to apply that knowledge to improve public administration, sustainable development and protection of the marine environment. ● The 22 member countries are Australia, Bangladesh, China, Fiji, France, Indonesia, Japan, North Korea, South Korea, Malaysia, New Zealand, Philippines, Russia, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Tonga, United Kingdom, United States, and Vietnam. ● A manual for monitoring marine debris is under development.

Table 2: Regional Framework related to Marine Debris Management (edited)

Name of Regional Framework	Objective and Overview	Member countries
ASEAN framework of Action on Marine Debris (Nov 2017)	The Framework for Action consists of four priority areas: 1. Policy support and planning 2. Research, Innovation & capacity building 3. Private sector engagement 4. Public awareness, education & outreach ● Each priority area consists of actions and proposed activities for further cooperation in the fight against marine debris in the ASEAN region and among ASEAN and its partners. ● It also proposes to seek standardization of methods for measuring and monitoring marine debris and to provide training on monitoring and management of marine debris.	ASEAN
COBSEA Regional Action Plan on Marine Litter	● It was introduced at the 24th Intergovernmental Meeting of the Coordinating Organization for East Asian Seas (COBSEA) held in Bali, Indonesia on June 19-20, 2019. ● It supports the COBSEA participating countries (Cambodia, People's Republic of China, Indonesia, Republic of Korea, Malaysia, Philippines, Thailand, Singapore, and Vietnam) achieve target 14.1 of Sustainable Development Goal 14 to prevent and significantly reduce all types of marine pollution. ● Its goals and objectives include improving the monitoring and assessment of marine litter and its impact on science-based approaches. Noting the lack of an adequate science-based monitoring and assessment program, it plans to 1. Establish an expert group on marine litter monitoring under COBSEA. 2. Develop regional guidance on the development of monitoring programs. 3. Conduct regional training for monitoring. 4. Develop a national monitoring program based on country policies and circumstances. 5. Prepare a regional report on marine litter and microplastics 6. Develop a regional marine litter and microplastics monitoring metadatabase/portal	Cambodia, China, Indonesia, South Korea, Malaysia, Philippines, Singapore, Thailand, Vietnam

Manila Plan of Action to Advance the Phnom Penh Declaration on the EAS Development Initiative (2018-2022)	● The objective is to promote cooperation on combating marine plastic pollution and to effectively establish and implement a coherent and coordinated regional approach focused on preventing and managing waste and debris and promoting investment in waste management infrastructure in cooperation with the private sector. ● It also aims to promote technical and scientific cooperation and capacity building based on the common needs and interests of the EAS participating countries in order to promote sustainable coastal and marine environment and economic cooperation and to address transboundary marine and coastal pollution damage arising from land and marine sources of marine debris in the region.	ASEAN, Australia, China, India, Japan, New Zealand, South Korea, Russia, United States
Bangkok Declaration on Combating Marine debris (June 2019)	The “Bangkok Declaration on Combating Marine Debris in ASEAN Region” aims to “promote cooperation for the protection, restoration and sustainable use of coastal and marine environment, respond and deal with the risk of pollution and threats to marine ecosystem and coastal environment, in particular in respect of ecologically sensitive areas”. ● It was proclaimed at the 34th ASEAN Summit in Bangkok, Thailand, on June 22, 2019. ● ASEAN Community Vision 2025, it states the commitment for strategic measures to promote cooperation for the protection, restoration and sustainable use of the coastal and marine environment, and to respond to and address the risks of pollution and threats to marine ecosystems and coastal environments, particularly with regard to ecologically sensitive areas. ● Highlighted the ASEAN Socio-Cultural Community (ASCC) Blueprint 2025 on the Conservation and Sustainable Management of Biodiversity and Natural Resources, which reaffirmed. ● It declared the prevention and significant reduction of marine debris from land-based activities, including environmentally sensitive management, especially through enhanced actions at the national level and cooperative actions among partners in ASEAN member countries.	ASEAN

APEC Roadmap on marine debris (2019)	● Developed by APEC in 2019 based on the Xiamen Declaration. ● Cross-sectional collaboration on harmonization of macroplastic and microplastic monitoring methods and best available technology (BAT) to reduce the release of plastic waste. ● Support research to assess the impact of marine debris on coastal ecosystems (mangroves, seagrass, corals, etc.) and the marine environment, and promote knowledge sharing. ● Support research on the sources, pathways, life cycles, and impacts of marine debris from land, sea, and air, including potential impacts on human health.	Chinese Taipei , Chile, Indonesia, The United States, Vietnam, Thailand
ASEAN Regional Action Plan for Combating Marine Debris (2021-2025) (adopted in May 2021)	● The ASEAN Framework for Action provides for the development of a regional action plan on combating marine debris in the ASEAN region. ● Plans are underway to develop a guidebook that will provide a common methodology for marine debris assessment and monitoring. ● It is also planned to conduct a regional survey on microplastics. ● The ASEAN Working Group on Coastal and Marine Environment (AWGCME) will be responsible for overall management and will coordinate with relevant sectoral organizations.	ASEAN

2.2 Country Policy Profiles

2.2.1 Cambodia

In Cambodia, managing plastic pollution, especially macroplastics, presents a significant challenge due to rapid urbanization and insufficient waste management infrastructure. Cities such as Phnom Penh, and Sihanoukville are significantly impacted, with increased flooding risks caused by plastic waste blocking waterways and clogging sewage and drainage systems. In Phnom Penh, plastic waste accounts for over 20% of the daily municipal solid waste, amounting to 3,600 tons. Research indicates that approximately 2.03×10^5 kg/day of plastic (42% of the total plastic waste generated in the city) is discharged into the Mekong River (Haberstroh et al., 2021). This waste migrates downstream from its origin point to lower points along the water's surface. A number of plastic fragments are carried into the water column from Phnom Penh via the Mekong River, adding to the plastic discharge from Southeast Asia into the oceans . Key types of plastic waste include polyethylene terephthalate (PET), soft polyolefin, hard polyolefin, polystyrene (PS), ML (multilayer), EPS (expanded polystyrene) and other plastic as shown in Figure 1.

In the coastal regions, plastic waste comprises 80% of the debris on Cambodia's beaches which has a negative impact on its tourism. Burning plastics also releases harmful chemicals into the atmosphere which heighten public health risks. In coastal areas, impacts of plastic waste to the tourism industry are particularly significant.

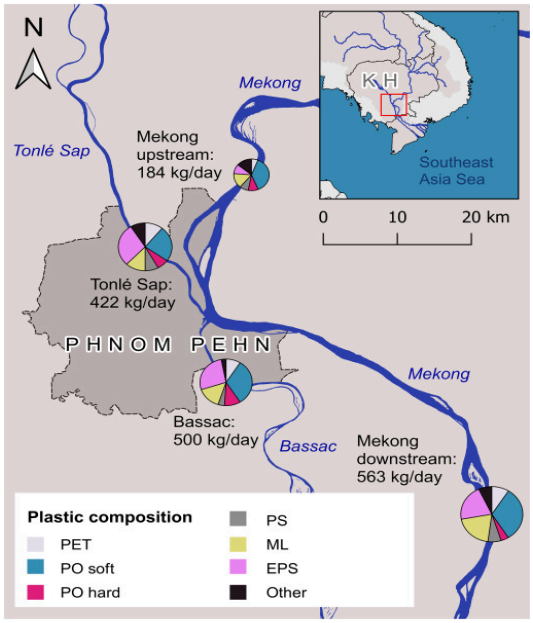

Figure 1: Floating plastic mass transport in Phnom Penh, Cambodia

Source: (van Emmerik et al., 2023)

In order to tackle plastic pollution in the country, the Royal Government of Cambodia has promoted the 4Rs – Refuse, Reduce, Reuse, and Recycle – framework since 2018. As a part of this framework, a small levy on plastic bags, targeting supermarkets and shopping centers was

introduced which has led to reduction on the use of plastic bags by more than 50% for major supermarkets. The funds collected from this levy are used to support green initiatives throughout Cambodia (UNDP, 2020).

While most of the programs for plastic waste monitoring in Cambodia are in combination with solid waste management, there are few initiatives for plastic litter monitoring which have been discussed in the following sections.

Table 3: Policy Framework pertaining to riverine plastic monitoring in Cambodia

Laws/Regulations	Description	Component			
		Monitor & leakage	Prevent leakage/dump	Removal	Waste mgt
Code on Environment and Natural Resources (2023) indirect	The goal of the code is to determine any relevant measures to strengthen, modernize, and improve the environmental protection and management, conservation, and restoration of the natural resources and ecosystem and its functions for sustainable livelihoods and development.	x	x	x	x
National Action Plan for Tackling Marine Litter in Cambodia	To tackle plastic pollution, in April 2018, the Ministry of Environment (MoE) introduced a small charge for the purchase of plastic bags at supermarkets. Since 2019, the MoE has promoted the 4Rs (Refuse, Reduce, Reuse, and Recycle) as a framework. The MoE has focused on three priority areas: 1) policies and regulations, 2) plastic waste communication and outreach, and 3) business development and support for plastic circularity.	x	x		x
Circular Strategy on Environment 2023– 2028 (2023)	<u>Core Strategy:</u> Angle 3: Broadening Extension - Priority 2: Upgrading the environmental database management center <u>Strategy 1: Clean</u> Angle 1: Controlling pollution Priority1: Improving the implementation and monitoring of solid waste, liquid, and hazardous waste management systems - Develop sub-degree on the management of single-use plastic products and plastic waste,	x x	 x		 x

	sub-decree on the management of hazardous wastes - Design and implement a plastic waste clean-up campaign after the first phase of the reduction of plastic use campaign accomplished - Foster and implementation of the 4R principle “refuse, reduce, reuse and recycle” to promote solid waste management, particularly plastic waste, as well as supporting a circular economy Angle 2: Modernizing pollution measurement system Priority 2: Establishing pollution analytical system to ensure quality and safety analysis results Priority 3: Strengthening the monitoring and evaluating of related programs and projects − Monitor, evaluate and recommend the implementation of programs and projects more effectively	 x x			
Law on Environmental Protection and Natural Resources Management (1996) (indirect link to PWM)	Article 12: The MoE shall collaborate with the concerned ministries to establish an inventory list in which will indicate the: - sources, types, and quantities of pollutants and wastes which are imported, generated, transported, recycled, treated, stored, disposed, or released into the airspace, water, land, or on land surface - sources, types, and quantities of all toxic and hazardous substances which are imported, produced, transported, stored, used, generated, treated, recycled, disposed, or released into airspace, water, land, or on land surface	x			
Waste Management Strategy and Action Plan of Phnom Penh (2018-2035)	Article 1.3: Support khan/sangkat administrations to strengthen their monitoring and implementation	x			

(indirectly related to PWM)					
Sub-decree No.168 on Plastic Bag Management (2017)	This sub-decree promotes the reduction of the import, production, distribution, and use of plastic bags in order to enhance public health, environment, and landscaping. It also includes provisions to manage and reduce single-use plastic (SUP), reduce and management plastic imports, and address microplastic pollution	x	x		x
Sub-decree No. 113 on Litter and Solid Waste management in Urban towns (2015)	This sub-decree aims to enhance the effectiveness, transparency, and accountability of waste services and management, protecting public health and the environment	x	x		x

2.2.2 Lao PDR

In Lao PDR, plastic waste is an integral part of municipal solid waste (MSW), primarily originating from residential and commercial sectors (such as stores, hotels, restaurants, markets, and office buildings) as well as institutions like schools, government offices, and hospitals. Most plastics in Lao PDR are imported as prepackaged products from other countries such as Thailand, China, Vietnam and Japan. Plastic waste accounts for 30% of total MSW generated in the country. A large portion of this plastic waste remains uncollected and is either dumped into waterways, open dumps or burned. This is due to improper disposal facilities in the country.

According to a survey conducted by the World Bank, single-use plastics were responsible for 95% of plastic pollution in the surveyed locations (Vientiane, Luang Prabang, Kaysone Phomvihane, Pakse, Thakhek, Vang Vieng). The two key contributors to plastic leakage hotspots were found to be restaurants, bars, cafes accounting more than 50% of hotspots and tourist areas- Vang Vieng and Luang Prabang. Plastic bottles and their caps and lids accounted for most plastic leakage in the Lao PDR (45 % of plastic waste) followed by plastic bags at 23%, and cups and lids followed at 11 % as shown in Figure 2. PET, LDPE and HDPE were found to be the top-three most littered plastics in numbers (World Bank, 2022).

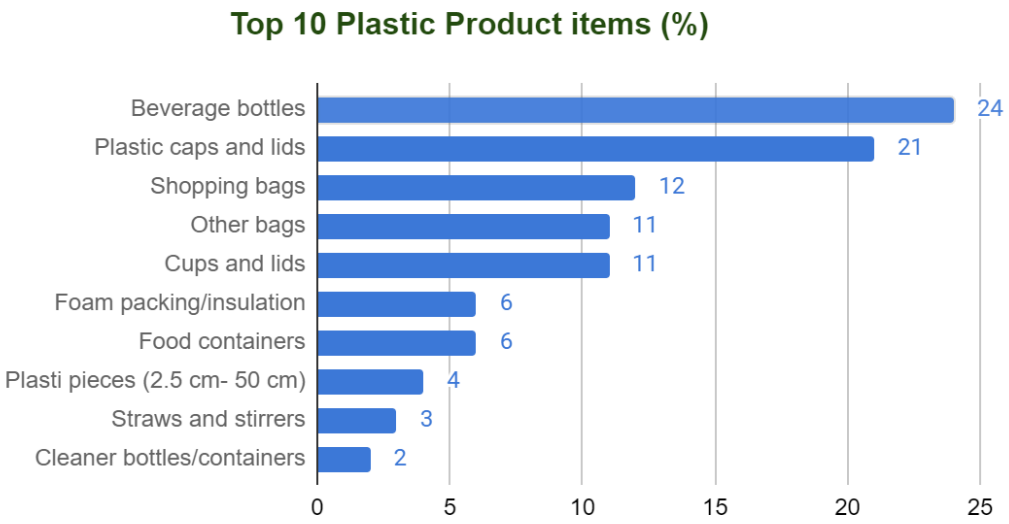

Figure 2: Plastic waste composition in Laos (Adapted from (World Bank, 2022))

Table 4: Policy framework pertaining to riverine plastic monitoring in Laos

Policy name	Related description	Component			
		Monitor & leakage	Prevent leakage/dump	Removal	Waste mgt
National Plastic action Plan for Lao PDR 2024-2030 (05 AUG 2024/MONRE) (Lao version)	http://nas.monre.gov.la:8080/share.cgi?ssid=0J9YvsD *For English version still improving, will be updated some important article later by K.Souvanna*	x	x		x
Ministerial Order on Suspend Establishment new Industrial that Use Plastic Waste as Raw Material (No. 930/MoIC.DIH, 2019)	- Control existing industries - Suspend establishment of new industries	x			x
Ministerial Instructions on Hazardous Waste Management (2015) (indirect link)	- Classification of hazardous waste based on definition of Basel Convention (Article 2); Import – export of hazardous waste (Article 4, and Article 5) organic matter.	x	x		x
Decision on Industrial and Handicraft Waste Management (2012)Related to plastic recycling	- Defined procedure of waste management procedures, include transportation of waste, and its disposal	x	x		
Environmental Protection Law (2012) (indirect link)	Article 41 Environmental Certification - Certification is an endorsement of an initial environmental examination report, environmental and social impact assessment of investment projects and activities including environmental management and monitoring plans.	x	x		

2.2.3 Thailand

In Thailand, plastic packaging consumption stands as a significant contributor to plastic waste. Plastic bags alone constitute approximately 80% of the total 2 million tons of plastic waste generated in 2018. Improper disposal practices include open burning in waste sites and illegal dumping, accounting for about 7.15 million tons of solid waste.

Regarding plastic waste management, local government organizations recycled around 0.77 million tons, which were reused in plastic production, while 0.22 million tons were incinerated for energy recovery. The majority, 2.08 million tons, was disposed of in landfills. However, the recycling of plastic waste is hindered by its low value and contamination, particularly from items like plastic bags and composite plastics.

Thailand's waste management governance operates under a decentralized framework, with local authorities primarily responsible. The Pollution Control Department (PCD) guides national waste management policy and practices to minimize environmental impact (RRC.AP, 2020).

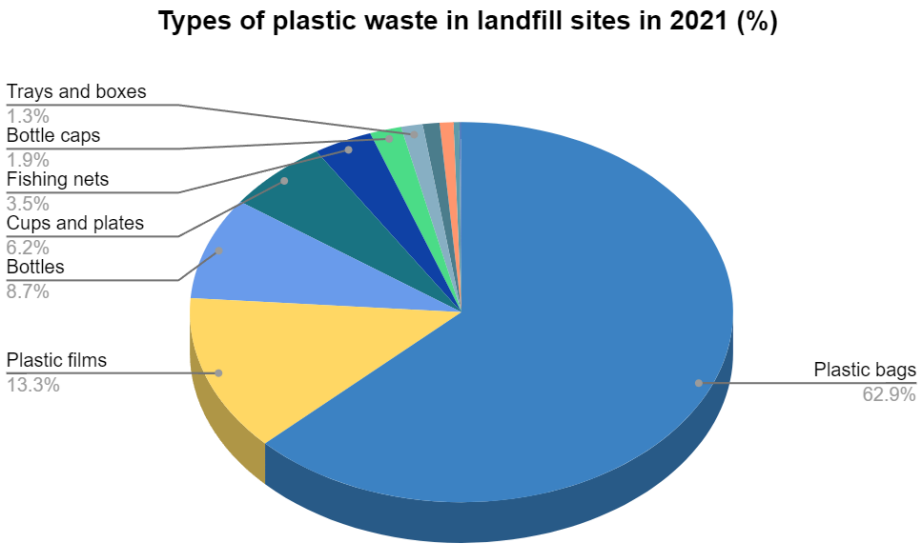

Figure 3: Plastic Wastes found in landfill sites in Thailand (Adapted from PCD (2023))

Table 5: Policy framework pertaining to riverine plastic monitoring in Thailand

Laws/Regulations name	Description	Component			
		Monitor & report	Prevent leakage/dump	Removal	Waste mgt
Marine and Coastal Resources Management Promotion Act, B.E. 2558 (2015)	Article 9: The National Policy and Planning Commission on Ocean and Coastal Management includes: 4. Monitor/evaluate the performance of each government agency related to coastal resources and management 7. Submit a report at least once a year showing the status of marine and coastal resources of the Council of Ministers.	x		x	
The Plastic Waste Management Road Map 2018-2037 (Draft)	Article 8: This article is aimed at ensuring that plastic waste management is tracked effectively, with a focus on improving practices and maintaining accountability.	x	x	x	x
Action Plan on Plastic Waste Management Phase I, 2020 –2022 (PCD, 2020)	Measure 3: Plastic waste management Action: Develop a law to prevent / solve the problem of marine plastic litter				x
Action Plan on Plastic Waste Management Phase II, 2023 –2027 (PCD, 2023)	Measure 1: Production of Eco-friendly plastic products 2. Continuously analyze the situation of plastic waste management, annually. 3. Report situation of plastic waste management to the public. Measure 4: Management of plastic marine debris 1. Surveying waste collection and logistics system of local administrative organizations along canals, rivers, and seashores and waste disposal systems in 23 provinces.	x x	 x		x x

	3. Setting up systems for sorting, collecting and managing plastic waste and other types of waste for tourist boats and travellers, and defining disposal pathways on land. 4. Place systems to prevent and collect plastic waste leaking into the sea such as installing buoy traps to collect waste at river mouths, and garbage collections in the sea and coastal areas.				
Plastic Debris Management Plan (2017–2021)	Article 12: Requires establishing systems to monitor and report plastic waste, including data collection and public transparency, to assess and improve management strategies.	x			x
Marine Waste Management Action Plan 2023 – 2027 (DMCR, 2023)	Activity 1: Prepare a database of waste problem information in coastal communities in 23 provinces by conducting surveys	x			x
Act on the promotion of Marine and Coastal Resources Management, B.E. 2558 (2015)	This is a legal framework designed to protect and sustainably manage the country's marine and coastal environments.	x		x	x

2.2.4 Vietnam

Vietnam produces and consumes about 5 million tons of plastic annually, with 80% of the materials sourced from imported scrap plastic. Per capita plastic consumption in Vietnam rose sharply from 3.8 kg/person/year in 1990 to 81 kg/person/year in 2019. In MekongRiver delta, the plastic waste generated in 2021 was found to be 1438 tons/d with rural and urban areas having 905 tons/d and 534 tons/d respectively (WWF, 2023). The country imports a significant amount of plastics and plastic articles, totaling approximately $15.3 billion.

Public awareness of plastic waste recycling in Vietnam remains low, with more than half of households and small businesses lacking knowledge about plastic characteristics and the detrimental effects of plastic waste leakage into the environment. Currently, 5 to 9% of households still dispose of plastic waste directly into the environment, resulting in an estimated discharge rate of 8 to 10% in 2019, equivalent to 0.4 to 0.7 million tons. About 25% of Vietnam's plastic waste is reintegrated into the recycling market through informal sectors (RRC.AP, 2020).

In 2021, it is estimated that the unmanaged plastic waste leakage into the environment is 1,152 tons/day, equivalent to 420,373 tons/year, and plastic leakage into the water environment is 66,900 tons/year, equivalent to 183 tons/day. Plastic leakage is highest in the Mekong River Delta region, with a value of 56 tons/day, equivalent to 20,484 tons/year. In addition, the plastic waste leakage from aquaculture and fishing activities also contributes a large amount of plastic waste, affecting the quality of the environment and ecosystems. According to the World Wildlife Fund (WWF), the plastic waste generated from coastal fishing boats in Vietnam is 64,143 tons/year with plastic waste leakage to the marine environment being 3,814 tons/year. Lobster farming activities generate 2,875 tons/year of plastic waste and 139 tons/year of plastics leakage into marine environments. Plastic waste generated from shrimp farming activities is about 301,477 tons/year, of which 164,644 tons are pond liners (WWF, 2023).

Table 6: Policy Framework pertaining to riverine plastic monitoring in Vietnam

Policy name	Related description	Component			
		Monitor & leakage	Prevent leakage/dump	Removal	Waste mgt
National Action Plan	Resolution No. 36-NQ /TW of October 22, 2018 of the Eighth Conference of the Party Central Committee XII on the strategy for sustainable development of Vietnam's marine economy to 2030, with a vision to 2045, set the goal of "Preventing, controlling, and significantly reducing pollution of the marine environment; becoming a regional leader in minimizing ocean plastic waste."		x	x	x
National Action Plan for Management of Marine Plastic Litter By 2030	Decision No. 1746/QD-TTg dated December 04, 2019 for marine plastic waste management until 2030 - Decision No. 28 / QD-TTg have contents related to investigation and assessment of the current status of marine plastic debris in Vietnam; propose control and management solutions	x x		x	x x
Decision 1316/QD-TTg dated July 22, 2021	Article 1: Approving the Proposal for the strengthened management of plastic waste in Vietnam - Investigating and evaluating the current status of marine plastic waste in Vietnam; building the ocean plastic waste database; proposing the establishment of networks for observation, monitoring and control of ocean plastic waste.	x	x		x
Decision No. 346/QD-BTNMT dated December 13, 2021 (MonRE)	General Department of Vietnam's Sea and Islands d) Researching and proposing the building of the network for monitoring and observation of plastic waste in 11 main river basins and 12 island districts to serve the annual and 5-year monitoring and evaluation of the current status of plastic waste.	x			x

3. Stakeholder Mapping

3.1 Regional Stakeholders

In this section, various regional stakeholders concerning plastic pollution and its management have been identified and illustrated in Figure 4. These have been categorised into five namely- NGOs, Non-Profit Organisation (NPOs), INGOs, Regional organizations and Regional Intergovernmental Organisations.

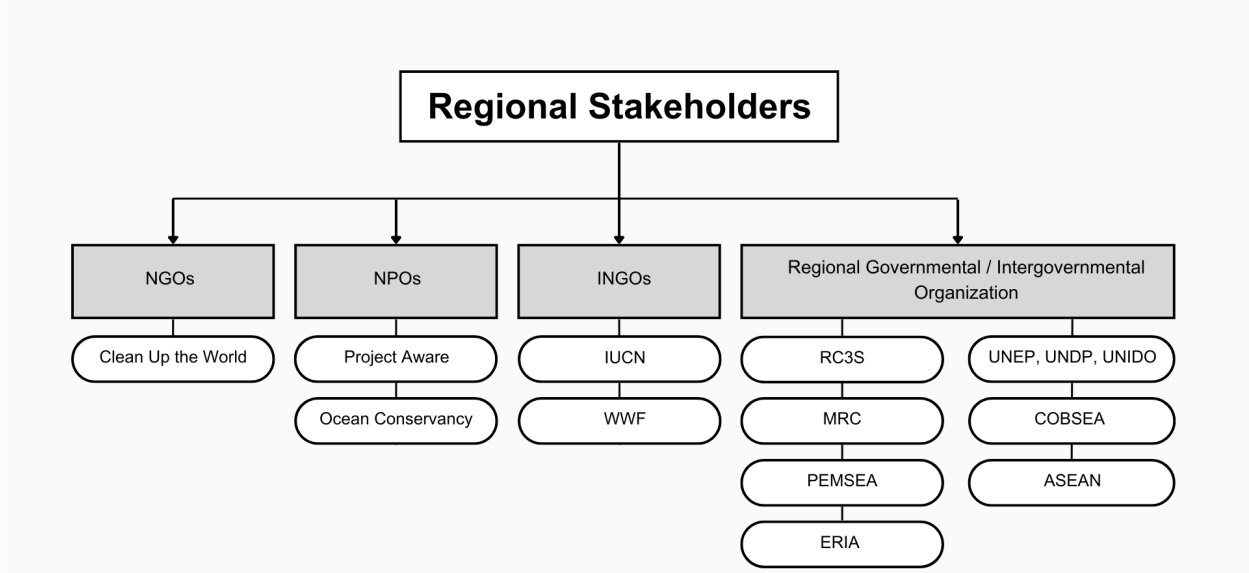

Figure 4: Regional Stakeholder for Plastic Management

NGOs play a significant role in marine litter management. Clean Up the World is renowned for organizing global clean-up campaigns and raising environmental awareness. NPOs such as Project Aware engage communities and divers in marine conservation and clean-ups, while Ocean Conservancy leads global initiatives aimed at reducing marine litter. Additionally, the Economic Research Institute for ASEAN and East Asia (ERIA) conducts research and provides policy recommendations pertinent to environmental management. Among International Non-Governmental Organisation (INGOs), WWF and IUCN are two of the key actors in plastic litter management in marine and coastal ecosystems.

For regional intergovernmental organisations, UN bodies particularly UNEP, UNDP, UNIDO and COBSEA have been supporting various projects related to plastic pollution monitoring in rivers and marine ecosystems across Mekong countries. The United Nations Environment Programme (UNEP) offers technical support and capacity building for plastic litter management. The United Nations Development Programme (UNDP) supports sustainable development and capacity building, including efforts related to marine litter. The United Nations Industrial Development Organization (UNIDO) promotes circular economy practices to address marine plastic litter by encouraging sustainable industrial production and resource efficiency. The COBSEA Secretariat

coordinates and supports the implementation of the COBSEA Regional Action Plan on Marine Litter. ASEAN plays a crucial role in coordinating regional efforts, implementing action plans, and fostering collaboration among member states to address marine pollution. The ASEAN Centre for Sustainable Development Studies and Dialogue (ACSDSD) also supports regional cooperation on sustainable development, including marine litter management.

In the regional organisations category which includes the Regional Capacity Centre for Clean Seas (RC3S), MRC and Partnerships in Environmental Management for the Seas of East Asia (PEMSEA). While RC3S provides technical support and capacity building for marine litter management, MRC addresses pollution from riverine sources within the Mekong Basin. PEMSEA, on the other hand, focuses on integrated coastal management and marine pollution control.

3.2 Country Stakeholder Profiles

3.2.1 Cambodia

In the Mekong region, macroplastic monitoring involves a diverse range of stakeholders across Thailand, Laos, Vietnam, and Cambodia which has been illustrated in Figures 5-8. In Cambodia, key stakeholders have been divided into government sector, private sector, NGOs, Intergovernmental organisations (IGOs), NPOs, academic institutions, international institutes and waste collectors.

The government sector includes MoE, Ministry of Industry (MoI), Ministry of Health (MOH), Ministry of Agriculture and Forestry (MAFF), Ministry of Public Works and Transport, and the National Council for Sustainable Development as shown in Figure 5. Prominent NGOs include COMPOSTED, COMPED, Fauna and Flora International (FFI), The Asia Foundation (TAF), World Bank, and IGES (Institute for Global Environmental Strategies). These NGOs work alongside private sector entities like CINTRI, Leap Lim, Luma System Co., Ltd., Super 800, Mizuda, and various plastic recycling companies such as Chipmong and GAEA. Academic institutions such as Royal University of Phnom Penh (RUPP), Institute of Technology of Cambodia (ITC), and Royal University of Agriculture (RUA) play a significant role in capacity building activities and implementing internationally funded plastic projects. Waste management is supported by local municipalities, including Battambang City Administration and Phnom Penh Capital Hall, while waste generators, citizens, tourists, and the informal sector, including junk shops, play crucial roles in the ecosystem.

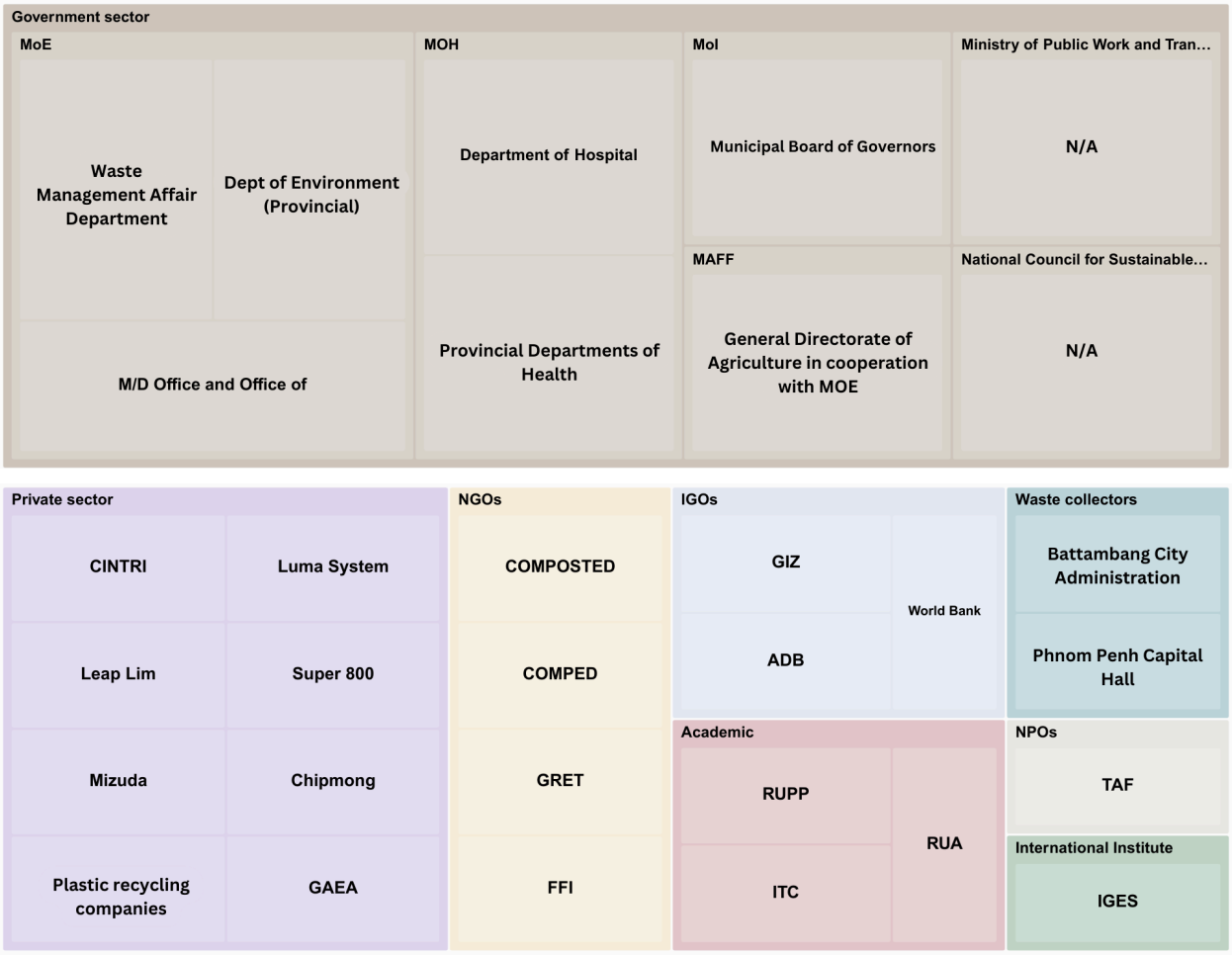

Figure 5: Stakeholder for Plastic Management in Cambodia

3.2.2 Lao PDR

Similarly for Laos, stakeholders have categorized into six types as shown in Figure 6. Government stakeholders include MoNRE and Vientiane City Office for Management and Service (VCOMS). NGOs and international organizations such as Swiss Contact, Zero Waste Laos, Global Green Growth Institute (GGGI), and WWF play critical roles, supported by academic input from the National University of Laos (NUOL) and waste management efforts from groups like VCOMS.

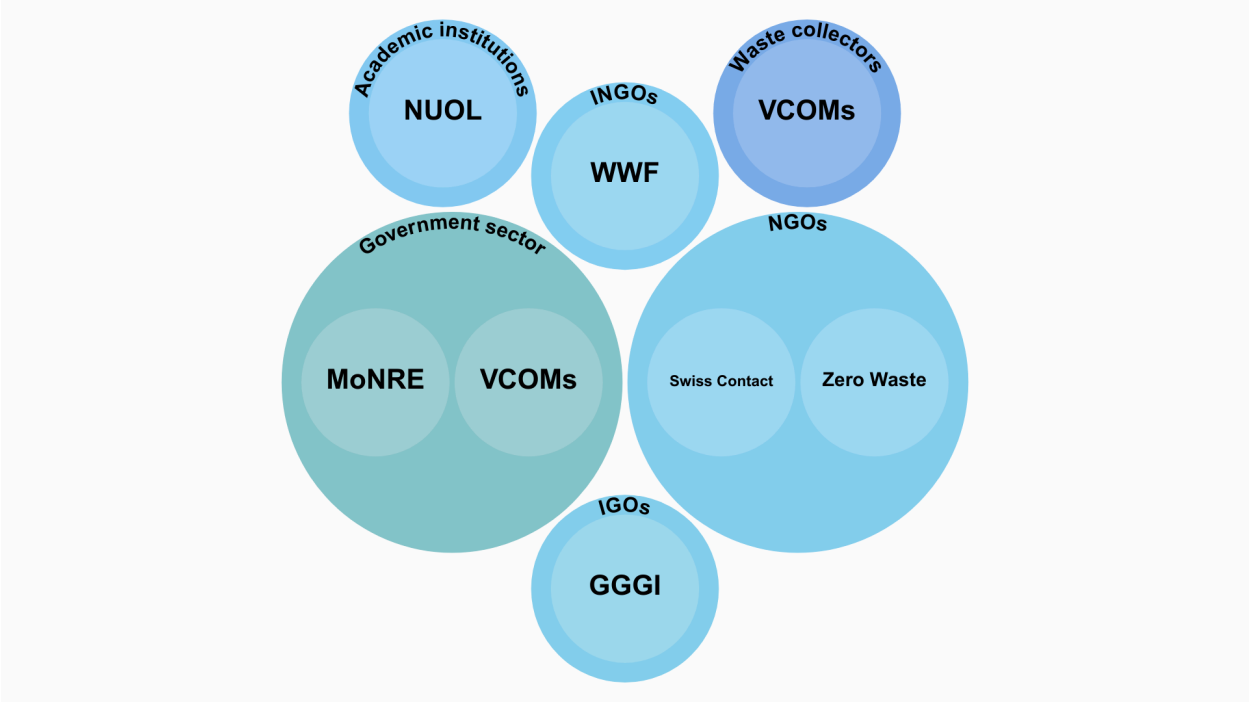

Figure 6: Stakeholder for Plastic Management in Laos

3.2.3 Thailand

In Thailand, the government sector includes MoNRE, Ministry of Industry (MIND), MoI, MoE, local governments, the Department of Environmental Quality Promotion (DEQP), and the Ministry of Public Health (MPH) as shown in Figure 7. Key NGOs in Thailand are Thailand Environment Institute (TEI), TerraCycle Thai Foundation, Thai Plastic Industry Association (TPIA) and Plastic Institute. INGO such as WWF, and International Union for Conservation of Nature (IUCN), work with private sector contributions from PPP Plastic, Thailand Business Council for Sustainable Development (TBCSD), and Federation of Thai Industries (FTI). Academic institutions include the Sustainable University Network (SUN), Chulalongkorn University, and Mahidol University which actively work with international funded projects for mitigating and monitoring plastic pollution in rivers.

Figure 7: Stakeholder for Plastic Management in Thailand

3.2.4 Vietnam

Vietnam engages a broad array of stakeholders, including government entities such as the Institute of Strategy, Policy on Natural Resources and Environment (ISPONRE), MoNRE, Ministry of Construction (MoC), Ministry of Agriculture and Rural Development (MARD), Ministry of Planning and Investment (MPI), Ministry of Finance (MoF), Ministry of Science and Technology (MoST), Ministry of Industry and Trade (MoIT), Provincial Departments of Natural Resources and Environment (DONREs), and URENCO.

Key NGOs include the Ocean Cleanup (TOC), ENDA, Marine Conservation and Community Development (MCD), Center for Environment and Community Research (CECR). INGOs and IGOs such as the World Bank, WWF, USAID, CSIRO and IUCN, which provide financial support for various plastic projects which are implemented by private companies like Coca-Cola, TontoTon, Vietcycle, Keep Vietnam Clean, and DOW. Academic institutions act as technical partners for implementations of these projects. Additionally, organizations like the Vietnam Zero Waste Alliance and the Alliance to End Plastic Waste (AEPW) are also actively involved in addressing plastic waste challenges.

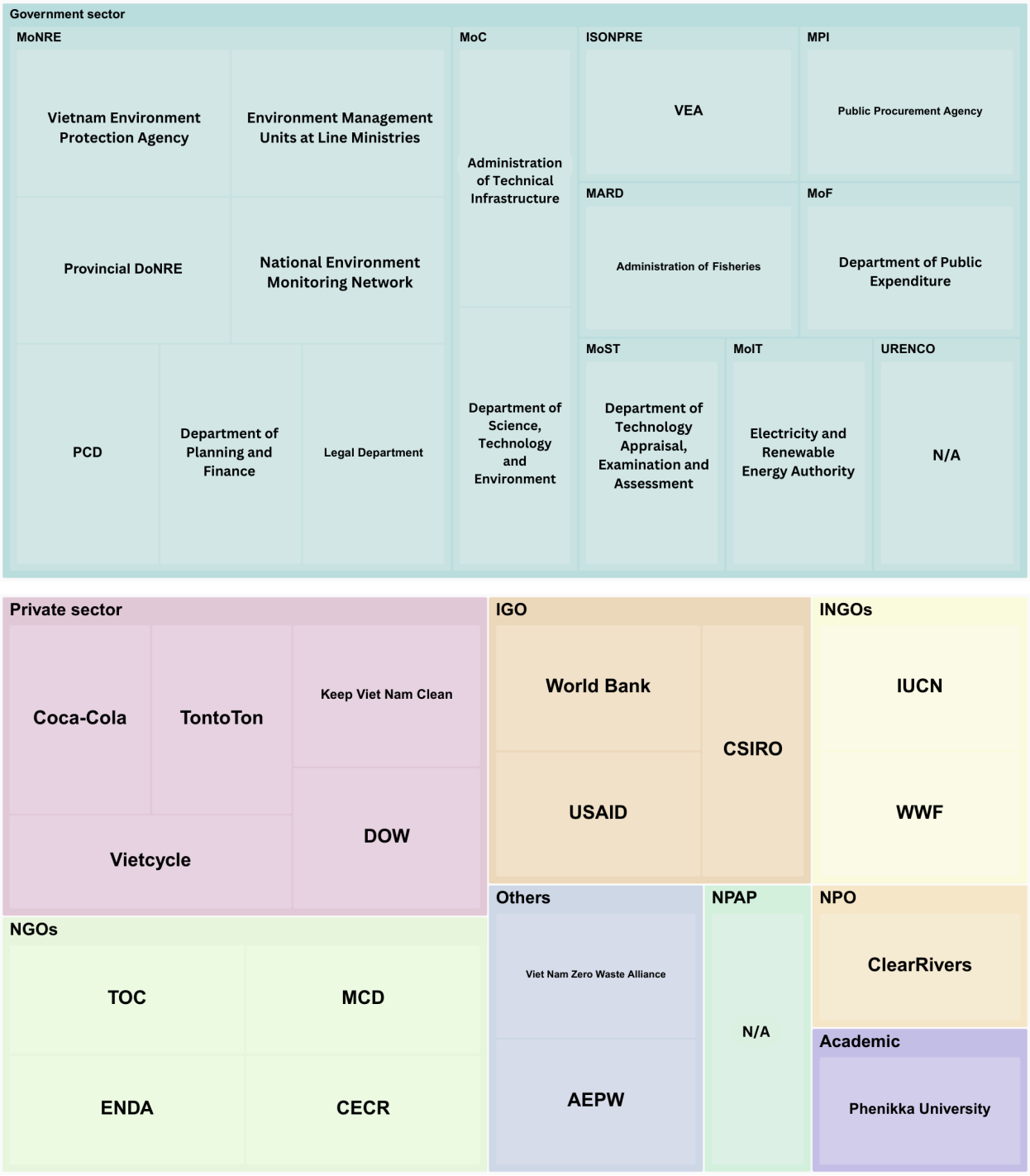

Figure 8: Stakeholder for Plastic Management in Vietnam

4. Technology

4.1 Global Guidelines for Plastic Monitoring

Some of the global guidelines for monitoring of plastics and plastic debris in oceans, rivers, water columns and pollution sources has been listed in Table 7. It also specifies which types of plastic waste—microplastics and macroplastics—are addressed by each guideline.

A. GESAMP Guidelines for the Monitoring and Assessment of Plastic Debris in the Ocean
The GESAMP (Group of Experts on the Scientific Aspects of Marine Environmental Protection) Guidelines for the Monitoring and Assessment of Plastic Debris in the Ocean provide a comprehensive framework for understanding and managing marine plastic pollution. These guidelines are designed to standardize monitoring practices and improve the accuracy of assessments related to plastic debris in marine environments.

Objective: The guidelines aim to provide a standardized approach for monitoring and assessing plastic debris in the ocean, enabling consistent data collection and comparison across different regions and time periods.

Key Components

- Monitoring Protocols: Detailed procedures for collecting and analyzing plastic debris from various marine environments, including surface waters, the water column, and seabeds.
- Data Collection Methods: Recommendations for sampling techniques, such as using trawl nets, surface skimmers, and sediment grabbers, to ensure representative and accurate data.
- Data Analysis: Guidance on how to process and interpret data, including identifying types of plastics, measuring quantities, and assessing the impact of debris on marine life and ecosystems.
- Quality Assurance: Best practices for ensuring the reliability and validity of data, including calibration of equipment, validation of methods, and regular quality checks.

B. WIOSMA Guidelines
The WIOSMA Guidelines (Western Indian Ocean Sustainable Marine and Coastal Development) provide a framework for monitoring and managing marine and coastal environments in the Western Indian Ocean region. The guidelines focus on sustainable development and conservation of marine and coastal resources.

Objective: Promote sustainable management and conservation of marine and coastal ecosystems in the Western Indian Ocean region.

Key Components

- Monitoring: Systematic data collection and indicator use.
- Integrated Management: Address various impacts and promote sustainable use.
- Stakeholder Engagement: Involve communities and build local capacity.
- Reporting: Standardize data reporting and communication.

- Adaptive Management: Update strategies based on new data and feedback.

C. UNEP- Guidelines for the Harmonisation of Methodologies

It provides the most current procedures for monitoring and analysing plastic content in rivers, lakes, reservoirs and water/wastewater treatment plants. In addition, recommendations are made based on a series of workshops for water managers and other stakeholders. A project group, consisting of seven experts in different fields, was created with the direct goal of developing guidelines for plastic monitoring in freshwater. The project group was co-led and funded by the United Nations Environment Programme (UNEP). This report provides a series of guidelines, methods and recommendations to support the development, design and implementation of monitoring and assessment programmes for freshwater plastic contamination (UNEP, 2020).

Objective: It details the state-of-the-art of monitoring plastic debris of all sizes in freshwater, ranging from whole items to micro-sized fibres and fragments.

Key Components

- Sampling Methods: Techniques for surface, subsurface, and shoreline plastic collection.
- Data Collection: Protocols for sampling frequency, location, and environmental documentation.
- Data Analysis: Methods for identifying, quantifying plastics, and ensuring data accuracy.
- Reporting: Standard formats for consistent reporting and communication.
- Impact Assessment: Evaluates effects on ecosystems and human health.
- Harmonization: Ensures methodology consistency across studies.
- Adaptive Management: Regular updates based on new research and technology.

D. UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter

The absence of harmonized and globally agreed upon scientific methodologies to monitor changes in accumulation rates and the composition of litter, and the effectiveness of management arrangements over time are critical issues that require the development of appropriate guidelines. In order to address this problem the Regional Seas Programme (RSP) of UNEP, together with the IOC of UNESCO, and with the support of the Government of Australia, within the context of the 'Global initiative on marine litter' initiated the work on developing guidelines for the 'standardization' and harmonization of the survey and monitoring of marine litter worldwide. Such guidelines will contribute to the global efforts, especially of developing countries, to address and abate marine litter and will assist scientists, governmental authorities and policy makers and respective efforts by governments, NGOs, Regional Seas Programmes and other relevant organizations to address the problem of the monitoring and assessment of marine litter (Cheshire & Adler, 2009).

Objective: The objective of this document is to develop standardized operational guidelines for marine litter survey and monitoring programmes so that litter levels on our beaches and within our seas and oceans can be estimated and interpreted through long-term, broad scale comparative studies that will support management at both national and international scales.

In total four sets of guidelines have been developed, one for each of:

- Comprehensive assessments of beach cast litter
- Assessments of benthic litter

- Assessments of floating litter
- Rapid assessments of beach cast litter

Table 7: International Monitoring Guidelines for Plastic Waste

Guideline	River	Ocean	Water Column	Beach	Pollution Source
GESAMP Guidelines for the Monitoring and Assessment of Plastic Debris in the Ocean			Macro Micro		
WIOSMA GUIDELINE	Macro Micro				Macro Micro
UNEP: Monitoring Plastics in Rivers and Lakes: Guidelines for the Harmonisation of Methodologies	Macro Micro				Macro Micro
UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter				Macro	Macro

4.2 Regional Protocols

Table 8 outlines four protocols concerning riverine macroplastic monitoring by the MRC, and Commonwealth Scientific and Industrial Research Organisation (CSIRO).

A. Community level sampling by fisherman

Plastics collected by fishers during fishing activities are counted and recorded using collection boxes provided to the fishery community office. Fishers place collected plastics in these boxes and count them periodically. While this method may lack precise quantitative results and scientific validity, it helps track long-term trends in riverine plastics and identify polluted areas when aggregated across multiple communities. The process also supports river clean-up efforts and raises awareness, particularly if ghost fishing nets are retrieved. Collection boxes are placed at community centers or piers, where fishers deposit trapped plastics. A record book tracks fisher participation, and plastics are counted and weighed monthly (Mekong River Commission, 2023).

B. Collection at artificial barriers

Monitoring the number and volume of plastic debris that accumulates against or drifts to artificial barriers provides insights into the plastic flux in rivers at specific locations. This method helps estimate both the volume and types of plastics trapped by these barriers. To estimate plastic flux, factors such as barrier configuration, collection frequency, and trap efficiency are considered. Effective implementation requires collaboration with multiple stakeholders, including port administrators, river and hydropower plant operators, and relevant government agencies. Key stakeholders involved in visual observations at artificial barriers typically include

responsible agencies, municipalities, irrigation departments, port authorities, marine departments, private port operators, and local governments (Mekong River Commission, 2023).

C. Sampling using net towing on a boat

This protocol aims to collect macroplastic floating in the open ocean using plankton net from a boat. The location of the monitoring program should be selected properly according to the purpose of monitoring and avoiding festival periods when implementing the protocol. The survey program should meet the objective for example;

- To identify pollution source: Downstream of river in a big city or industrial area should be selected.
- To evaluate transboundary plastic flux: Upper, medium, and downstream of the water body should be selected.

The equipment needed, sampling methods, towing information and sample collection has been explained under this protocol. The samples should be pretreated by sieving the sample with a stainless-steel sieve (mesh size 22.4 mm), Isolate the possible macroplastic, then dry and Weigh and count according to the reporting format.

D. Transect surveys for rivers

CSIRO's protocol for river survey using transects is used to monitor macroplastics on the riverbanks. The first river transect should be conducted at least 50m from the access point. Each subsequent transect should be at least 50m apart. Recommended areas for river transect surveys are 30-40 river sites in a specific geographic area. Each site includes 3-6 transects, each 2 m wide, extending from the water's edge to 2 m beyond the riverbank, with a minimum 50 m spacing between them. The items lying within these transects are counted. If litter is observed in the initial three transects, no further transects are required. However, if no litter is initially found, an extra transect is added. The maximum number of transects per at a site is 6.

Table 8: Protocols for Plastic Monitoring

Protocols	Description	Unit	References
Community level sampling	The fishermen gather the plastic waste that has been caught while fishing on a daily basis.	particles size by mesh (mm) particles/time (time that fishermen catch fish)	MRC
Collection at artificial barriers	Accumulated debris at a designated spot, such as an artificial barrier at ports or piers, is tracked by retrieving the trapped waste at the artificial barrier. The collected waste is then counted, categorized, and weighed.	pieces/time	MRC
Sampling by net towing on a boat	This method is used to sample river debris using net towing onto a vessel navigating in the river. The plastic waste collected is then counted, categorized, and weighed.	weight of debris (kg/m^3) plastic concentration Cp ($Piece/m^3$)	MRC

Transect survey for rivers	Recommended areas for river transect surveys are 30-40 river sites in a specific geographic area. Each site includes 3-6 transects, each 2 m wide, extending from the water's edge to 2 m beyond the riverbank, with a minimum 50 m spacing between them. The items lying within these transects are counted. If litter is observed in the initial three transects, no further transects are required. However, if no litter is initially found, an extra transect is added. The maximum number of transects per at a site is 6.	count (items) weight (kg) density (g/cm^3)	CSIRO (2022)

4.3 Technology Assessment

Macroplastic monitoring methodologies typically involve passive sampling using 20-litre bags (visual inspection), net or boom traps, CCTV or UAV camera systems for visual observations, field surveys, remote sensing, laboratory analyses and mobile applications. However, the readiness and availability of technology for plastic monitoring vary across countries. Among the four countries assessed, Laos exhibits the lowestThailand demonstrates the highest technological advancement in riverine plastic monitoring methodologies, whereas . Cambodia has initiatives focused on marine litter monitoring using GIS tools, local efforts to protect marine environments, and capacity-building workshops. In Vietnam, common plastic monitoring methodologies include clean-up activities, single-use plastic audits in tourist accommodations, and the use of a plastic pollution calculator. The details on each of these methods have been discussed in the sections below.

Plastic litter monitoring technologies can be broadly categorised as follows.

A. Technology for understanding the amount and distribution of plastic litter
B. Technologies for source analysis and understanding the mechanism
C. Technologies for information analysis/gathering
D. Technology for marine debris collection

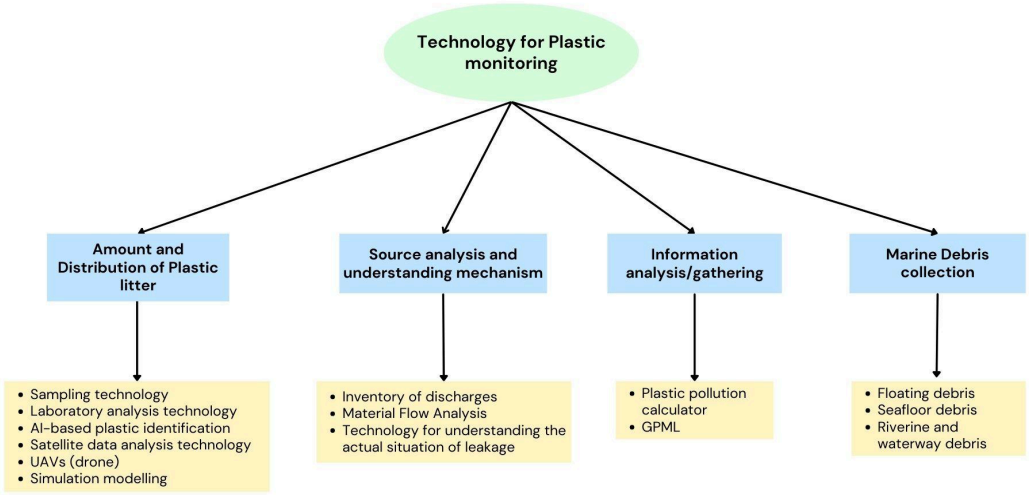

Figure 9: Technology categorisation for plastic monitoring based on criteria

A. Technology for understanding the amount and distribution of plastic litter

Major individual technologies in this category are sampling technology (and the manual), laboratory analysis technology (and the manual), AI-based plastic identification (distribution and amount of presence), image analysis technology, satellite data analysis technology, surveys using UAVs (use of drones) and simulation models.

B. Technologies for source analysis and understanding the mechanism

Major individual technologies are as follows inventory of discharges, Material Flow Analysis (MFA) and technology for understanding the actual situation of leakage (e.g. RIAD: River Image Analysis for Debris transport)

C. Technologies for information analysis/gathering

This includes information analysis tools such as Plastic pollution calculator and information gathering technology eg. GPML, pLitter Mobile app with data visualization platform.

D. Technology for marine debris collection

This includes technologies for collecting floating debris (eg. SEABIN), seafloor debris (eg. multi-beam sonar and acoustic localization systems) for locating, detecting, and recovering fishing gear in the seabed and riverine debris (eg. artificial barriers)

In this report, various technologies capturing floating riverine plastic waste shall be covered in section 4.4 for Cambodia, Thailand, Vietnam and Laos.

4.4 Country-Specific Technologies

4.4.1 Cambodia

Cambodia's macroplastic monitoring technologies include:

A. Amount and Distribution of Plastic Litter

❖ *GIS and Remote sensing*

There are numerous programs in place to keep an eye on marine garbage. For example, monitoring of marine debris in Cambodia is carried out by PEMSEA and other international organisations such as GIZ and the World Bank Group. These programs concentrate on developing capacity, putting laws and regulations for managing marine litter into effect, and making strategic use of GPS/GIS systems. GIS tools help in mapping pollution patterns, analysing spatial relationships, and visualising data trends over time (Ministry of Interior, 2022).

As a part of the CounterMeasure 2 project, the Geoinformatics centre (GIC), AIT conducted a study using GIS and remote sensing-based approach in construction of the model of monitoring and assessing plastic leakage in six cities along the lower Mekong River. Phnom Penh, Cambodia was one of the study locations. Fuzzy overlay data was imputed into the GIS to identify local macroplastic hotspots in the city. The indicators for plastic leakage mapping were classified into static, dynamic and natural indicators which were adapted from the Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean (The Geoinformatics Center, 2022).

B. Marine Debris Collection

❖ *Biobars*

BioBars are cylindrical structures made from recycled water bottles and fishing nets designed to trap floating plastic waste. It is a type of riverine debris collection technology in Cambodia by the Save the Children foundation. The project involved teaching school children to construct BioBars, which were then strategically placed around the lake by teachers and community members to capture floating plastic waste. The project emphasises community involvement and education (Brennan, 2023).

The effectiveness of the BioBars is monitored through regular collection and removal of the trapped plastic waste by local waste collectors. Reductions in visible plastic debris within the lake served as a key success metric. Community feedback and visual assessments are used to gauge the impact of the BioBars. The project aims to achieve a significant and noticeable reduction in plastic pollution, thereby contributing to a cleaner and healthier environment.

Figure 10: Cylindrical structure covered with fishing nets- Biobars

Source: (iDE, 2024)

❖ *One Earth-One Ocean SeeKuh*

This technology can collect waste up to 4 m deep from bays, estuaries, and coastal regions and has been used in Cambodia for plastic capture, removal since 2018. The SeeKuh is the central cleaning vessel used in coastal regions and estuaries. It collects plastic debris into the lowerable mesh of 2.5 cm size hung between the two hulls. They collect the plastic waste up to a depth of 2 m. Currently, up to two tons of garbage can be collected per trip or network. In addition to plastic waste collection, there is a small laboratory where water samples can be examined directly with an infrared spectrometer for plastic to observe what kind of plastic the SeeKuh collects (AIT Solutions, n.d.).

Figure 11: SeeKuh technology

Source: (OEOO, n.d.)

To be able to collect large areas effectively, the SeeKuh II is an innovative technique from OEOO. Two motorized boats (local fishing vessels, conventional workboats) pull the SeeKuh II through the polluted operating areas. The floating barriers are placed between the tugboats and the SeeKuh II. It creates a kind of funnel through which the marine litter is directed toward the conveyor belt of the SeeKuh II (AIT Solutions, n.d.).

❖ *SeeHamster*

SeeHamster are small catamarans equipped with fold-down nets collecting debris from inland waters. It was invented by One Earth-One Ocean (OEOO) in 2012 and is currently used in Battambang, Cambodia (Sangkae river) for plastic capture and removal from rivers and streams. The SeeHamster is the smallest unit of collecting waste with a length of about 4.5 - 6 m and a width of 2-3 m and a shallow draft. It is used in inland waters including lakes and rivers worldwide. It initially worked with a fold-down safety net which is used to collect the waste special ramp and conveyor belts are used in the modern version of the SeeHamster which has a collecting capacity of up to 500 kg. There are four types of SeeHamster including SeeHamster Type Cairo, SeeHamster Type Jakarta 1, SeeHamster Type Jakarta 2, and SeeHamster Type Jakarta Solar depending on their various size, and various system appliances (AIT Solutions, n.d.).

Figure 12: SeeHamster Type Jakarta 2

❖ *Collectix*

CollectiX is a garbage collection boat. The CollectiX boat collects garbage on any water and is especially suitable for smaller rivers and canals because it is narrow and flexible.Sensors located at the CollectiX boat and drones are paired with artificial intelligence. They determine accumulations of waste and their exact composition in terms of quantity and type. This enables the identification of polluters and creates valuable data on water pollution – detect, count, and analyze objects, and collect data on the composition and origin of the waste.

In Cambodia, this technology was used as a part of the Cleanup Mission in 2022 in Phnom Penh. The CollectiX garbage collection boat is planned to deploy in the Mekong, Tonlé Sap, and Bassac Rivers in Phnom Penh. As well as in highly polluted rivers and lakes in the area from 2023 – 2025. The collected plastics are sorted into recyclables and non-recyclables (AIT Solutions, n.d.).

Figure 13: CollectiX

Source: (MediaInfo, n.d.)

C. Information Gathering

❖ *Coastal Plastic Audit*

The coastal plastic audit was conducted on three high-traffic beaches in Sihanoukville, Cambodia during peak tourist season. Sites were chosen based on the availability of unobstructed 100m stretches of beach which were then broken down into 25m wide transects perpendicular to the water's edge. The Marine Debris Tracker was used to log data with focus on macroplastics collection (Roberts et al., 2020).

❖ *pLitter Mobile- GIC*

pLitter Mobile is a mobile survey application with ESRI Survey123 for the collection of plastic litter data. This pLitter App allows users to click a photo of the plastic litter spotted, which will be directly geotagged using the mobile phone location. This mobile app was used during CounterMEASURE Project's Phase II macroplastic data collection in both dry and wet seasons. The survey was implemented in 6 lower Mekong River Delta cities, 4 cities in India, 3 cities in Sri Lanka, and other cities from Japan, Korea, and Uganda. In Cambodia, the survey was conducted in Tonle Sap and Phnom Penh. The survey aims to identify the dominant plastic waste varieties at three different types of sampling sites from the cities which are artificial barriers, littering spots, and uncontrolled dumps. The data submitted through this app was recorded in the data visualization platform developed by GIC, AIT.

The data will be displayed immediately after submitting the data from the mobile. For this platform, the data collected with the phone will be displayed in the form of a dashboard, showing the results of each study area, and include a survey report as well. This page shows the results of the surveys of each pilot area. It showed all the data according to the survey and visualised each point.

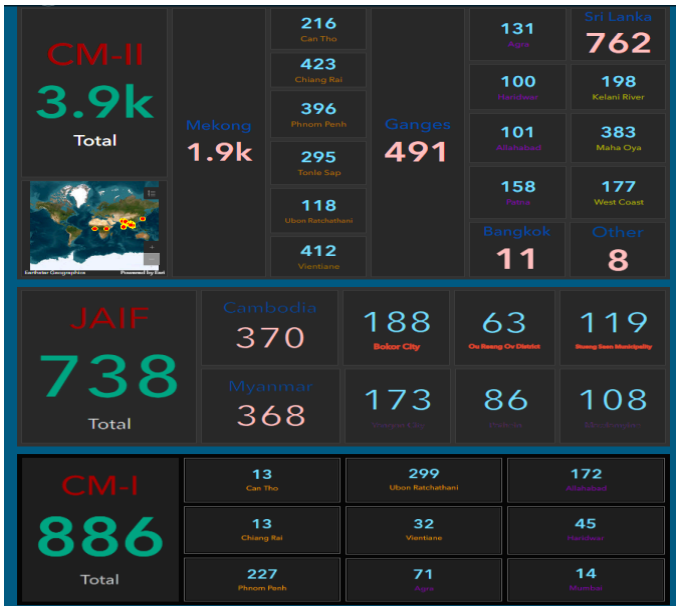

Figure 14: Data visualisation dashboard- GIC

❖ GPML

UNEP operates the Global Partnership on Marine Litter (GPML), a global partnership on marine litter, and has developed the GPML Digital Platform, which covers data and policies on marine debris around the world (Figure 11). The Global Partnership on Marine Litter (GPML) is a collaborative initiative that unites various stakeholders dedicated to combating marine litter and plastic pollution. It offers a unique global platform for sharing knowledge and experiences, enabling partners to collaborate on developing and advancing solutions to this urgent issue (UNEP, 2017).

4.4.2 Lao PDR

A. Amount and Distribution of Plastic Litter

❖ *GIS and Remote sensing*

In the CounterMeasure 2 project, the Geoinformatics centre (GIC), AIT conducted a study using GIS and remote sensing-based approach in construction of the model of monitoring and assessing plastic leakage in Vientiane, Laos. Fuzzy overlay data was imputed into the GIS to identify local macroplastic hotspots in the city. The indicators for plastic leakage mapping were classified into static, dynamic and natural indicators which were adapted from the Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean.

B. Information Gathering/Analysis

❖ *pLitter Mobile- GIC*

pLitter Mobile is a mobile survey application with ESRI Survey123 for the collection of plastic litter data. This pLitter App allows users to click a photo of the plastic litter spotted, which will be directly geotagged using the mobile phone location. This mobile app was used during the CounterMEASURE Project's Phase II macroplastic data collection in both dry and wet seasons.

The survey was implemented in 6 lower Mekong River Delta cities, 4 cities in India, 3 cities in Sri Lanka, and other cities from Japan, Korea, and Uganda.

In Laos, the survey was conducted in Vientiane. The survey aims to identify the dominant plastic waste varieties at three different types of sampling sites from the cities which are artificial barriers, littering spots, and uncontrolled dumps. The data submitted through this app was recorded in the data visualization platform (Figure 8) developed by GIC, AIT. The data will be displayed immediately after submitting the data from the mobile. For this platform, the data collected with the phone will be displayed in the form of a dashboard, showing the results of each study area, and include a survey report as well. This page shows the results of the surveys of each pilot area. It showed all the data according to the survey and visualize each point.

4.4.3 Thailand

A. Amount and Distribution of Plastic Litter

❖ *Solid Waste Management Model*

A Solid Waste Management (SWM) model was developed to quantify human-generated plastic emissions and map their pathways from origin to disposal. It focuses on estimating mismanaged plastic waste (MPW) leaking into terrestrial and riverine environments, identifying specific leakage points crucial for fate and transport models. This model begins at the point of solid waste generation, excluding upstream processes. The model integrates data from the Pollution Control Department (PCD), local administration organizations (LAOs), Bangkok Metropolitan Administration (BMA), and National Statistical Office (NSO) in Thailand. This data, combined with hydrological modelling, tracks plastic waste flow from land sources to waterways and through rivers to marine environments.

Initial steps involve estimating solid waste generation and formal collection rates, determining plastic fractions using PCD and BMA waste composition figures, and obtaining formal collection and recycling data from these agencies. The final destination of collected waste is determined by PCD data. Uncollected waste is estimated by subtracting formally collected amounts from total generation, with disposal site characteristics guiding estimates of waste exposure to wash-off (exposed MPW), assessed through expert judgement due to data gaps.

Wash-off drives plastic transport to surface water, modelled using a hydrological rainfall runoff model (wflow_sbm) and a fate and transport model (D-Emissions) to compute plastic leakage from land to rivers. River transport modelling employs wflow_sbm and DELWAQ to quantify plastic debris reaching marine environments (The World Bank, 2022a).

❖ *GIS and Remote sensing*

In the CounterMeasure 2 project, the Geoinformatics centre (GIC), AIT conducted a study using GIS and remote sensing-based approach in construction of the model of monitoring and assessing plastic leakage in six cities along the lower Mekong River. Ubon Ratchathani and Chiang Rai were two of the study locations from Thailand. Fuzzy overlay data was imputed into the GIS to identify local macroplastic hotspots in the city. The indicators for plastic leakage

mapping were classified into static, dynamic and natural indicators which were adapted from the Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean.

❖ *Aerial survey (UAV)*

Aerial surveys are used for surveying riverbanks or areas that are challenging to access on foot. UAVs (Unmanned aerial vehicle) can capture high resolution imagery and they can be analyzed manually and AI assisted programs. The limitation of UAV is its dependency on UAV pilots for operation and on weather conditions.

❖ *CCTV systems*

CCTV systems provide real-time monitoring and are mostly installed at bridges, pointing at rivers. Parallel camera installation covers the entire river stream width. Given the impracticality of manually analysing extensive footage, AI assisted methods are employed and proven reliable. pLitter CCTV (Figure 15) developed by the Geoinformatics Center, AIT is commonly used technology for riverine macroplastic monitoring across Lower Mekong cities especially in Thailand. It has been operated in numerous cities such as Bangkok, Pathumthani and Chiang Rai in Thailand.

The advantages of this tool include: AI-based to automatic detection and classification into multiple categories; cloud-based data storage for web-based data visualization; solar-powered cells and sustainability; cost-effective and open-source development. The limitations are, requiring expertise in Computers and Electronics to build the CCTV setups. The number of cameras required per location may vary depending on the width of the river.

Figure 15: pLitter CCTV at Bangkok, Thailand

C. Information Gathering

❖ *pLitter Mobile- GIC*

pLitter Mobile is a mobile survey application with ESRI Survey123 for the collection of plastic litter data. This pLitter App allows users to click a photo of the plastic litter spotted, which will be directly geotagged using the mobile phone location. This mobile app was used during the

CounterMEASURE Project's Phase II macroplastic data collection in both dry and wet seasons. The survey was implemented in 6 lower Mekong River Delta cities, 4 cities in India, 3 cities in Sri Lanka, and other cities from Japan, Korea, and Uganda.

In Thailand, the survey was conducted in Chiang Rai and Ubon Ratchathani. The survey aims to identify the dominant plastic waste varieties at three different types of sampling sites from the cities which are artificial barriers, littering spots, and uncontrolled dumps. The data submitted through this app was recorded in the data visualization platform (Figure 9) developed by GIC, AIT. The data will be displayed immediately after submitting the data from the mobile. For this platform, the data collected with the phone will be displayed in the form of a dashboard, showing the results of each study area, and include a survey report as well. This page shows the results of the surveys of each pilot area. It showed all the data according to the survey and visualised each point.

❖ *GPML*

UNEP operates the Global Partnership on Marine Litter (GPML), a global partnership on marine litter, and has developed the GPML Digital Platform, which covers data and policies on marine debris around the world (Figure 16a and 16 b). The Global Partnership on Marine Litter (GPML) is a collaborative initiative that unites various stakeholders dedicated to combating marine litter and plastic pollution. It offers a unique global platform for sharing knowledge and experiences, enabling partners to collaborate on developing and advancing solutions to this urgent issue (UNEP, 2017).

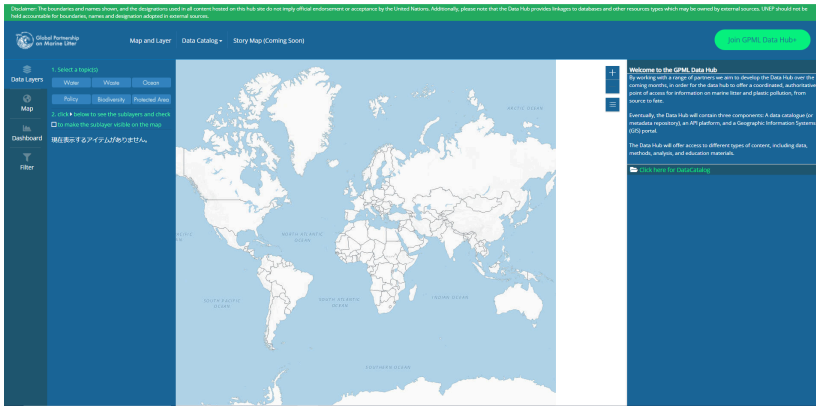

Figure 16 a: GPML Digital Platform

Source: GPML Digital Platform

The GPML facilitates:

- Cooperation and Coordination: Fostering collaborative efforts among stakeholders.
- Knowledge Sharing: Exchanging ideas, expertise, and experiences.
- Identifying Issues: Spotting gaps and emerging challenges.
- Leveraging Resources: Utilizing the skills, resources, and enthusiasm of all involved parties, including the private sector, civil society, non-governmental organizations, and regional bodies, to address and prevent marine litter and plastic pollution from both land and sea sources.

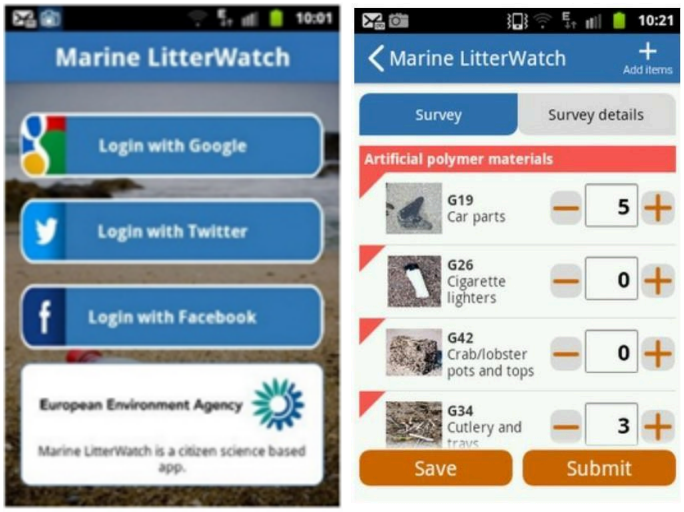

Figure 16 b: Information Gathering Application for Citizens

Source: (Perseus, 2012)

D. Marine Debris Collection

❖ *SCG-DMCR Trap*

The SCG litter trap innovation is an improved version of its prototype, “Oil Boom,” developed by the Department of Marine and Coastal Resources (DMCR) in 2018. The problem in its prototype was that these booms could not hold litter without scattering with the tide. The collected trash flowed out of the boom with the tide (AIT Solutions, n.d.).

Figure 17: SCG-DMCR trap

Source: (scginnovation, 2020)

To overcome this limitation, SCG developed the innovative SCG-DMCR Litter Trap, a floating waste trap that utilises water flow and pressure principles to capture debris on the water's surface. This mechanism ensures that waste remains trapped despite shifting water currents influenced by tides. Since 2019, SCG, in collaboration with the DMCR, has installed over 24 of these traps across 13 provinces in Thailand, strategically placed at river and canal mouths

connected to the sea. This initiative has successfully collected more than 40 tons of waste, effectively preventing it from reaching the ocean (scginnovation, 2020).

❖ *Photo benchmarking*

This is a manual method of detecting plastic pollution across river banks, accumulation points using visual observation. It provides quick baseline data, visual documentation and is a standard protocol from MRC.

❖ *Water sampling using nets*

Net towing using nets of mesh sizes above 5 mm are used for captured microplastics from river surfaces.

❖ *Passive sampling*

In this type of sampling, plastic accumulation locations are identified and random samples are filled into 20 L bags which are then visually sorted and analysed for composition and volume. This technique causes sampling bias and requires frequent sampling to be performed for capturing seasonal variations and representative data.

4.3.4 Vietnam

A. Amount and distribution of plastic litter

❖ *CCTV systems*

CCTV systems provide real-time monitoring and are mostly installed at bridges, pointing at rivers. Parallel camera installation covers the entire river stream width. Given the impracticality of manually analysing extensive footage, AI assisted methods are employed and proven reliable.

a. pLitter CCTV

pLitter CCTV developed by the Geoinformatics Center, AIT is commonly used technology for riverine macroplastic monitoring across Lower Mekong countries. It was operated in three locations in Can Tho, Vietnam-Quang Trung bridge, Cai Rai bridge and Ninh Kieu pedestrian bridge as a part of UNEP project but currently is non-operational. The advantages of this tool include: AI-based to automatic detection and classification into multiple categories; cloud-based data storage for web-based data visualization; solar-powered cells and sustainability; cost-effective and open-source development.

b. Go-Pro camera with APLASTIC-Q

The World Bank developed a plastic analytics system called APLASTIC-Q, which uses machine learning technology to analyze images for detecting and managing plastic pollution. APLASTIC-Q can: i) identify and estimate plastic waste volumes in a given area, ii) determine the types of plastics present, and iii) quantify these different plastic types. This system was piloted in Vietnam, where it was used in conjunction with GoPro cameras for river monitoring. The initial results show that APLASTIC-Q effectively detects floating plastic waste larger than 10 cm with good accuracy.

River monitoring was conducted using cameras mounted on bridges (see Figure 13a) to capture and analyze videos of plastics floating on river surfaces over time. The study included three

locations in Vietnam—Hai Phong, Lao Cai/Sa Pa, and Hai Duong—with three survey sites in each. The bridge-mounted camera surveys, which took images at set intervals, were successful in documenting floating plastics in the rivers (The World Bank, 2022b).

❖ *GIS and Remote sensing*

In the CounterMeasure 2 project, the Geoinformatics centre (GIC), AIT conducted a study using GIS and remote sensing-based approach in construction of the model of monitoring and assessing plastic leakage in Can Tho, Vietnam. Fuzzy overlay data was imputed into the GIS to identify local macroplastic hotspots in the city. The indicators for plastic leakage mapping were classified into static, dynamic and natural indicators which were adapted from the Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean.

a)

b)

c)

Figure 18: a) Bridge surveys using GoPro camera; b) UAV drones across river; c) Net sampling facing camera

Source: (The World Bank, 2022b)

❖ *Aerial surveys*

Drone surveys were conducted in Vietnam at five sites in Hai Phong, two sites in Hai Duong, and two sites in Sa Pa. These surveys utilised drones equipped with cameras to capture images over extensive areas (see Figure 13c). The UAVs collected two types of images: high-resolution

images from altitudes of 60–100 m to identify pollution hotspots, and very high-resolution images from lower altitudes of 3–6 m to analyze these hotspots in detail. The images were automatically processed to detect and classify plastic items.

The high-altitude images provided a broad view for spotting pollution hotspots across the survey sites, while the low-altitude, high-resolution images allowed for a detailed analysis of these hotspots. UAVs offered several advantages, including the ability to complete surveys quickly (within 1–2 hours) and to present data in a clear and accurate manner with extensive spatial coverage (The World Bank, 2022b).

❖ *Field surveys*

According to a World Bank study, a comprehensive field survey was conducted across 10 rivers and coastal sites in Vietnam to assess the quantity, types, and key locations of plastic waste entering waterways, aiming to gauge the extent of plastic pollution. In total, surveys were carried out at 38 sites, comprising 14 coastal locations across 8 areas and 24 riverbank sites across 10 areas. These sites were distributed as follows: Lao Cai Province and Hai Phong in the Northern region; Thua Thien Hue Province, Da Nang, Quang Nam Province, and Khanh Hoa Province in the Central region; and Soc Trang, Ho Chi Minh City, Can Tho, and Kien Giang (Phu Quoc Island) in the Southern region. The river sites were categorized into four groups: the Red River, rivers in the central provinces of Vietnam, the Phu Quoc rivers, and the Dong Nai-Sai Gon rivers. The river sites in Ho Chi Minh City are part of the Dong Nai-Sai Gon river group. The surveys identified the top 10 most common types of plastic waste (see Figure 14).

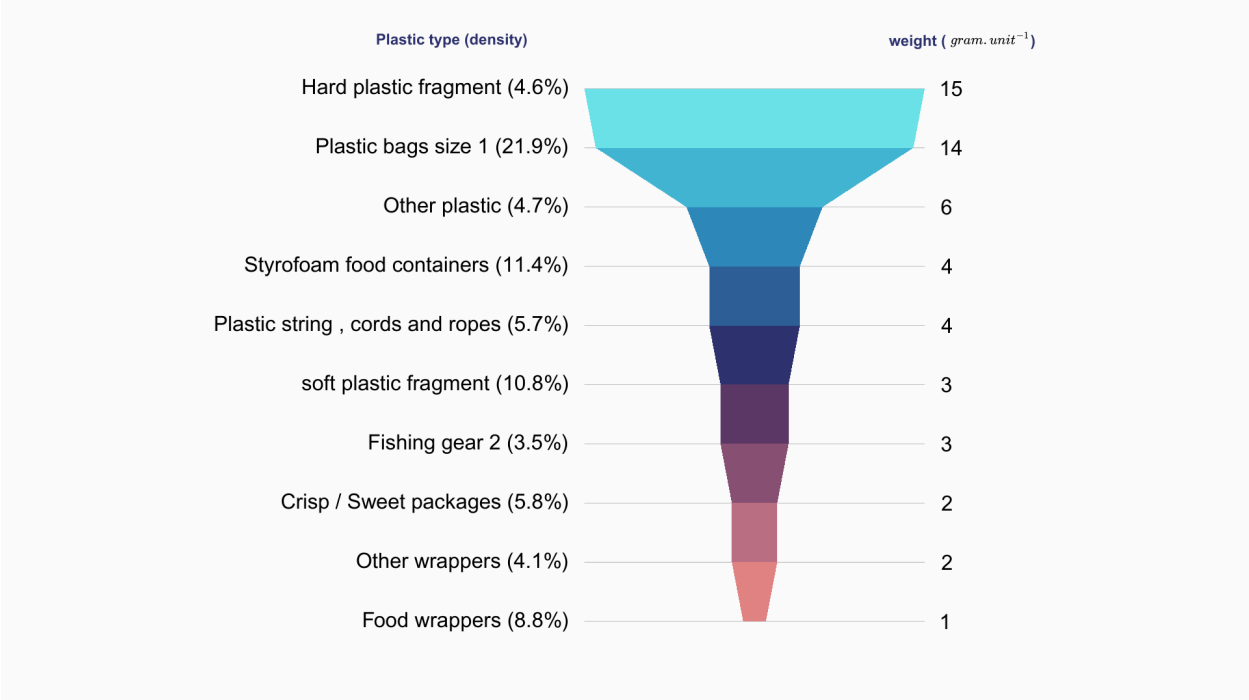

Figure 19: Top 10 Plastic Waste Items at river sites in Vietnam (Adapted from The World Bank, 2022b)

B. Source Analysis and Understanding Mechanism

❖ *Plastic Pollution Calculator (PPC)*

The Plastic Pollution Calculator (PPC) is a globally utilized waste modeling methodology developed by the International Solid Waste Association (ISWA) and the University of Leeds. It has been implemented in Da Nang City at the district level. The PPC employs a comprehensive Material Flow Analysis (MFA) approach to quantify sources, destinations, and pathways of plastic pollution. This method integrates various factors influencing plastic pollution, such as waste composition, terrain, infrastructure quality, local socio-economic conditions, climate, and waste management practices. Using a digital elevation model and flow routing algorithm, the PPC maps how plastic waste enters the environment, including modeling surface runoff and entry points (UN-ESCAP et al., 2021).

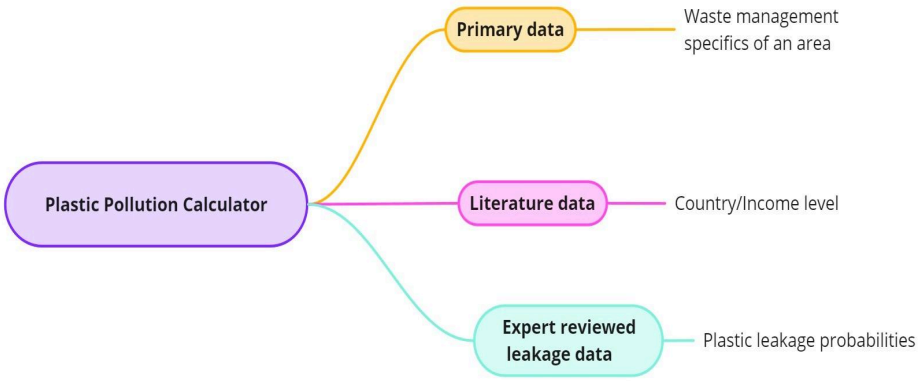

Figure 20: Plastic Pollution Calculator

❖ *National Analysis and Modelling (NAM) Tool*

Supported by SYSTEMIQ, GPAP has developed an online analytics tool called the National Analysis and Modelling (NAM) Tool, with a pilot version implemented in Vietnam (World Economic Forum, n.d.). The tool operates in three stages:

- Baseline Creation: The NAM Tool first establishes a baseline of plastic waste flows, providing key metrics such as waste generation, plastic waste import and export, collection and sorting rates, recycling rates, disposal rates, mismanaged waste rates, costs, GHG emissions, and associated jobs and revenues.
- Scenario Simulation: With the baseline established, the tool simulates various solution scenarios to assess the economic, environmental, and social impacts of different plastic pollution management pathways.
- System Change Scenario: Based on the simulation results, the tool helps countries identify the most effective and realistic System Change Scenario and outlines the necessary steps to achieve it.

C. Information Analysis/ Gathering

❖ *Single Use Plastic (SUP) Audit*

In 2020, GreenHub introduced an effective method to assess the use of single-use plastics (SUP) in three hotels—Sala Hotel, Kala Hotel, and Star Viet Resort in Phu Yen province, Vietnam. This initiative involved creating a handbook that showcases strategies to minimize SUP usage, establishing criteria to evaluate plastic reduction efforts, and designing roadmaps for plastic reduction in 2 tourist accommodations, complemented by communication campaigns. The waste audit was conducted in 47 out of the 360 tourist accommodations in the country. The enthusiastic participation from stakeholders resulted in favourable feedback during the audit, demonstrating its potential as a replicable model for similar tourism accommodations and other regions (Greenhub, 2020).

❖ *Digital Platform on Plastic and Health*

The digital platform on Plastic and health was launched by Greenhub with support from the country's government agencies. This platform connects stakeholders and the public to address plastic pollution and enhance solid waste management. Its primary aim is to reduce plastic pollution through collective action, fostering stronger networks among communities, individuals, and organizations. The platform emphasizes environmental education, locally-driven solutions backed by data, policy advocacy, innovative business practices, and leveraging traditional and emerging media for effective communication (*Reducing Viet Nam's Plastic Pollution through Digital Data*, 2024). Some of the features of this platform are:

- Raw data on plastic pollution and monitoring: Dashboard, geographic information system layers
- Networking experiences: Stakeholders in the plastic value chain can register as members and post information relating to their work, creating opportunities for collaboration
- Up-to-date database on national and local policies, strategies, and action plans
- Successful case studies on reduction of plastic pollution with emphasis on positive changes, SUP reduction, and improved health conditions.

3.3 GPML

UNEP operates the Global Partnership on Marine Litter (GPML), a global partnership on marine litter, and has developed the GPML Digital Platform, which covers data and policies on marine debris around the world (Figure 11). The Global Partnership on Marine Litter (GPML) is a collaborative initiative that unites various stakeholders dedicated to combating marine litter and plastic pollution. It offers a unique global platform for sharing knowledge and experiences, enabling partners to collaborate on developing and advancing solutions to this urgent issue (UNEP, 2017).

3.4 pLitter Mobile- GIC

pLitter Mobile is a mobile survey application with ESRI Survey123 for the collection of plastic litter data. This pLitter App allows users to click a photo of the plastic litter spotted, which will be directly geotagged using the mobile phone location. This mobile app was used during the CounterMEASURE Project's Phase II macroplastic data collection in both dry and wet seasons.

In Vietnam, the survey was conducted in Can Tho. The survey aims to identify the dominant plastic waste varieties at three different types of sampling sites from the cities which are artificial barriers, littering spots, and uncontrolled dumps. The data submitted through this app was recorded in the data visualization platform (Figure 8) developed by GIC, AIT. The data will be displayed immediately after submitting the data from the mobile. For this platform, the data collected with the phone will be displayed in the form of a dashboard, showing the results of each study area, and include a survey report as well. This page shows the results of the surveys of each pilot area. It showed all the data according to the survey and visualize each point.

D. Marine Debris Collection

❖ *Cleanups*

Clean-up programs generally are coordinated by a group which organises to remove and dispose of litter that has accumulated in a chosen area. The priority of clean-ups is to raise awareness along with removing litter and engaging communities, while data recording is a secondary or tertiary goal. As part of Vietnam's National Action Plan, the country aims to conduct biannual nationwide beach clean-up campaigns and ensure that 80% of marine-protected areas remain free of plastic debris. Key targets include reducing plastic waste and discarded fishing gear by 50%, and slashing the use of single-use plastics and non-biodegradable bags at coastal tourism sites by approximately 80% (RRC.AP, 2020).

❖ *Net trawl sampling*

According to the World Bank study, a net trawl pilot was conducted at the Chanh Duong 2 bridge in Hai Phong. Nets were lowered from the bridge to collect plastic items from different depths of the water column, providing insights into submerged plastic waste. The study measured plastic transport across various vertical positions and throughout the entire water column. Using mobile nets for sampling at different depths proved effective in assessing plastic transport in a cross-section of the river. Each net was deployed for 120 minutes before the collected contents were retrieved, identified, and counted. A comparison of camera-based detection and net measurements revealed that the nets recorded approximately twice the number of plastic particles across the entire water column compared to what the camera detected in the uppermost layer (The World Bank, 2022b).

5. Challenges for Monitoring

Many gaps were identified both for the region and the four countries for their available plastic monitoring programs. Some of these have been listed below.

5.1 Regional Challenges

Some of the gaps in Lower Mekong countries in terms of plastic monitoring are:

1. Lack of separate plastic waste management: Plastic waste is often not managed separately from municipal solid waste, leading to challenges in accurately monitoring and managing its disposal and impact.

2. Less focus on plastic monitoring: Most policies focus on viewpoints of material flow such as production, consumption and waste management, which does not cover monitoring of plastic leakage.
3. Capacity for Plastic Litter Leakage Monitoring: Governmental institutions lack adequate capacity for monitoring plastic litter leakage, resulting in limited data and understanding of the extent of plastic pollution.
4. Technological Disparities: Varying levels of technological advancement hinder the establishment of uniform monitoring standards and the adoption of advanced monitoring technologies across the region.
5. Infrastructure Limitations: Insufficient infrastructure, particularly in rural and remote areas, poses challenges in deploying effective monitoring systems for plastic waste.
6. Data Standardization Challenges: Lack of standardized protocols and methods for data collection make it difficult to compare and consolidate plastic waste data across borders.
7. Inconsistent Technology Integration: Technologies such as GIS tools and mobile applications are inconsistently integrated for real-time data collection and analysis, hindering comprehensive monitoring capabilities.

5.2 Country-Specific Challenges

A. Cambodia
- Legal and Data Gaps: Lack of a data-sharing platform for plastic production, import, export, and waste management. No regulations for the informal plastic recycling sector.
- Guideline Deficiency: No standardized plastic pollution monitoring guidelines.
- Capacity Issues: Insufficient resources in national and municipal agencies for effective riverine plastic pollution control.
- Waste Management Challenges: High plastic consumption and waste generation with low collection and recycling rates lead to significant plastic leakage into rivers.
- Insufficient budget: No dedicated funding for long-term plastic monitoring programs.

B. Lao PDR
- No Specific Legislation: Absence of legislation for plastic pollution monitoring in Lao PDR.
- Lack of Monitoring Programs: No monitoring programs due to financial and manpower shortages from the central government.
- Technology gap: Tools and technologies for monitoring plastic pollution in rivers are limited.
- No Mandatory Reporting: No binding data requirements for local plastic pollution reporting.
- Donor-Dependent Data Collection: Waste management data often relies on international donor projects.
- Integrated Waste Management: Plastic waste management is not differentiated from household waste and solid waste management.
- Infrastructure Challenges: Financial, technical, and human resource constraints hinder waste management infrastructure in major cities.

C. Thailand
- No technical guidelines for the monitoring and assessment of plastic waste.
- Legal regulations for the informal plastic recycling sector not available in the existing legal framework.
- No specific protocols or procedures for cross sectoral collaborations for plastic pollution assessment and monitoring.

D. Vietnam
- No Specific Regulations: Legal regulations for plastic waste management lack specificity.
- Incomplete Policy Implementation: Policy implementation is fragmented, with gaps in issue formulation and guidelines.
- No specialized PWM: Absence of specialized local management for plastic waste.
- Resource and Policy Gaps: Resource shortages and policy mismatches affect effectiveness.
- Informal Sector Reliance: Plastic waste collection and recycling are largely informal, using outdated technology and machinery, resulting in secondary plastic waste release.
- Limited Awareness: Low awareness of plastic waste management regulations.

Table 9: Country-specific challenges in plastic waste monitoring

Country	Challenges in Plastic Waste Monitoring and Management
Cambodia	● Capacity issues ● Legislation and data gap ● No guideline ● Waste management ● Budget constraint
Lao PDR	● Legislation gap ● Technology gap ● Infrastructure challenges ● Lack of Monitoring Programs ● Insufficient reporting data ● Donor-dependent data collection ● Integrated waste management
Thailand	● Legislation gap (informal sector) ● No guideline ● No specific frameworks for cross-sectoral collaboration
Vietnam	● Legislation and policy gap ● Policy implementation gap ● Integrated waste management ● Resource gap ● Capacity issues ● Informal sector reliance

6. Recommendations

Some of the recommendations for improving plastic pollution monitoring on a regional scale have been listed below.

1. Implement separate PWM systems
    - Develop and enforce regulations that require the segregation of plastic waste from other municipal solid waste streams. This will improve tracking and data collection.
    - Educate the public on the importance of separating plastic waste and provide clear guidelines on how to do so.
2. Focus on plastic leakage monitoring
    - Include plastic leakage metrics in policy frameworks to ensure that monitoring is not limited to material flow but also considers leakage into the environment.
    - Establish specialized agencies or task forces focused on monitoring plastic leakage and its environmental impacts.
3. Capacity building
    - Systematically bridge regional resource gaps by fostering an enabling environment that integrates community, organizational, and individual levels.
    - Offer training for governmental and non-governmental personnel on plastic litter monitoring techniques and data collection methods.
    - Partner with academic institutions and international organizations to leverage expertise and resources for improved monitoring.
4. Address technology gaps
    - Encourage the sharing of monitoring technologies and best practices between regions with varying levels of technological advancement.
    - Support initiatives that facilitate the transfer of advanced monitoring technologies to less developed areas.
5. Improvement in monitoring infrastructure
    - Invest in mobile and low-cost monitoring solutions that are suitable for rural and remote areas.
    - Enhance waste management infrastructure to support effective plastic waste monitoring and data collection.
6. Standardise data collection protocols
    - Create and adopt standardized protocols for plastic waste data collection and reporting to ensure consistency and comparability.
    - Work with international bodies to harmonize data collection methods and reporting requirements across borders.
7. Enhance Technology Integration
    - Encourage the use of GIS tools and mobile applications for real-time data collection and analysis.
    - Ensure that different technologies used for monitoring are compatible and can share data seamlessly.
8. Foster Multi Stakeholder Engagement
    - Involve the Private Sector: Engage businesses and industry stakeholders in developing and implementing monitoring solutions.
    - Encourage Community Participation: Involve local communities in monitoring efforts, leveraging citizen science to enhance data collection and awareness.

6.1 Country Specific

6.1.1 Cambodia

1. Capacity building programs: Implement training programs for staff in national and municipal agencies. Develop training programs for staff to improve their technical skills.
2. Develop Data-Sharing Platform: Create a centralized system for plastic production, import, export, and waste data.
3. Regulate the Informal Plastic Recycling Sector: Develop and enforce regulations for informal recycling operations to ensure they meet environmental and safety standards.
4. Standardize Monitoring Guidelines: Establish uniform guidelines for plastic pollution monitoring and train relevant personnel.
5. Improve Waste Management Infrastructure: Invest in better plastic waste collection and recycling systems. Promote policies to reduce plastic consumption and waste.
6. Secure Dedicated Funding: Advocate for specific budget allocations for plastic monitoring programs and explore alternative funding sources.

6.1.2 Lao PDR

1. Specific Legislation: Develop and implement dedicated legislation for plastic pollution monitoring in Lao PDR. This should include clear regulations and standards for tracking plastic waste and setting up monitoring frameworks.
2. Invest in Technology: Acquire and deploy advanced tools and technologies for monitoring plastic pollution, particularly in rivers. Explore partnerships with technology providers and international agencies for support and training.
3. Upgrade Infrastructure: Invest in upgrading waste management infrastructure in major cities. Focus on increasing financial resources, technical support, and human capacity to enhance waste management systems.
4. Establish Monitoring Programs: Initiate government-funded monitoring programs to address plastic pollution. Consider partnering with local universities or NGOs to leverage additional expertise and resources.
5. Mandatory Reporting: Implement binding data reporting requirements for local authorities and businesses involved in plastic waste management. This will ensure consistent and reliable data collection across regions.
6. Diversify Funding Sources: Reduce reliance on international donor projects by exploring alternative funding mechanisms, such as public-private partnerships, to support waste management data collection and initiatives.
7. Plastic Waste Management Systems: Establish separate waste management protocols for plastic waste distinct from general household and solid waste. This includes specialized collection, sorting, and recycling processes for plastic waste.

6.1.3 Thailand

1. Develop Technical Guidelines: Establish comprehensive technical guidelines for the monitoring and assessment of plastic waste. These guidelines should include standardized methods for data collection, analysis, and reporting to ensure consistency and accuracy in measuring plastic pollution.

2. Implement Legal Regulations: Create and enforce legal regulations specifically targeting the informal plastic recycling sector. This should include standards for safety, environmental impact, and operational practices to ensure that informal recycling activities are conducted responsibly and sustainably.
3. Cross-Sectoral Protocols: Develop and formalize protocols and procedures for cross-sectoral collaboration in plastic pollution assessment and monitoring. This should involve coordination between government agencies, industry stakeholders, and NGOs to streamline efforts, share data, and enhance overall effectiveness in tackling plastic pollution.

6.1.4 Vietnam

1. Specific regulations: Develop detailed plastic waste management and monitoring regulations.
2. Specialized local PWM units: Establish specialized local plastic waste management units to enhance local capacity and focus on plastic waste.
3. Allocate resources: Address resource shortages and align policies with practical needs and align policies with practical needs
4. Community awareness: aim to have measures to raise awareness and responsibility of community in plastic waste management and related regulations
5. Budgets for upgrading monitoring technologies: Formalize the informal plastic waste sector and upgrade technology. Providing grants or subsidies to informal sector plastic collectors for better collection.
6. Capacity building: Training to build capacity and share best practices for collecting, monitoring and reporting plastic waste to relevant stakeholders including representatives from the informal sector.

Table 10: Country-specific challenges vs recommendations for plastic waste management

Country	Challenges	Recommendations
Cambodia	● Capacity issues ● Legislation and data gap ● No guideline for plastic waste monitoring ● Waste management ● Budget constraint	● Capacity building programs ● Develop Data-Sharing Platform ● Regulate the Informal Plastic Recycling Sector ● Standardize Monitoring Guidelines ● Improve Waste Management Infrastructure ● Fixed budget for PWM
Lao PDR	● Legislation gap ● Technology gap ● Infrastructure challenges ● Lack of Monitoring Programs ● Insufficient reporting data ● Donor-dependent data collection ● Integrated waste management	● Specific legislations for plastic waste management and monitoring ● Invest in advanced technologies for plastic monitoring. ● Upgrade waste management infrastructure ● Standardized and comprehensive plastic pollution monitoring programs ● Enhance data collection and reporting mechanisms ● Diversify funding sources ● Plastic waste management systems

Thailand	● Legislation gap (informal sector) ● No guideline ● No specific frameworks for cross-sectoral collaboration	● Implement Legal Regulations ● Develop Technical Guidelines ● Cross-Sectoral Protocols for plastic pollution assessment and monitoring
Vietnam	● Legislation and policy gap ● Policy implementation gap ● No specialized PWM ● Resource gap ● Capacity issues ● Informal sector reliance	● Detailed plastic waste management regulations. ● Specialized local plastic waste management units ● Allocate resources and align policies with practical needs ● Community awareness and capacity building ● Budgets for upgrading monitoring technologies

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Annex 1

Table 11: List of existing technologies for plastic monitoring in the Lower Mekong countries

S.N	Country	Technology			
		Amount and distribution of plastic litter	**Source analysis and understanding mechanism**	**Information analysis/ gathering**	**Marine debris collection**
1.	Cambodia	GIS and remote sensing	-	Coastal plastic audit pLitter mobile app GPML	Biobars Seekuh SeeHamster Collectix
2.	Laos	GIS and remote sensing	-	pLitter mobile app	-
3.	Thailand	Solid Waste Management Model GIS and Remote sensing Aerial surveys (UAV) CCTV systems	-	pLitter mobile app GPML	SCG-DMCR Trap Photo benchmarking Water sampling Passive sampling
4.	Vietnam	GIS and Remote sensing CCTV systems (pLitter CCTV, GoPro cameras) Aerial surveys (drones) Field surveys	Plastic Pollution Calculator GPAP's NAM tool	SUP audit Digital Platform on Plastic and Health GPML pLitter mobile app	Cleanups Net trawl sampling

Annex 2

Table 12 : Existing Methods for Monitoring Plastic Waste into Rivers

S.N	Method	Tool	Analysis	Coverage	Technologies for analysis (if any)	City/ Country	Organisations/ Institutions	Strengths	Weakness
1.	Water Sampling	Net towing	Manual	River surface	-	Lower Mekong river, Thailand	MRC	- Low cost - Direct collection -Selective sampling	- Turbulence and Sampling Bias - Requires sampling to be done for longer durations to be representative of the location.
2.	20L bag sampling	Artificial barriers / Litter traps	Manual	River banks, Accumulation points	-	Lower Mekong river & Thailand	MRC	- Quick and easy - Repeatability - Standard protocol from MRC	- Sampling Bias - Requires frequent sampling for capturing seasonal variations and representative data
3.	Traps / Sampling	SCG-DMCR Trap	Manual	River surfaces and partially submerged		Thailand	SCG, DMCR	- Leakage free design - Longer life - Minimal operation cost	- Cannot collect plastics which has been transported to lower waters

S.N	Method	Tool	Analysis	Coverage	Technologies for analysis (if any)	City/ Country	Organisations/ Institutions	Strengths	Weakness
4.	Survey-Visual Observation	Photo benchmarking	Manual	River banks, Accumulation points	-	Lower Mekong river basin & Thailand	MRC	-Quick and baseline data -Visual documentation - Standard protocol from MRC	- Limited to visual assessment - Subjective analysis
5.	Survey	Macro Plastic Survey (GIC App)	GIS analysis	River banks, Accumulation points, Littering spots	ArcGIS or QGIS or WebGIS	Thailand, Global	GIC-AIT	- Supports offline and sync later -Auto report generation - Can export results	- Demonstration required
6.	Camera	pLitter CCTV	AI	River surfaces	AI and Edge computing	Global	GIC-AIT	- AI based and automatic - Low cost - Real time - Web-based dashboard	- Night time functioning requires artificial light source - Detects only floating plastics - Accuracy needs to be improved
7.	Survey/ Camera	UAV System	Manual+ AI	River banks, surfaces	GIS mapping, AI	Global	GIC-AIT	- Access to remote areas - Quicker survey than manual - Precise mapping	- Depends on UAV pilot - Variance due to weather conditions