East Asia and Pacific Region: **MARINE PLASTICS SERIES**

# Vietnam: Plastic Pollution Diagnostics

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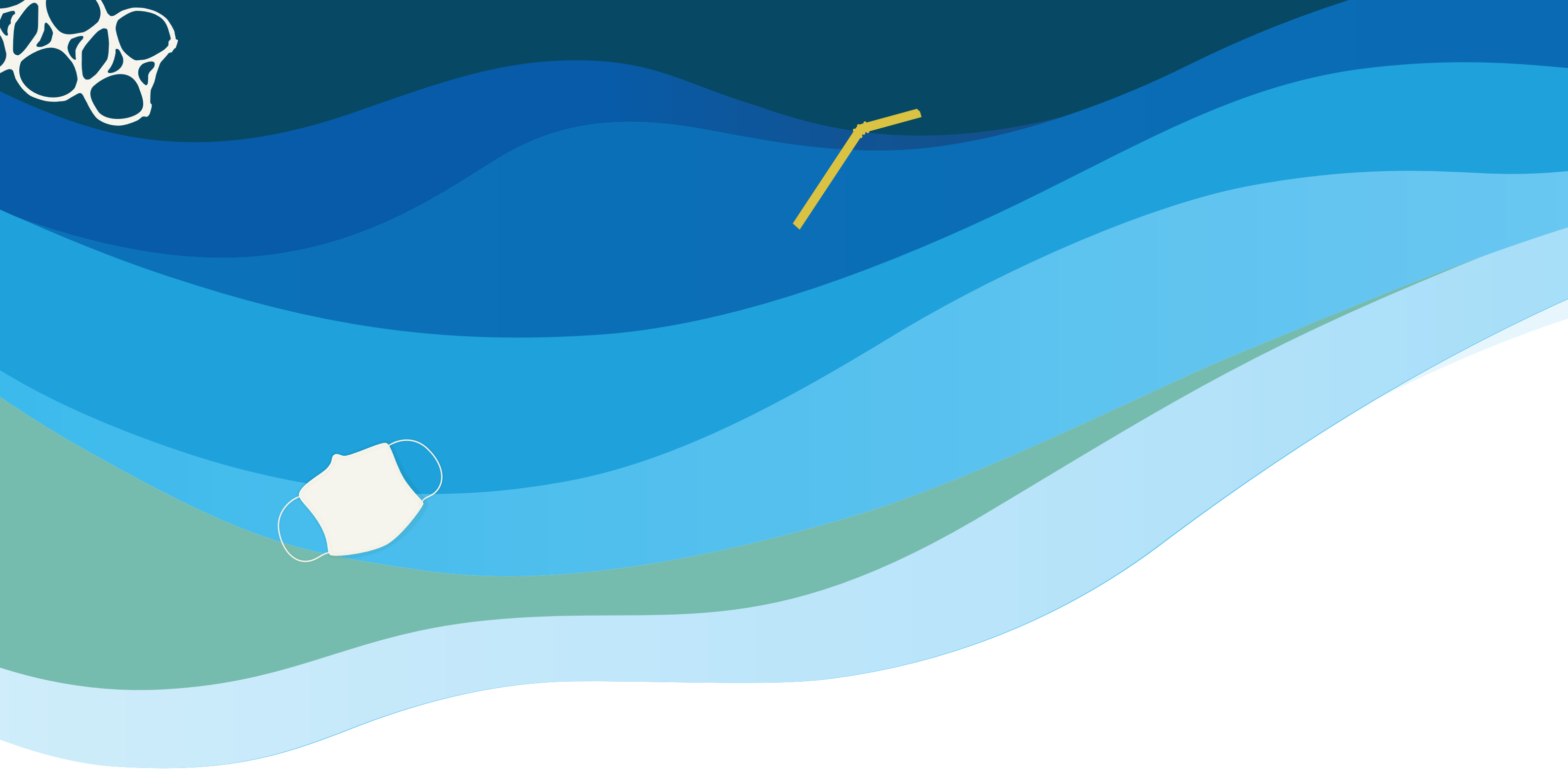

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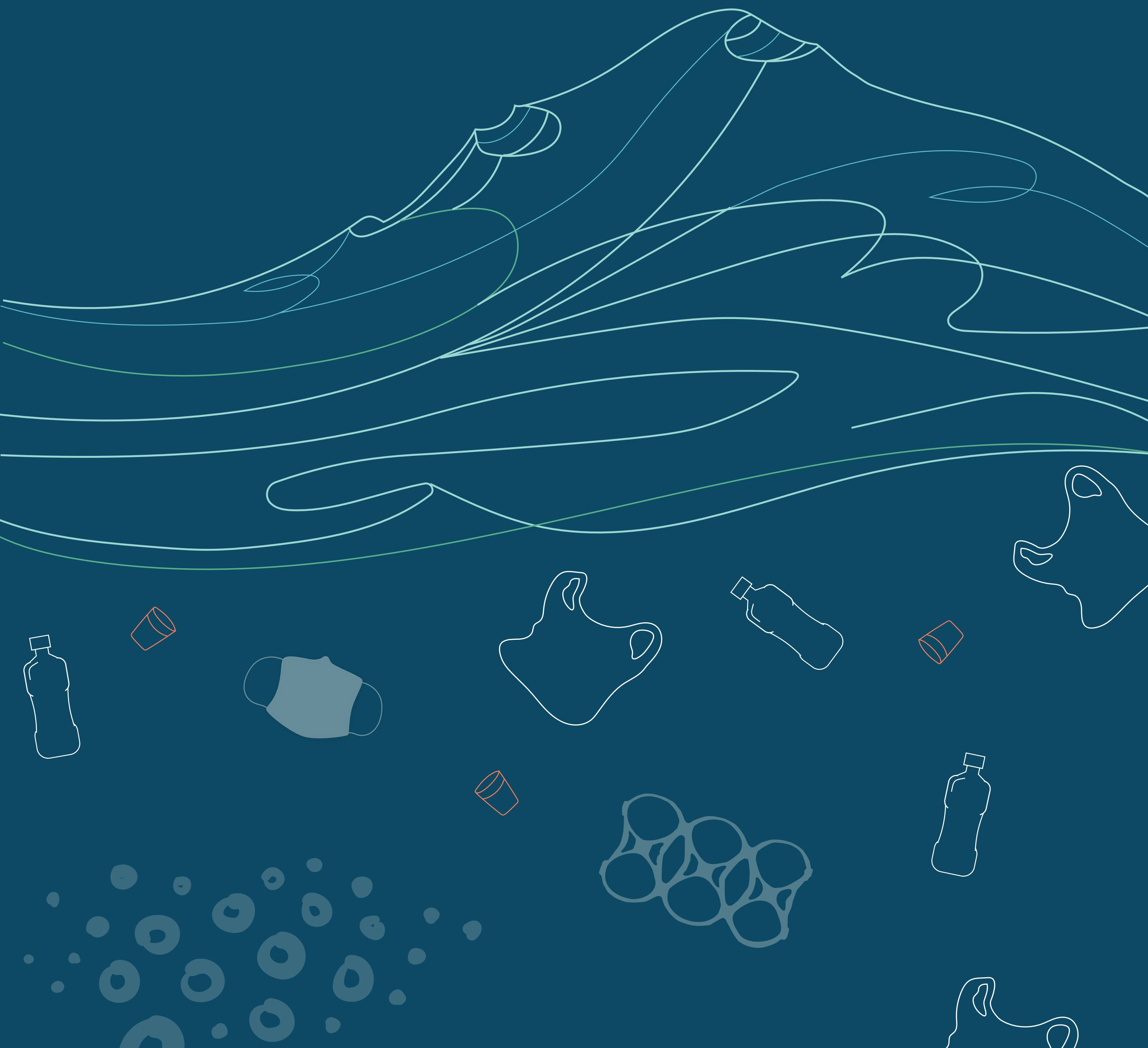
# ABBREVIATIONS

| | |
|---|---|
| **ASEAN** | ASSOCIATION OF SOUTHEAST ASIAN NATIONS |
| **CCI** | Clean Coast Index |
| **DASI** | Department of Sea and Islands (Province) |
| **EPR** | Extended producer responsibility |
| **EPS** | Expanded polystyrene |
| **HPDE** | High density polyethylene |
| **IUCN** | International Union for Conservation of Nature |
| **LDPE** | Low density polyethylene |
| **MONRE** | Ministry of Natural Resources and Environment |
| **NPAP** | National Plastic Action Partnership (Vietnam) |
| **PE** | Polyethylene |
| **PET** | Polyethylene terephthalate |
| **PP** | Polypropylene |
| **PPCP** | Polypropylene copolymer |
| **PVC** | Polyvinyl chloride |
| **SDG** | United Nations Sustainable Development Goal |
| **SUP** | Single-use plastic |
| **SWM** | Solid Waste Management |
| **UAV** | Unmanned aerial vehicle |
| **VASI** | Vietnam Administration of Sea and Islands |
| **VEA** | Vietnam Environment Administration |

# EXECUTIVE SUMMARY



# EXECUTIVE SUMMARY

In response to a request from the Government of Vietnam, this World Bank study was conducted from July 2020 to April 2021 to deepen knowledge about the different plastic waste types leaking into rivers and the ocean in Vietnam, and identify their market alternatives for potential substitution. This report summarizes three diagnostics: field surveys on riverbanks, and at coastal sites to determine the extent of plastic pollution, and the top 10 polluting items; remote sensing and net trawl surveys that monitored plastic waste in, and alongside, waterways that flow into the ocean; and a preliminary analysis of alternatives to Vietnam's most-polluting plastic items.

### Key Messages:

#### Overall level of Plastic Pollution in Vietnam

- **Plastic waste was by far the most abundant type of waste collected in the field surveys** (around 94 percent in the number of items; and around 71 percent by weight).
- **Take-away food packaging waste was the most abundant source of plastic waste found in the field surveys (44 percent in number)**, followed by fisheries-related waste (33 percent in number), and household-related waste (22 percent in number).
- **The Clean Coast Index (CCI) measurement, which is a tool to assess relative coastal cleanliness, showed that 71 percent of the coastal sites surveyed were extremely dirty** (a CCI of more than 20) and 86 percent were *extremely dirty* or *dirty* (a CCI of more than 10).

#### The most common plastics items found in field surveys in Vietnam, and the potential to replace them in the value chain

- **In number, the top 10 common plastic items accounted for over 81 percent of all the plastic items collected in river sites, and over 84 percent found in coastal sites. The top five common plastic items accounted for over 63 percent** in number in both river and coastal sites.
- **Single-use plastic (SUP) items accounted for 72 percent (in number) of the total plastic waste identified at riverbanks and 52 percent (in number) of the total plastic waste identified at coastal sites in the field surveys.** Plastic bags and their fragments (around 26 percent of items) were the most common single-use items in the survey locations. When both of these categories of waste were combined, they were the most prevalent in river locations, and the second most prevalent in coastal locations. **Styrofoam food containers were among the top five items** in both river and coastal locations.
- **Fishing gear was very prevalent, accounting for around 30 percent of plastic waste** (in number).

- **Addressing plastic pollution caused by these items should not be based on replacing SUPs with non-plastic single-use items, or plastic multi-use items**, because both may have negative impacts, and not align with Vietnam's goal of a more circular economy. Thus, in promoting alternative products, the focus should be on promoting reusable, non-plastic items that support overall reduction in the generation of plastic waste. Specific policy measures should be reviewed and analyzed for addressing the use of these items and a roadmap should be developed for their progressive phase-out. This should be coupled with a phased approach toward a modern, integrated and sustainable solid waste management system.
- **Much greater effort is required to educate Vietnam's population about waste reduction, reuse, and halting littering**, in order to reduce the demand for low-utility plastic, support more cost-effective waste management infrastructure, and reduce littering that ends up in rivers and the ocean.

### Prospects for a monitoring system for marine plastic pollution

- **Field surveys have become a widely accepted method for identifying the top 10 polluting plastic items fairly quickly, and with relatively little capacity required.** The European Union (EU) used this approach prior to developing the EU single-use plastics directive, and the approach has been successfully applied in a number of countries in East Asia and Pacific, including Cambodia, Vietnam, and the Philippines.
- **The automated detection and analysis of plastic items with remote sensing methods was carried out in Vietnam, using both drone and bridge surveys. The findings of these diagnostics indicate that these methodologies could be easily upscaled by local stakeholders.** With both approaches, the images collected were automatically analyzed through machine-learning processes. Drone surveys are a state-of-the-art method of plastics assessment that was piloted initially in Cambodia, and then used, successfully, in this study, to assess plastics pollution along the riverbanks of selected cities in Vietnam. By mounting a camera on a drone, a large area could be surveyed in a short period of time. Through conducting drone and bridge surveys, using locally available and affordable equipment, this study developed local capacity to continue carrying out these surveys. Based on this study and previous ones, surveying large areas though drone surveys has become an increasingly effective and quick way to identify the most prevalent types of plastic, and to so with minimal labor.
- **Based on lessons learned in previous drone surveys, this study conducted remote sensing-based bridge monitoring for the first time in Vietnam.** For this pilot, cameras were mounted on bridges to record plastics flows over long periods of time. This approach for conducting long-term plastics monitoring will enable the Government of Vietnam to monitor the impact of its pollution reduction policies over time. Through measuring the volume of plastic items floating on rivers over long periods of time, this study's bridge surveys have proven to be particularly suitable for quantifying plastic leakage into rivers.
- Also, for the first time, this study assessed submerged plastics by using trawls (nets) lowered from bridges. While this method was quite labor intensive, by identifying the total volume of plastics in a column of river water, as well as floating on the surface, this study significantly improved understanding about Vietnam's plastics pollution. The effectiveness of surveying plastics with trawls is well established now, and can be replicated if there is adequate time and labor to conduct such surveys. In order to establish a relationship between the amount of plastic, and the types of surface and submerged plastics, net trawls should be replicated in several locations, in combination with remote sensing bridge surveys. This combination will allow the modelling of total plastics river transport that is based only on automated surface measurement.

**Rapid economic growth, urbanization, and changing lifestyles in Vietnam have led to a country-wide plastic pollution crisis.** Since 1990, there has been a spectacular increase in plastic use in Vietnam, rising from 3.8 kg/capita in 1990 (MONRE 2020) to 81 kg/capita in 2019 (IUCN-EA-QUANTIS 2020). Only about 15 percent of the country's plastic waste is recycled, and more than half—the equivalent of 3.6 MT/year—is mismanaged (IUCN-EA-QUANTIS 2020). The remainder of Vietnam's plastic waste, if not disposed of in landfills, is buried in dumps, openly burned, or dumped in waterways. As a result of the latter, Vietnam is estimated to be one of the top five polluters of the world's oceans (Jambeck et al. 2015).

**Vietnam is committed to addressing its plastic waste pollution challenges.** In October 2018, the 8th plenary session of the Party Central Committee (12th tenure) adopted Resolution No. 36-NQ/TW (October 22, 2018) on "the Strategy for Sustainable Development of Vietnam's Marine Economy to 2030, with a vision to 2045". This resolution set the goals of "preventing, controlling, and significantly reducing pollution of the marine environment" and "becoming a regional leader in minimizing ocean plastic waste." On December 4, 2019, the Prime Minister adopted Decision No. 1746/QD-TTg, which promulgated the National Action Plan for Management of Marine Plastic Litter by 2030. In addition, the new Law on Environmental Protection, which will go into effect on January 1, 2022, introduces "pay as you throw" policies that require separating different types of waste, and sets out the legal basis for extended producer responsibility (EPR) schemes.

**In response to a request from Vietnam's Ministry of Natural Resources and Environment (MONRE), the World Bank Group has mobilized financing from PROBLUE, a multi-donor trust fund, to support Vietnam in its efforts to address plastic waste pollution.** The overall objective of this technical assistance and advisory services program is to support Vietnam in addressing its plastic waste problems, including the plastic waste that pollutes the ocean. The program's three components are: (1) supporting diagnostics on plastic waste; (2) identifying priority solid waste management and plastic policies and investments; and (3) conducting value chain diagnostics on plastics in Vietnam, and recommending a private sector action plan. This report, which was produced for Component 1, is intended to deepen knowledge about the extent of plastic pollution in Vietnam, overall; the plastic wastes that are polluting rivers and the ocean off Vietnam; and the alternatives available for these plastic items. The results of this diagnostic will be used as evidence to support strategies, policies, and investments that are designed to enhance Vietnam's plastic waste management.

**This report summarizes three diagnostics:** (1) field surveys conducted on riverbanks, and at coastal sites to determine the extent of plastic pollution, and the top 10 polluting items; (2) remote sensing and net trawl surveys that monitored plastic waste in, and alongside, waterways that flow into the ocean; and (3) a preliminary analysis of alternatives to Vietnam's most-polluting plastic items.

## Overall Objective

**The objective of the diagnostics was to deepen knowledge about the different plastic waste types leaking into rivers and the ocean in Vietnam, and identify and analyze their market alternatives for potential substitution.** The field and river monitoring surveys aimed to identify the priority plastic items (i.e. the top 10 polluters) to inform subsequent analysis of targeted measures for phasing out low-value plastic items. The objective was to identify the quantities and types of plastic waste, and the key locations where the waste is entering Vietnam's waterways. The overarching goal of the surveys was to inform government agencies, mobilize their buy-in to solve plastic waste problems, build their capacity, and develop local relationships. For example, the remote sensing and net trawl surveys aimed to serve as a proof-of-concept pilot of innovative methodologies for plastics monitoring. Another intention was to introduce scientific methodologies for monitoring and evaluating plastic waste to key audiences that have an interest in plastics management and research in Vietnam. These audiences include national and local government officials, academics, officers in not-for-profit organizations, and other relevant individuals and organizations.


Photo: Al.geba - Shutterstock

## Approach

Table 1 provides an overview of the different methodologies used in the plastics diagnostics studies.

Table 1:
**OBJECTIVES, LOCATIONS, AND BRIEF DESCRIPTIONS OF THE SURVEY METHODOLOGIES USED IN THE PLASTICS DIAGNOSTICS STUDIES**

| Survey Methodology | Objective | Locations | Brief description of methodology |
|---|---|---|---|
| Field Surveys | The objectives of the field surveys were to: 1) reveal plastic waste quantities, and the types and key locations for plastic waste leakage into waterways, in order to understand the extent of plastic pollution, and the top 10 polluting plastic items on riverbanks, and at coastal sites; and 2) inform government agencies, mobilize buy-in to solve plastic waste problems, build capacity, and develop local relationships. | In total, surveys were conducted at 38 sites: 14 coastal sites in 8 locations, and 24 riverbank sites in 10 locations. These were in 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. | Standardized surveys of river and coastal sites were carried out to identify the composition of the top 10 most common plastic waste items, spanning 7 categories, and 38 sub-categories. For coastal sites, a score was calculated for the standard metric of pollution—the Clean Coast Index (CCI). Section 2.1.2 gives an overview of the methodology and discusses its limitations. |

| Survey Methodology | Objective | Locations | Brief description of methodology |
|---|---|---|---|
| Remote Sensing – Drone Surveys | The objectives of plastics monitoring in, and alongside rivers, involving a drone, and bridge and net trawl surveys were to: 1) deepen knowledge about the different plastic waste types leaking into rivers and the ocean; 2) increase knowledge about plastic waste quantities, and the key locations for plastic waste leakage into waterways; 3) develop and pilot an integrated plastics transport monitoring concept for rivers; and 4) inform policies and investment programs to reduce marine plastic pollution by assessing the results. | Drone surveys were carried out in Hai Phong (5 sites), Hai Duong (2 sites), and Sa Pa (2 sites). | Cameras mounted on drones were used to take images over larger areas. These images were automatically analyzed to detect and classify plastic items. Sections 2.2.3 and 2.2.5 provide an overview on the methodology and discuss its limitations. |
| Remote Sensing – Bridge Surveys | | Plastics transport monitoring was carried out in 3 locations in Vietnam – Hai Phong, Lao Cai/Sa Pa, and Hai Duong – with 3 survey sites in each location. | Cameras were mounted on bridges. Videos were automatically analyzed to detect and classify plastic items floating on the water over a given period of time. Sections 2.2.3 and 2.2.5 provide an overview of the methodology, and discuss its limitations. |
| Net Trawl Surveys | | The net trawl pilot was carried out at Chanh Duong 2 bridge in Hai Phuong. | Net trawls were lowered from bridges to collect plastic items at different depths of the water column to gain a better understanding of submerged plastics. The transport of plastics at various vertical positions over a cross-section, and over the whole water column was measured. Sections 2.2.3 and 2.2.5 provide an overview of the methodology and discuss its limitations. |
| Plastic Alternatives Survey | The analysis of plastic alternatives provides an initial view of the main importers and producers; production and consumption figures; and alternatives to, and/or the recyclability of the plastic products that are most commonly found on riverbanks, in waterways, and at coastal sites in Vietnam. | N/A. Country-level market assessment. | This assessment of plastic alternatives was based on field surveys that revealed the top 10 polluting plastic items at river and coastal sites in Vietnam. Relevant data on the plastic alternatives available in the market in Vietnam were collected from primary sources via interviews and a desk study of secondary sources. Section 2.3.2 provides an overview of the methodology and discusses its limitations. |

## Key Findings

The findings of the three diagnostic studies answer questions related to: 1) the extent of plastic pollution on Vietnam's riverbanks and coasts, and in its waterways, 2) the top 10 polluting plastic items found on Vietnam's riverbanks and coasts, and in its waterways; 3) the potential for scaling up continuous plastic monitoring in waterways; and 4) the alternatives that are available in the market in Vietnam to the country's top 10 polluting plastics.

### 1. What is the estimated extent of plastic pollution in selected Vietnam riverbank and coastal sites, and in selected waterways?

**The extent of pollution on riverbanks (based on field surveys):** At the 24 riverbank sites surveyed, a total of 2,707 solid waste items were collected, with an average of 22.5 items per unit.[1] Plastic waste accounted for 79.7 percent of the number of items, and 57.2 percent of the weight. Single-use plastic items accounted for 72 percent of the total plastic waste. Across the Northern, Central, and Southern subzones, no statistically significant differences were found in the totals for plastic waste. However, the average number of plastic waste items on urban riverbank sites (21.4 items per unit) was nearly two times higher than the average number on rural riverbank sites (12.1 items per unit). Specifically, plastic waste items on riverbanks in Can Tho (34.5 items per unit), Ho Chi Minh City (33.4 items per unit), and Lao Cai (30.1 items per unit), were higher than those in other locations; while the number of items on the riverbanks in Soc Trang Province was the lowest (4.3 items per unit).

**The extent of pollution at coastal sites (based on field surveys)**: Plastic waste items accounted for 95.4 percent of the total solid waste, with an average of 81 items per meter of coastline.[2] Analyses showed that the overall pollution density in Thua Thien Hue (141.1 items per meter of coastline), in Ho Chi Minh City (135.6 items per meter of coastline), and in Quang Nam (133.7 items per meter of coastline) was significantly higher than in other locations. The density of plastic items was significantly lower in Hai Phong (36.23 items per meter of coastline) and Da Nang (27.9 items per meter of coastline). Single-use plastics accounted for 52 percent of the total plastic waste encountered at coastal survey sites. The Clean Coast Index (CCI) measurement results showed that 10 sites (71.4 percent of the total) were extremely dirty (a CCI of more than 20), two sites were dirty (a CCI of between 10 and 20), and another two sites were moderate (a CCI of between 5 and 10). The highest CCIs were recorded at Binh Lap Beach (379) and My Ca (192) in Khanh Hoa, Lai Hoa Beach in Soc Trang (176), Truong Beach on Phu Quoc Island (163), and Got Ferry Beach in Hai Phong (73).

**The extent of pollution in, and alongside, waterways (based on remote sensing and net trawl surveys):** High-altitude drone surveys enabled the identification of pollution hotspots across survey sites. Low altitude, high-resolution imagery was then effective for analyzing the hotspots. This approach was successful in analyzing the abundance of quantities of waste, along with the area and waste volume assessments. The waste situation was alarming in all of the sites investigated. In the sites where no large accumulations were present, plastics were usually trapped in the vegetation on the shore or were floating in the river. Figure 1 provides an illustration of strongly polluted hotspots in Hai Duong (large waste accumulations), and in the sites in Hai Phong (mostly plastic waste trapped in vegetation).

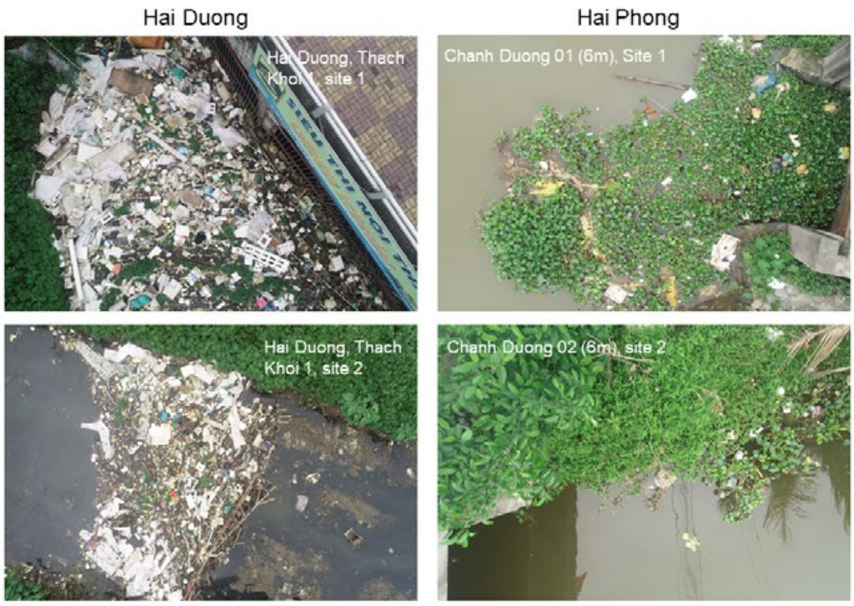
River monitoring surveys with cameras mounted on bridges to take images at defined time intervals were proven successful in recording floating plastics. For example, the surveys at Suoi Cat (Cau Lao Chai) bridge in Sapa identified a high number of objects (360) floating by on the survey day, with substantial transport of more than 10 waste items/half hour estimated for long periods of the survey day.

Net sampling at several depths using mobile nets was effective in determining plastics transport in a cross section. Thus, all particle sizes (even small objects) could be collected, and the plastic concentration could be determined in connection with flow velocity measurements. For example, at the Chanh Duong 2 tributary in Hai Phong, the concentration varied from 3 to 18 pieces of plastic per 1,000m$^3$ of water. When extrapolated for the total profile, this resulted in the transport per hour of approximately 440 pieces of plastic, or approximately 4kg of plastic. A comparison between the camera's detection, and the net measurement results, showed that about twice the number of plastic particles were registered over the total depth of the water column than the camera detected in the uppermost layer of the water.

1 For riverbank sites, a survey "unit" is an area 1m$^2$ dug to a 0.3 meter depth.

2 "Meter of coastline" was used as the unit for the coastal site surveys.

Figure 1.
**EXAMPLES OF HOTSPOTS INVESTIGATED THROUGH DRONE SURVEYS**




## 2. What were the top 10 polluting plastic items in selected Vietnam riverbank and coastal sites, and in selected waterways?

**Top 10 plastic waste items on riverbanks:** With regard to density, the top 10 common plastic waste items at riverbank sites accounted for between 81.5 percent (Mekong River) and 93.4 percent (Red River) of total plastic waste. In both rural and urban river sites, the sub-category plastic bags size 1 (0–5kg) was the most frequently encountered item (20.6 percent and 22 percent, in number, respectively). Therefore, the overall average results for the surveys at river sites indicated that 21.9 percent of the total plastic waste encountered was plastic bags, varying between 0–5 kg, followed by Styrofoam food containers, and soft plastic fragments (the latter mostly comprised of plastic bag fragments) (Figure 2).

Figure 2:
**PERCENTAGES OF THE TOP 10 POLLUTING PLASTIC ITEMS ON RIVERBANKS BY DENSITY (ITEMS PER UNIT) AND WEIGHT (WEIGHT PER UNIT)**

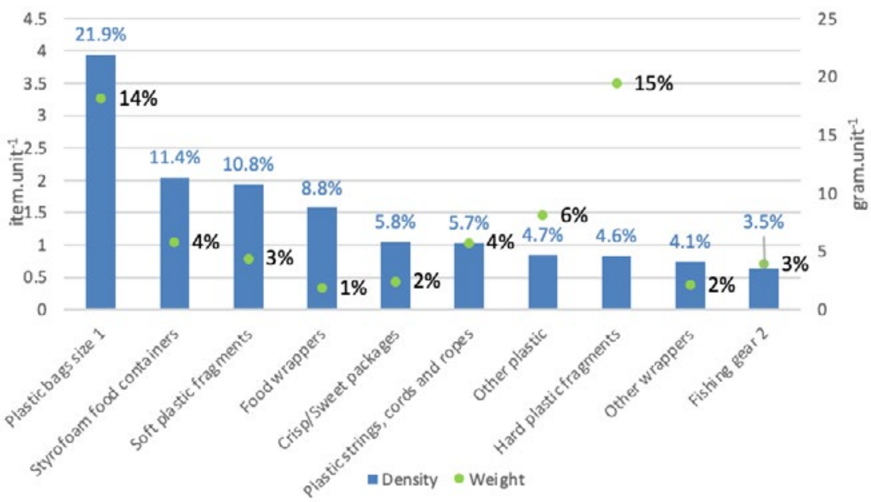
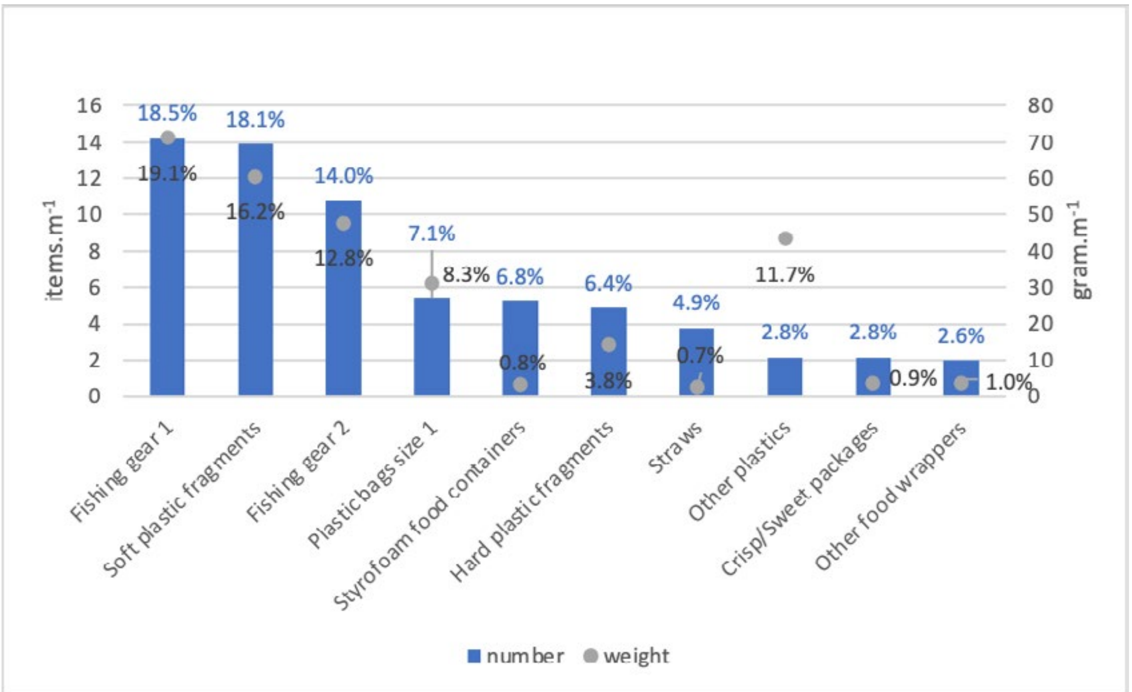


Figure 3:
**PERCENTAGES OF THE TOP 10 POLLUTING PLASTIC ITEMS AT COASTAL SITES BY DENSITY (ITEMS PER METER OF COASTLINE) AND WEIGHT (WEIGHT PER METER OF COASTLINE)**




**Top 10 plastic waste items at coastal sites:** At coastal sites, the top 10 plastic items accounted for 84 percent of the total plastic waste. Among them, combined *fisheries-related waste* was the most common (32.5 percent),[3] followed by *soft plastic fragments* (18.1 percent), *plastic bags size 1 (0–5kg)* (7.1 percent), and *Styrofoam food containers* (6.8 percent) (see Figure 3). Single-use plastic items accounted for 52 percent.

**The most common plastic waste items identified through remote sensing and the net trawl surveys:** Drone surveys were effective in detecting waste types. Across survey sites, the following items were identified as the most abundant (from the highest to the lowest percent): *Polystyrene, including food containers* (40 percent), *Cup lids, caps, and small plastics* (19 percent), *LDPE bags, Wrappers,* and *PET bottles* (18 percent). The net trawl pilot was also effective in analyzing the quantity and weight of different types of waste. For example, in the Chanh Duong 2 tributary in Hai Phong, over six hours, the total amount of collected waste was 121 pieces, of which *packages and other wrappers* were the most abundant (41.3 percent), and *plastic bags* ranked second (30.6 percent).

### 3. Is it feasible to employ remote sensing methods and net trawl surveys to monitor plastics transport in waterways?

**In this study in Vietnam, the globally novel approach of remote-sensing-based plastics monitoring was successfully piloted.** This positive outcome provides a foundation for the Government of Vietnam to carry out longer-term plastic waste monitoring that will improve knowledge about plastic pollution, establish baselines and, over time, measure the impacts of policies and programs. Valuable technical lessons were learned in this first pilot that can provide the foundation for upscaling plastics monitoring in Vietnam, as well as other countries. For example, the simultaneous application of net trawls showed the potential to link the results to remote sensing, and establish models to estimate the total plastics load, including submerged plastics, which are based on the automated detection of surface plastics. With regard to scaling up plastics transport monitoring, the overall limitations of remote sensing and net trawl surveys are discussed in section 2.2.3.4.

3 Fishing gear comprises two categories: i) *fishing gear 1* (Plastic fishing rope, pieces of net, fishing lures and lines, and hard plastic floats); and, ii) *fishing gear 2* (Polystyrenes–EPS, buoys, and floats).

### 4. Are there alternative products in Vietnam to the top 10 polluting plastic items?

**The results of the preliminary analysis of alternative products showed that for most of the identified priority single-use plastics (SUPs), alternative products are already available in the Vietnamese market.** These alternatives were mainly for plastic bags and take-away food-related[4] waste (for details, see Section 2.3).

**While alternative products are currently often higher priced than their respective SUP, most of the alternatives are reusable products.** In principle, the objective should not be to replace SUPs with non-plastic single-use items, or plastic multi-use items, because these may also have negative impacts, and may not align with the pathway toward a more circular economy.

**Thus, in promoting alternative products, the focus should be on the promotion of reusable, non-plastic items that support overall reduction in the generation of plastic waste.** However, for plastic straws, in particular, due to the availability of relatively cheap raw materials for alternatives, high customer acceptance, and a large number of producers of substitute products, single-use alternatives to plastic straws are already well established. Also, these are sold in volumes that are comparable to plastic straws. Promotion of other alternative products through policies and incentives, and supporting the transition to a reuse model by compensating for the higher unit price, will be crucial in further reducing the single-use plastic products that are responsible for most of Vietnam's plastic pollution.

4 In this paper, the term 'take-away' applies to the packaging for food cooked and sold for eating elsewhere. The term 'takeaway' applies to the key points made in this report.

Photo: 22August - Shutterstock

## Knowledge gaps and next steps

### 1. Recommendations for an integrated plastics monitoring concept

**The diagnostics conducted for this study illustrate the feasibility of undertaking low-cost field surveys using different methodologies that can provide governments (both national and local) with a snapshot of plastic waste leakage, in terms of its volume, types, brands, flow, and hotspots.** In addition, this study successfully piloted remote sensing-based identification of plastics floating on rivers, combined with automated image analysis from cameras mounted on bridges that automatically detected and analyzed plastic items over longer periods of time. These positive outcomes of both the field and remote sensing surveys provide the foundation for the Government of Vietnam to carry out longer-term plastics monitoring that increases knowledge about plastic pollution, establishes baselines, and measures the impacts, over time, of government policies and other measures.

**Depending on the policy objective for monitoring, multiple methodologies could be employed, but location-specific protocols would need to be developed to determine the appropriate survey types and frequency.** Lessons learned from the different methodologies used in this study could feed into national guidelines on plastics monitoring to support local governments in regularly tracking the progress on plastics policy implementation. To guide such local-level monitoring, the development of guidelines by MONRE would be necessary.

### 2. Policy roadmap to address low-value and single-use plastic waste

**The survey results indicate that most of the plastic waste leakage at the studied sites was from a small number of items, many of which were single-use and low-value products. Therefore, these plastic items could be prioritized for policy measures.** However, additional policy analysis is needed to support the creation of a roadmap for policy development, and its implementation at both the national and subnational levels. Based on international good practices, a range of policy instruments would need to be assessed to address plastics issues, including bans; levies; design requirements; extended producer responsibility (EPR) schemes; standards for plastic alternatives; and reporting, monitoring, and enforcement options. A stakeholder engagement plan should also be developed to inform policy dialogue on each of these items. The second component of this World Bank technical assistance and advisory services program aims to support these activities.

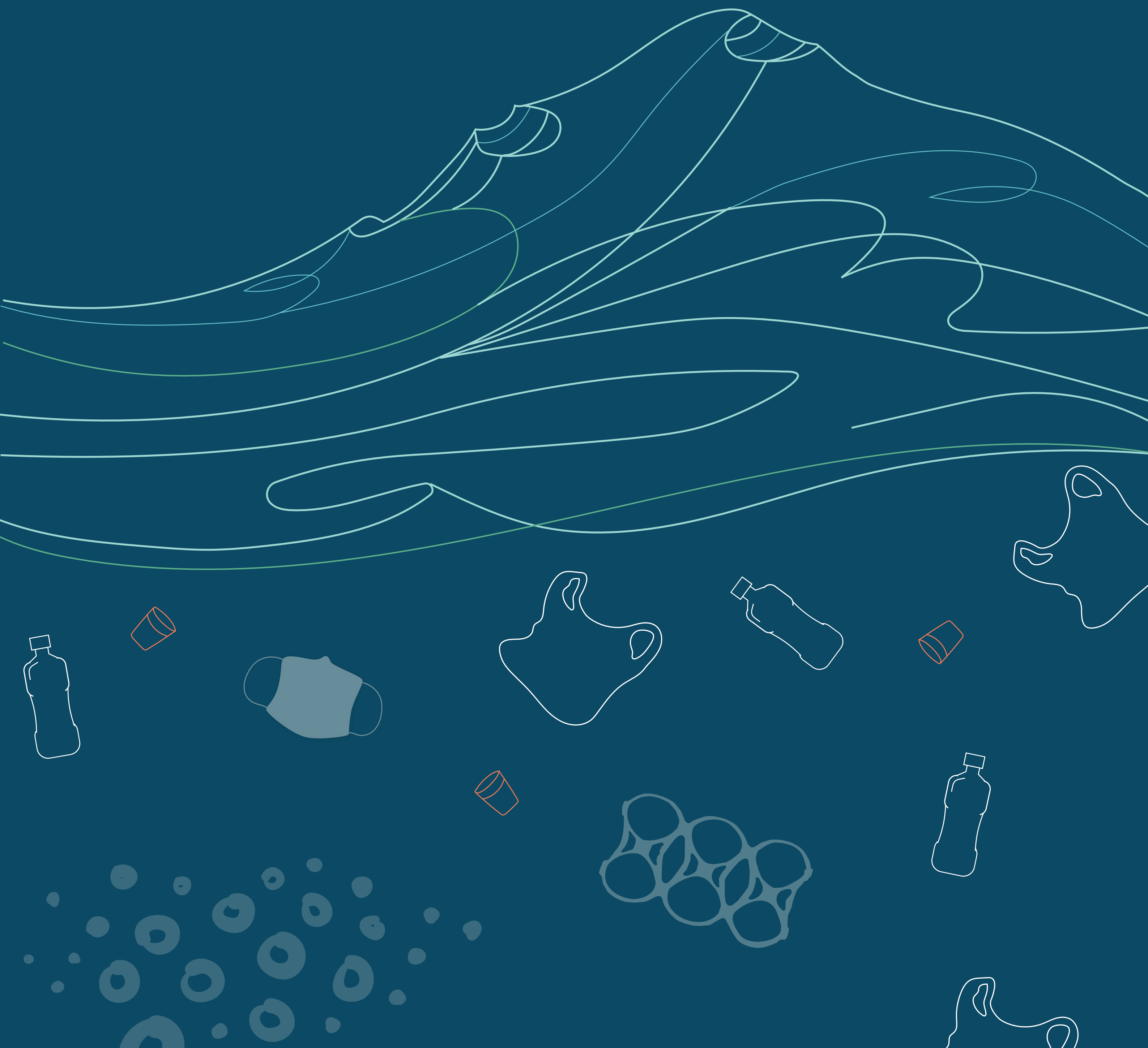
### 3. Analysis and recommendations for measures to address fisheries- and aquaculture-related plastic waste.

**The field survey results revealed that fishing gear was the most common plastic item encountered on coastal sites.** Considering that the diagnostic studies primarily focused on land-based sources of plastics pollution, a more thorough baseline assessment of marine plastic pollution from the fisheries and aquaculture sectors is required, along with an assessment of potential mitigation measures and policy recommendations. In this regard, under the upcoming World Bank Sustainable Fisheries Development Project, the World Bank will initiate technical assistance to support this goal, and identify concrete entry points to kick-start implementation of the Action Plan for Marine Plastic Waste Management in the Fisheries Sector, which the Ministry of Agriculture and Rural Development has recently adopted.

### 4. Developing public awareness and communications strategies about the top 10 plastic waste items

**The survey results, along with the preliminary market analysis of plastics alternatives highlighted the importance of public awareness in addressing plastic pollution.** A substantial increase in citizen and youth education on waste reduction, reuse, and halting waste littering, is required to reduce the demand for low-utility plastic, support more cost-effective waste management infrastructure systems, and reduce littering that ends up in rivers and the ocean. An awareness raising and communication strategy should be developed in tandem with the plastics policy analysis and roadmap, discussed above.

# 1. INTRODUCTION



# 1. INTRODUCTION

Globally, plastics are widespread, mismanaged, and are dangerous pollutants in the air, on land, and in the water. No other pollutant can match the geographic scale of plastics' impact, which spreads from the highest mountains to the bottom of the deepest seas, and greatly impacts economies as well as people's lives. Comprising over 170 chemicals, plastics-related pollution can cause health impacts such as cancer; neurotoxicity; and reproductive, immune, and genetic impacts. Plastic waste in landfills releases toxic chemicals that affect communities (Azoulay et al. 2019) and plastic particles attract, host, and transfer human disease-causing antibiotic-resistant bacteria (Arias-Andres et al. 2018) and viruses (Azoulay et al. 2019, and Van Doremalen 2020). However, limited safeguards, and conflicting and questionable information prevent consumers from making informed choices and reducing their exposure.

**Vietnam is one of the major polluters of the world's oceans.** Annually, about 2.8 to 3.1 million tons of plastic waste are discharged on land in Vietnam, and the country is estimated to be a major plastics polluter. As a result of discharging an estimated 0.28 to 0.73 million tons, annually, Vietnam is one of the top five polluters of the world's oceans (Jambeck et al. 2015). Vietnam is also mentioned as one of the countries with the highest level of mismanaged plastic waste generated by its coastal population (Law et al. 2020). In 2016, 0.57 million tons of mismanaged plastic waste leaked into Vietnamese coastal areas (Law et al. 2020). Related health threats include microplastic fibers found in 12 of 24 commercial fish species in the Gulf of Tonkin (Koongolia et al. 2020), and severe plastic pollution of Vietnam's coral reefs and coastal mangroves. In 2010, Lamb et al. (2018) estimated that 41 million plastic items are embedded in Vietnam's reefs, and this will rise to 177 million plastic items by 2025. These threats cause coral disease and a decrease of mangrove cover, which, in turn, causes greater flooding in coastal communities, as well as water-borne diseases. Plastic pollution is especially a problem for families that are dependent on fisheries and tourism (Menéndez et al. 2020).

**Economic growth, urbanization, and changing lifestyles in Vietnam have increased solid waste.** In urban areas, an estimated 10–15 percent of waste is uncollected, and in rural areas this rises to 45–60 percent. Also, only 10 percent of waste is recovered through recycling or reuse (MONRE 2020). The situation is urgent: domestic solid waste generated nationwide averages 64,500 tons/day (23.5 million tons/year), and 71 percent is dumped in landfills, most of which are not sanitary landfills (MONRE 2020). Furthermore, total waste is expected to increase by 100 percent in less than 15 years (MONRE 2020). However, addressing the solid waste challenge could bring development co-benefits. Studies indicate that achieving the United Nations Sustainable Development Goal (SDG) 12.4 (responsible chemical and waste management) is a low-risk strategy for achieving national progress on many of the SDGs (UNEP 2019; WWF 2020).

**The rapid rise of plastic imports, production, and use, and mismanaged waste in Vietnam has led to a country-wide crisis of plastic pollution, especially in urban and coastal areas, and 55 percent of consumers consider it a serious problem** (Quach & Milne 2019). Annual use of plastics has increased from 3.8 kg/capita in 1990, to 33 kg/capita in 2010, 41 kg/capita in 2015 (MONRE 2020), and 81 kg/capita in 2019 (IUCN-EA-QUANTIS 2020). Since China enacted its "National Sword" policy in 2018, which banned the import of most waste plastics and materials, these wastes were diverted to Southeast Asia, and to less-regulated countries, including Vietnam. After China announced its plan to stop waste imports in July 2017, there was a surge in plastic waste imports in Vietnam from around 40,000 tons per month to a peak of 100,000 tons per month in November 2017 (Greenpeace 2019). Currently, only 20 percent of plastic materials for industrial use (including primary and recycled materials) are locally produced in Vietnam; the rest (80 percent of input materials for manufacturing [a total of 8 million tons]) are imported (IUCN-EA-QUANTIS 2020).

**Vietnam is committed to addressing its plastic waste pollution challenges.** In October 2018, the 8th plenary session of the Party Central Committee (12th tenure) adopted Resolution No. 36-NQ/TW (October 22, 2018), "the Strategy for Sustainable Development of Vietnam's Marine Economy to 2030, with a vision to 2045", which set the goals of "preventing, controlling, and significantly reducing pollution of the marine environment", and "becoming a regional leader in minimizing ocean plastic waste." On December 4, 2019, Vietnam's Prime Minister adopted Decision No. 1746/QD-TTg, which promulgated the National Action Plan for Management of Marine Plastic Litter by 2030. This set targets for reducing marine plastic waste by 50 percent by 2025, 75 percent by 2030, and eliminating single-use plastics from coastal tourism destinations and marine protected areas by 2030. In turn, Vietnam's Ministry of Natural Resources and Environment (MONRE) is seeking to increase its understanding about plastic waste problems so that it can formulate plastics management policies and investment programs. In addition, the new Law on Environmental Protection, which goes into effect on January 1, 2022, introduces "pay as you throw" policies, requires different wastes to be segregated, and sets the legal basis for extended producer responsibility (EPR) schemes.

**At the 34th Association of Southeast Asian Nations (ASEAN) Summit in June 2019, member states, including Vietnam, expressed their concerns about the high levels of marine plastic debris in the region.** This led to adopting the Bangkok Declaration on Combating Marine Debris in the ASEAN Region, and the ASEAN Framework of Action on Marine Debris. Building on this commitment, the World Bank was asked by Thailand (the chair of ASEAN in 2020) to support the preparation of the ASEAN Regional Action Plan for Combating Marine Debris. Drawing on three regional stakeholder workshops, and additional rounds of review and inputs from the 10 ASEAN member states, the Regional Action Plan, adopted in May 2021 (ASEAN 2021), proposes an integrated approach to address marine plastic pollution in ASEAN over the next five years (2021–2025) through 14 regional actions at three key stages of the value chain. These are: 1) Reducing Inputs into the System, 2) Enhancing Collection and Minimizing Leakage, and 3) Creating Value for Waste Reuse.

**Despite these recent commitments, challenges remain in formulating policies to phase-out single-use plastic consumption and incentivize circular economy measures on both the supply and demand sides.** Greater budget allocations to expand collection coverage and improve controlled disposal are also needed. Implementation of institutional reforms to address the fragmented approach of public actors on this issue will also be key. However, a major obstacle to hinder the commitments is the lack of analytical studies and data on the amount and varieties of plastic in rivers, river basins, and the sea.

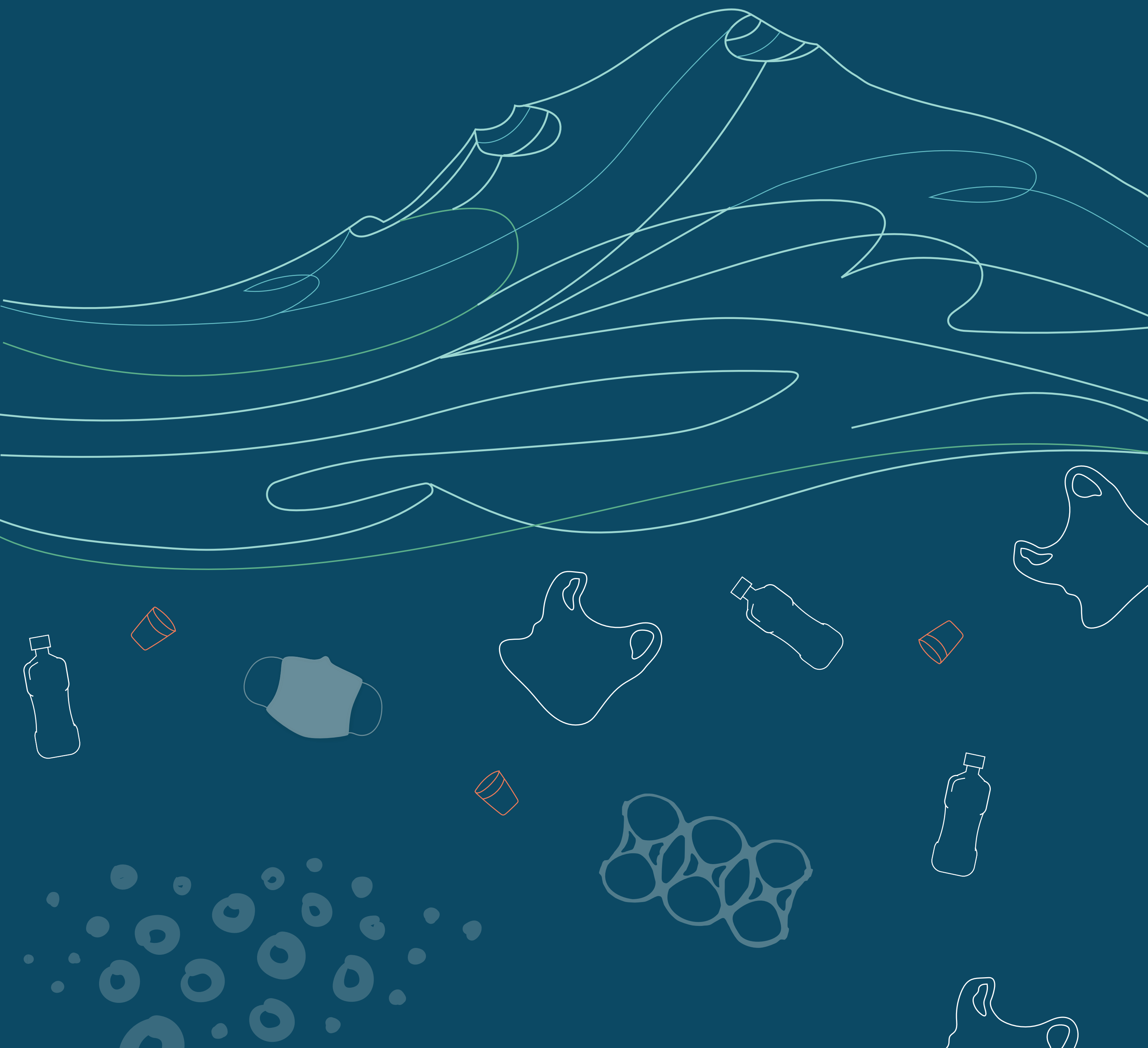
**In response to a request from MONRE, the World Bank Group has mobilized resources from PROBLUE, a multi-donor trust fund, to support Vietnam in its efforts to address plastic waste pollution.** The objective of the World Bank's technical assistance and advisory services is to support Vietnam's efforts to address plastic waste issues, including ocean plastics, through enhancing knowledge about plastic pollution and value chains, and identifying effective policies and public and private investments. The ASA program has been administered by the World Bank, in close coordination with the Vietnam Agency of Sea and Islands (VASI), and the Vietnam Environment Administration (VEA), both of which are under MONRE, as well as provincial authorities. The ASA program comprised three components: (1) Supporting diagnostics on plastic waste; (2) Identifying priority solid waste management and plastic pollution policies and investments; and (3) Conducting value chain diagnostics for plastics in Vietnam, and recommending a private sector action plan. The studies summarized in this report fell under Component 1.

**The overall objective of Component 1 was to deepen knowledge about the different plastic waste types leaking into rivers and the ocean in Vietnam, and identify and analyze their market alternatives for potential substitution.** For this purpose, Component 1 aimed to quantify the plastic waste at key locations where leakage occurs (such as riverbanks and beaches), and monitor the transport of plastics in rivers. Component 1 intended to identify the most common plastic items accumulating on riverbanks and at coastal sites, as well as flowing through rivers, and also identify market alternatives. The overarching goal was to provide an evidence base to support the development of strategies, policies, and investments in Vietnam that will enhance plastic waste management.

**This report summarizes three diagnostic studies.** These were: (1) field surveys on riverbanks and at coastal sites to determine the extent of plastic pollution, and the top 10 polluting plastic items; (2) remote sensing and drone surveys to monitor plastic leakage through waterways into the ocean, and (3) preliminary analysis of alternatives to the top-polluting plastic items in Vietnam. The field surveys, plastic monitoring, and analysis of alternatives complement each other to provide a holistic picture of the extent of pollution, the polluting items that end up in waterways and the ocean, and ways to address the problem.

**This report comprises three chapters.** Following the introduction (Chapter 1), the diagnostic studies are presented in Chapter 2: field surveys (Section 2.1), plastic monitoring (Section 2.2), and the analysis of plastic alternatives (Section 2.3). Chapter 3 presents conclusions, limitations, and the way forward.

# 2. PLASTIC POLLUTION DIAGNOSTICS



# 2.1 PLASTIC FIELD SURVEYS

## 2.1.1 Plastic Field Survey Objectives

**The overall objective of the plastic field surveys was to deepen knowledge about the different plastic waste types leaking into rivers and the ocean in Vietnam.** This has been achieved through surveys that increased understanding about plastic waste quantities and the key locations for plastic waste leakage into waterways. Based on the surveys, the top 10 most common plastic waste items were identified. The results are intended to inform policies and investment programs that will reduce marine plastic pollution.

**The specific objectives of the plastic field surveys are listed below:**

1. To quantify the amount of solid waste leaking into the environment in 10 selected river and coastal sites in Vietnam. This enabled the identification of the 10 most common plastic waste types to inform policies and investments.
2. To inform government agencies, mobilize buy-in to solve plastic waste problems, build capacity, and develop local relationships.
3. To introduce scientific methodologies for plastic waste monitoring and evaluation to national and local government officials, academics, not-for-profit officers, and other individuals and organizations that have an interest in plastic management and research in Vietnam.

## 2.1.2 Study Design and Methodology

**The plastic field surveys were carried out in seven steps from location selection to submission of the final report:**

1. A set of criteria for choosing suitable locations in Vietnam was developed, based on consultation with government agencies such as the Vietnam Environment Administration (VEA) and the Vietnam Administration of Seas and Islands (VASI), and then 10 field survey locations were selected.
2. Taking Vietnam's situation into account, field survey methodologies were identified, selected, and modified.
3. Documents were sent to local authorities in each location to obtain permission to carry out a survey.
4. Assigned local officers were consulted through email and calls about the selection of survey sites, logistics, and the process of recruiting volunteers.
5. The survey team met local officers during field trips to introduce the project and discuss the circumstances of local solid waste management. The survey team also worked with different volunteers in the field such as students, government officers, workers, and farmers to collect data.
6. After each trip, the data collected were analyzed, a report was prepared that identified the top 10 plastic waste items leaking into the environment in each location, and this report was shared with the local authority to get their comments.

7. The final report was prepared that summarized all data obtained in the 10 locations selected for the field surveys.

#### 2.1.2.1 Survey Location and Site Selection

**In consultation with government agencies, *survey locations* were defined as a city or a province in Vietnam, and survey *sites* as the specific points within locations where on-the-ground surveys would be undertaken.**

**The selection of sites aimed to provide a good representation of plastic pollution in Vietnam.** Criteria for location selection were based on a number of factors: population level; geographic location; expected amount of plastic waste; potential negative environmental and economic impacts from plastic waste (for example, in a tourism area or protected area); inclusion of river and coastal areas; priority areas identified by the Government of Vietnam; and commitment at the local level to address plastic waste challenges, including through local legislation, waste management initiatives, and plans. Information on all these criteria was collected through desk studies of published and "gray" (unpublished) literature such as government reports and working papers, as well as discussions with national and local authorities.

**In each location, three to four survey sites were selected, comprising both coastal and river areas.**[5] The criteria for each area type are listed in Table 2.

5 However, some landlocked locations did not have coastal sites; see Section 2.1.3.1.

#### 2.1.2.2 Field Survey Protocol

**The survey design methodology and interpretation was based on the internationally recognized scientific survey manuals of the United Nations Environment Programme (UNEP), *Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean* (GESAMP 2019).** The techniques adapted to Vietnam's context concerned (i) waste lists and categories, and (ii) additional details for each step, such as division of the two categories ***plastic bag*** and ***beverage bottle*** (PET) into two categories, each: ***plastic bags size 1*** (bags with a weight-holding capacity of up to 5kg), and ***plastic bag size 2*** (bags with a weight-holding capacity of more than 5kg); and ***beverage bottle size 1*** (0–500 ml), and ***beverage bottle size 2*** (more than 500 ml). While the survey protocol which was employed was based on the GESAMP guidelines, for quality checking purposes, OSPAR's[6] method (González et al. 2016) was applied in the Danang river survey.

**In each location, at least two members of the survey team, together with 6 to 10 local volunteers, carried out the surveys.** Survey team members focused on managing the whole survey process and ensuring its quality and diligence. This included collecting information from the local authority; identifying survey sites; and managing and participating in the

6 OSPAR is the mechanism by which 15 governments and the European Union cooperate to protect the marine environment of the North-East Atlantic.

Table 2:
**COASTAL AND RIVER SITE SELECTION CRITERIA**

| Coastal Site Criteria | River Site Criteria |
|---|---|
| • Sandy beach or pebble shoreline<br>• Clear, direct, year-round access<br>• No breakwaters or jetties<br>• At least 100 meters in length, parallel to the water<br>• If the survey includes two coastal sites in a location, choose a beach with no regular clean-up activities (or cleaning at least three months prior to the survey time), and a beach with regular clean-ups. If the survey includes only one coastal site in a location, choose either. | • At least 100 meters in length, parallel to the water<br>• Digging on the banks is possible<br>• Regularly flooded during the rainy season |

collection, classifying, counting, and weighing of plastic items, as well as data entry. The volunteers focused on waste collection, classification, and counting and weighing. Before the start of survey work in each location, volunteers were introduced to the survey method, including the size of items to collect, how to classify items into different categories, how to count and weigh items, and safety protocols (see Annex 2.1.A for the data sheet template used in the survey).

**While the collection, classification, and tallying of waste broadly followed the same principles at coastal and river sites, there were certain methodological differences between the two.** These differences concerned the selection of sections of the site to sample, and the actual sampling. While survey teams at river sites dug down to a depth of 30cm in an area one meter square, sampling at coastal sites did not involve digging, and instead items were collected from the surface of the ground (see Annex 2.1.B). At coastal sites to assess the impact of the tide on standing stock[7] and the accumulation rate,[8] surveying was carried out on two consecutive days.

7 Standing stock is a measure of the amount of debris at a coastal site expressed as the [unit quantity of debris] per [unit length or area of the coastal site]. Each survey event was a snapshot of the concentration of debris at a survey site, and a series of these snapshots over time provided information on changes in the baseline concentration of debris. This is an efficient way to assess large-scale spatial patterns in the distribution and composition of debris (Cheshire et al. 2009; GESAMP 2019; Lippiatt et al. 2013).

8 The accumulation rate provides information on the balance of debris over a given length of beach at a coastal site (arrival minus removal rates), over a given period of time. This is expressed as [unit quantity of debris] per [unit length of the coastal site] per [unit of time], for example, kg/km/month. Accumulation survey data indicate the net flux of debris (Cheshire et al. 2009; GESAMP 2019; Lippiatt et al. 2013).

### 2.1.2.3 Waste Categorization and Brand Audit

**Based on the GESAMP guidelines (2019), the data sheet (see Annex 2.1.A) was designed with seven categories: i) Plastic, ii) Metal, iii) Glass, iv) Rubber, v) Paper, vi) Cloth/Fabric, and vii) Mixed Waste, as well as 28 sub-categories of plastic (henceforth called *items*).**

**Both the International Coastal Cleanup (ICC) method (Ocean Conservancy 2006) and the scoring method (Whiting 1998) were used to identify the source of the plastic items that were collected.** The ICC method assigns waste items to one of five sources: shoreline/recreational, ocean/waterway, smoking-related, dumping, and medical/personal hygiene activities. Whiting's cross-tabulation probability scoring system assigns a score for the probability that an item of waste comes from a particular source.

**By combining the ICC method and the Whiting method, the plastic waste collected in this study was classified into five sources:** i) Fisheries-related waste, ii) Agriculture-related waste, iii) Take-away food-related waste, iv) Household-related waste and v) Sanitary and medical-related waste. These five categories were cross-matched with the 28 plastic items presented in Table 3. Table 3 also identifies those plastic items that are classified as single-use plastics (SUPs[9]).

9 According to the GESAMP (2019), single-use plastic waste—often referred as disposable plastics—is commonly plastic used for packaging, and includes items intended to be used only once before they are thrown away or recycled.

Table 3:
**SOURCES AND PLASTIC SUB-CATEGORIES**

| # | Sources | Plastic Items | SUP? |
|---|---|---|---|
| i) | Fisheries-related waste: items used for fishing and aquaculture activities | Fishing gear 1: Plastic fishing rope, net pieces, fishing lures & lines, hard plastic floats | No |
| | | Fishing gear 2: Polystyrenes-ESP, buoys & floats | No |
| | | String, plastic cords, and rope; Plastic rope | No |
| ii) | Agriculture-related waste: items used in agriculture | Fertilizer bags or containers | No |

| # | Sources | Plastic Items | SUP? |
|---|---|---|---|
| iii) | Take-away related waste: items used for packaging take-away food in the hospitality and tourism sector | Plastic bags size 1 (0–5kg) | Yes |
| | | Plastic bags size 2 (>5kg) | Yes |
| | | Soft plastic fragments (mostly from plastic bags) | Yes |
| | | Styrofoam food containers | Yes |
| | | Cups, utensils... (PET) | Yes |
| | | Cups, utensils...(PP) | Yes |
| | | Straws | Yes |
| iv) | Household-related waste: items that originate from different human activities, and discarded or left by the public on the coast or inland, and carried by wind and rivers. | Hard plastic fragments (from plastic toys, kitchenware, unidentified objects) | Yes |
| | | Plastic film fragments | Yes |
| | | Crisp/Sweet packages | Yes |
| | | Food wrappers | Yes |
| | | Other wrappers (Wet tissue wrappers, chopstick wrappers...) | Yes |
| | | Beverage bottles (PET) size 1 (0–100ml) | Yes |
| | | Beverage bottles (PET) size 2 (>100ml) | Yes |
| | | Other beverage bottles (HDPE…) | Yes |
| | | Food bottles (for sauces and cooking oil ) | Yes |
| | | Cleaner and cosmetic bottles (e.g., shampoo bottles, cosmetic jars, shower gel) (0–100ml) | Yes |
| | | Cleaner and cosmetic bottles (e.g., shampoo bottles, cosmetic jars, shower gel) (>100ml) | Yes |
| | | Bottle caps/HDPE | Yes |
| | | Cigar tips | Yes |
| | | Lighters | No |
| | | Other plastics (slippers, sanitary products, diapers...) | No |
| v) | Sanitary and medical-related waste: items related to personal care and health/hygiene | Personal hygiene products (toothbrushes, toothpaste tubes, razors...) | No |
| | | Medical products (band-aids, medical masks, syringes...) | No |

**Brand audits were conducted after all waste items had been sorted, tallied, and weighed.** The survey groups filtered out all the waste with brands that could be identified, and then classified the waste by the commercial product's brand name. The item counter gathered all the pieces of a specific product, and called out to the data recorder: the name of the i) product, ii) variant, iii) material, and iv) manufacturer, and v) the total number of pieces. The data recorder then wrote this information down on a brand audit form.

#### 2.1.2.4 Data Analysis

**Statistical analyses were performed to determine whether the deposition rates of debris differed significantly across the survey sites (river soil and coastal beaches), with respect to their geographic location.** Kruskal–Wallis one-way analysis of variance (ANOVA) by ranks was used for the statistical analyses because the sample groups did not show normality and equal variance, and differed in their sample size. Where differences were detected, Tukey's HSD (Honestly

Significant Difference) test was performed to identify the beach survey groups that were significantly different at the 5 percent level.

**The combined survey results provided a simple overview of the surveyed items, based on the total item numbers and weights observed.** However, to enable a comparison between different sites, locations, and groups of locations (for example, all locations along a specific river system), the analysis considered the number of items per unit (called density, henceforth) and the weight per unit.

**The definition of units differed, depending on the type of site:** for river sites, one unit was defined as 1m2 x 0.3m depth (1m length x 1m width x 0.3m depth—for more information see 2.1.2.2); for coastal sites, one unit was defined as 1m2 (1m long x 1m wide).

**In addition, the Clean-Coast index (CCI) developed by Alkalay, Pasternak, and Zask (2007) was used as a tool for the relative evaluation of coastal cleanliness.** The calculation used for the CCI is presented in the following equation:

$$Plastic\,\frac{parts}{m2} = \frac{Total\ plastic\ parts\ counted\ in\ Z\ line}{Z\ x\ 5\,[m] x\ beach\ width\,[m]}\,x\ k$$

Where the coefficient k = 20, to simplify the presentation of data for communicating with the public, results for the appearance of waste at coastal sites were graded as shown in Table 4.

Table 4:
**CLEAN-COAST INDEX**

| CCI | Very clean<br>No waste was seen | Clean<br>No waste was seen over a large area | Moderate<br>A few pieces of waste were detected | Dirty<br>A lot of waste on shore/at sites | Extremely dirty<br>Most of the beach/site was covered with waste |
|---|---|---|---|---|---|
| Numeric index | 0–2 | 2–5 | 5–10 | 10–20 | 20+ |

### 2.1.2.5 Limitations

Limitations of the study were related to meteorological factors, sample size, and the use of quadrats along rivers during the surveys.

- **The planned survey schedule based on the occurrence of the Southwest (May-October) Monsoon during the year could not be followed.** The plan was to conduct the surveys during the Southwest Monsoon season (May–October). However, the field trips were delayed and rescheduled many times due to COVID-19 pandemic restrictions. As a result, the surveys were conducted from July 2020 to January 2021, over two monsoon seasons, and 11 locations were not surveyed in the same monsoon season. This possibly influenced the quantities and types of waste deposited on the shore, and, therefore, interpretation of the results across locations and sites needs to take this into account.[10]
- **In terms of sample sizes, the number of survey sites at each location was small:** 3–4 sites/sampling units, each, in a 100-meter section, from which four 5-meter-transects of coastal area were selected. Local authorities were advised to apply the same method, and to conduct surveys at additional sites in both monsoon seasons so that they could gather more robust baseline data.
- **In interpreting the data, the survey team recognized the possibility that widespread impacts on travel and group behavior of the local population, reductions in foreign tourists, and other travel industry changes caused by the COVID-19 pandemic, may have biased the comparison of data between tourist and non-tourist locations.** In future surveys that include a tourist/non-tourist site comparison, it would be useful, as well, to collect information on any changes in the local population (local or tourist).
- Regarding the use of quadrats along rivers, digging down 30cm helped to show the effect of water flow and plastic waste movement, but the amount did not reflect what was on the surface. Therefore, to compare results for river sites, GreenHub added OSPAR's method (González et al. 2016).

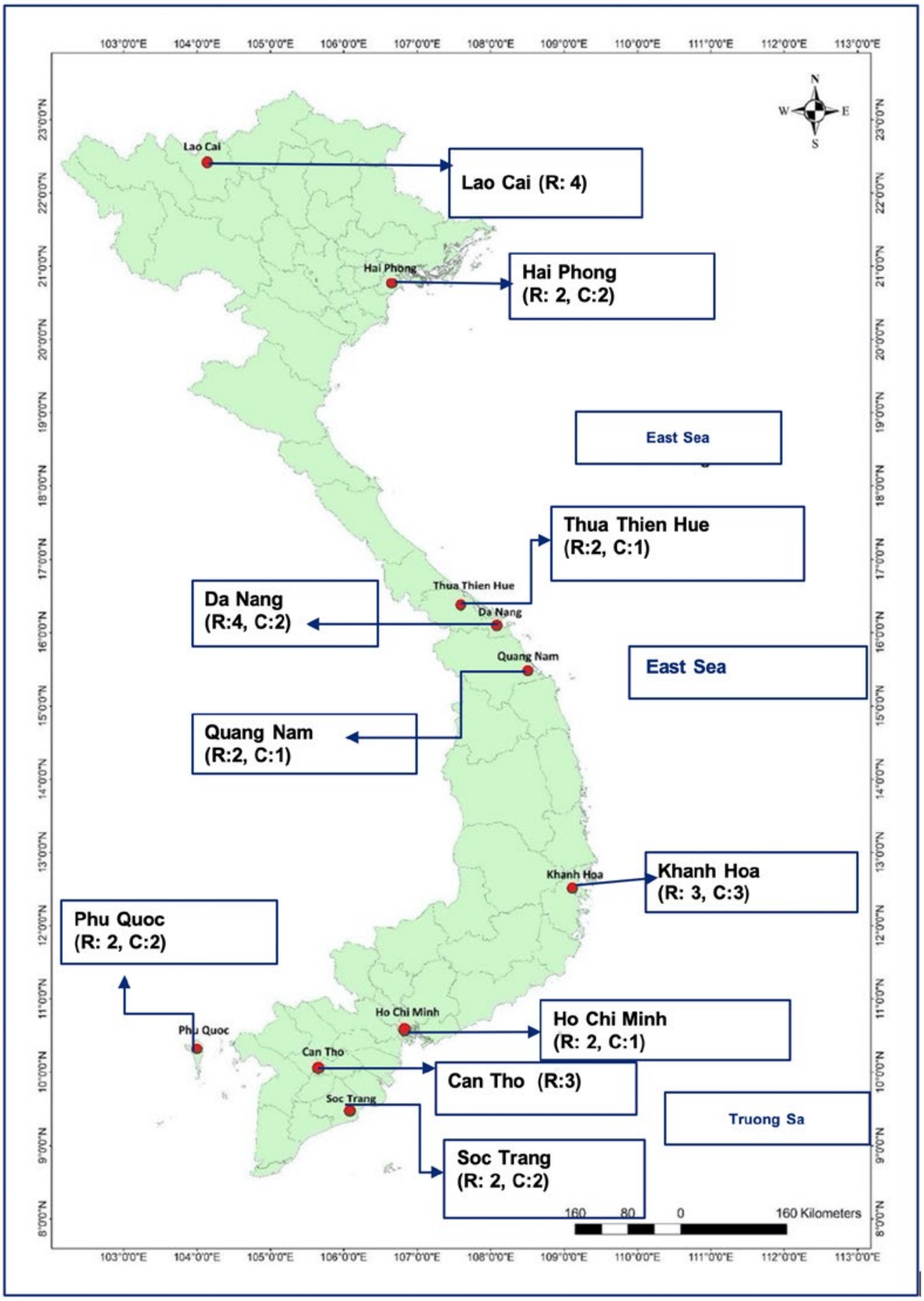
10 Anecdotal information given by coastal inhabitants during the GreenHub and IUCN marine protected area surveys in 2019 indicated that greater volumes of marine waste were deposited during the Northeast Monsoon season than in the Southwest Monsoon season.

## 2.1.3 Results

### 2.1.3.1 Survey Locations

**In total, there were 38 survey sites—24 river sites and 14 coastal sites—in 10 different locations.** Figure 6 provides a map of all the survey locations.

Figure 4:
**OVERVIEW OF SURVEY LOCATIONS**




*Note: The numbers in brackets represent the number of survey sites per location.*

*R = River site; C = Coastal site*

To enable a comparison between different zones and river systems, the survey sites in the 10 different locations were clustered as follows:

### Coastal Sites

**Based on the criteria of geology-landform, climate-hydrology, ecology-biogeography, and land-sea interaction, the Vietnamese coastal zone was divided into three coastal subzones:** the Northern subzone (Hai Phong and Thua Thien Hue), the transitional subzone (Da Nang, Quang Nam, and Khanh Hoa) and the Southern subzone (Ho Chi Minh City, Soc Trang, Can Tho, and Phu Quoc island).

The **Northern subzone** from Mong Cai to Hai Van cape is the place where interaction occurs between the land in northern Vietnam with tropical monsoons and cold winters, and the part in the East Sea with tropical monsoons.

The **transitional subzone** in the center of Vietnam, stretching from Hai Van cape to Dai Lanh cape, is characterized by the interaction between the land of southern Vietnam with sub-equatorial monsoons and year-round warmth, and the marine part of Northern subzone in the East Sea that has tropical monsoons.

The **Southern subzone,** from Dai Lanh cape to Ha Tien sees interaction between the land of southern Vietnam with the sub-equatorial monsoons, and the marine part of the Southern subzone in the East Sea that has sub-equatorial monsoon.

### River Sites

**Vietnam has up to 2,360 rivers, streams, and canals.** The country has 112 estuaries, and along the coast, there is an estuary every 23km. Most major rivers in Vietnam originate in other countries, with the middle and lower parts of rivers flowing through Vietnam and into the ocean. Nine major river systems stretch from North to South.

**River sites were compared by clustering them as follows:** According to Lebreton et al. (2017), the Mekong river is one of the 20 most-polluted rivers in the world, and therefore it was included in this study's surveys. Other river sites were clustered into four groups: the Red River; the rivers in the central provinces of Vietnam; the Phu Quoc rivers; and the Dong Nai-Sai Gon rivers. The surveyed river sites in Ho Chi Minh City belong to the Dong Nai-Sai Gon rivers.

Table 5 lists the survey sites along with several characteristics for each site (region/river system, location, type of site, survey date, and site conditions).


Photo: Claudiovidri - Shutterstock

Table 5:
**LIST OF SURVEY SITES**

| No. | Survey locations | Survey sites | River System/ Subzone | Site Type | Rural (R) versus Urban (U) | Tourism (T) versus Non-tourism (NT) | Survey Date |
|---|---|---|---|---|---|---|---|
| 1 | Lao Cai Province | Ngoi Dum | Red River | River | U | NT | July 2020 |
| 2 | | Muong Hoa | Red River | River | R | T | |
| 3 | | Ta Van | Red River | River | R | T | |
| 4 | | Ngoi Duong | Red River | River | U | NT | |
| 5 | Hai Phong city | Do Son | Northern | Coastal | U | T | September 2020 |
| 6 | | Cat Hai | Northern | Coastal | U | T | |
| 7 | | Lach Tray | Red River | River | U | NT | |
| 8 | | Van Uc | Red River | River | R | TNT | |
| 9 | Hue city | Thuan An | Northern | Coastal | U | T | November 2020 |
| 10 | | Huong | Central rivers | River | U | T | |
| 11 | | Bo | Central rivers | River | R | NT<S | |
| 12 | Da Nang | Bien Dong | Transitional | Coastal | U | T | November 2020 |
| 13 | | Nam O | Transitional | Coastal | U | T | |
| 14 | | Cu De upstream | Central rivers | River | R | NT | |
| 15 | | Cu De downstream | Central rivers | River | U | NT | |
| 16 | Quang Nam | Rang | Transitional | Coastal | R | T | November 2020 |
| 17 | | Tam Ky | Central rivers | River | U | NT | |
| 18 | | Truong Giang | Central rivers | River | U | T | |

| No. | Survey locations | Survey sites | River System/ Subzone | Site Type | Rural (R) versus Urban (U) | Tourism (T) versus Non-tourism (NT) | Survey Date |
|---|---|---|---|---|---|---|---|
| 19 | Khanh Hoa | Vinh Nguyen | Transitional | Coastal | U | T | November 2020 |
| 20 | | Quang Truong (middle-class area) | Central rivers | River | U | NT | |
| 21 | | Quang Truong (downstream area) | Central rivers | River | U | T | |
| 22 | | My Ca | Transitional | Coastal | U | NT | January 2021 |
| 23 | | Binh Lap | Transitional | Coastal | R | NT | |
| 24 | | Can | Central rivers | River | R | NT | |
| 25 | Ho Chi Minh City | April 30 | Southern | Coastal | R | T | October 2020 |
| 26 | | Sai Gon | Dong Nai – Sai Gon | River | U | NT | |
| 27 | | Dong Nai | Dong Nai – Sai Gon | River | R | T | |
| 28 | Soc Trang Province | Lai Hoa | Southern | Coastal | R | NT | October 2020 |
| 29 | | Ho Be | Southern | Coastal | R | NT | |
| 30 | | Long Phu | Mekong river | River | U | NT | |
| 31 | | My Thanh | Mekong river | River | R | NT | |
| 32 | Can Tho city | 3/2 | Mekong river | River | U | NT | October 2020 |
| 33 | | Rau Ram | Mekong river | River | U | NT | |
| 34 | | Cai Khe | Mekong river | River | U | NT | |
| 35 | Phu Quoc Island | Sao | Southern | Coastal | U | T | October 2020 |
| 36 | | Truong | Southern | Coastal | U | NT | |
| 37 | | Cua Can | Phu Quoc | River | R | NT | |
| 38 | | Duong Dong | Phu Quoc | River | U | T | |

### 2.1.3.2 Combined Survey Results

Major Waste Categories

**At both river and coastal sites, plastic waste dominated the total composition.** Across all sites, a total of 24,461 items and 164 kg of waste were collected during the surveys; the percentage of plastic waste was 93.6 percent in number, and 70.7 percent in weight, followed by cloth/fabric (1.5 percent in number and 5.1 percent in weight), mixed waste (1.5 percent in number and 6.6 percent in weight), and glass (1.4 percent in number and 8.9 percent in weight). Rubber, metal, and paper/timber comprised less than 1 percent in number, and about 3 percent in weight (see Figure 5 and Figure 6).

Figure 5:
**TOTAL NUMBER OF WASTE ITEMS (PERCENTAGE) ON SURVEYED SITES IN VIETNAM**

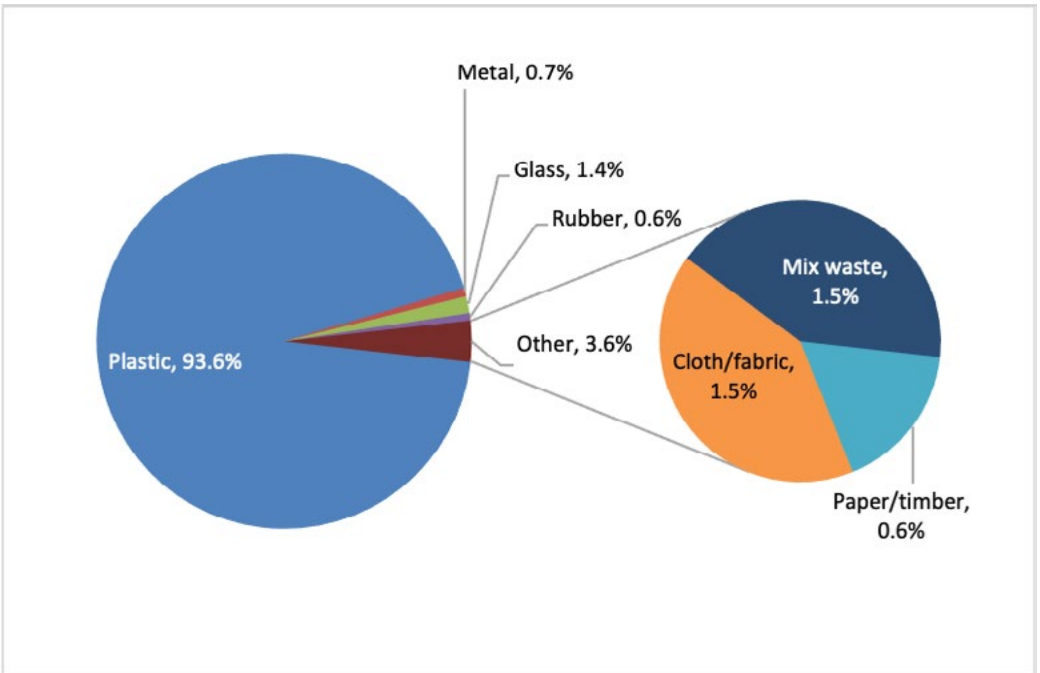
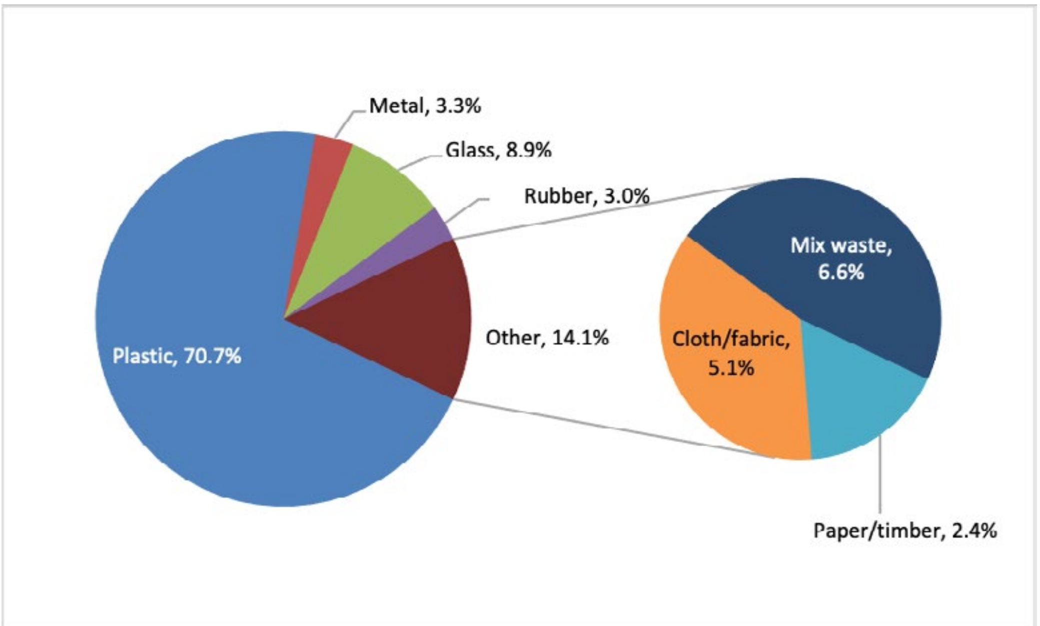


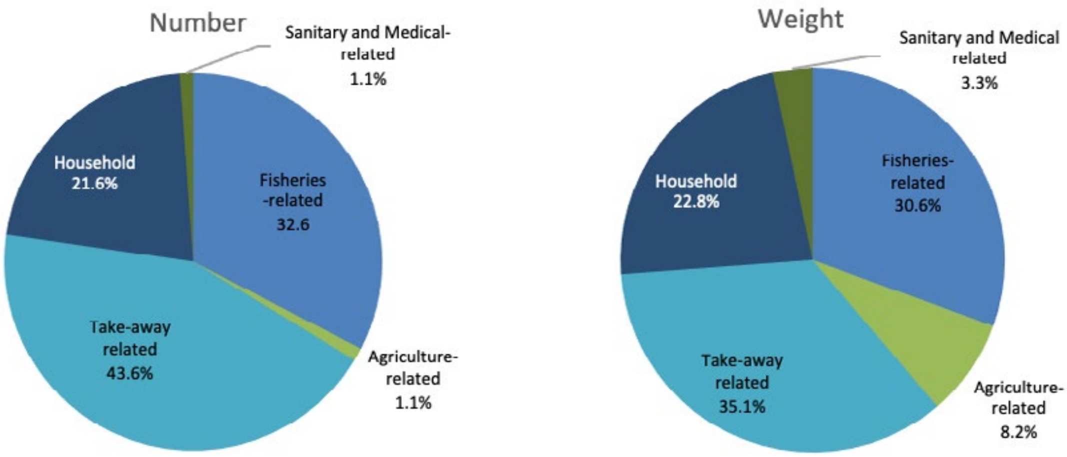

Figure 6:
**TOTAL WEIGHT OF WASTE (PERCENTAGE) ON SURVEYED SITES IN VIETNAM 2020**



## Plastic Waste Sources

**Plastic waste at both surveyed river and coastal sites came mostly from take-away related sources, fisheries-related sources, and household sources.** *Take-away related waste* was the most abundant source of plastic waste found (43.6 percent in number and 35.1 percent in weight), followed by *fisheries-related waste* (32.6 percent in number and 30.6 percent in weight), and *household-related waste* (21.6 percent in number and 22.8 percent in weight). *Agriculture-related and medical-related plastics* comprised only about 1 percent in number and 3 to 8 percent in weight (see Figure 7).

Figure 7:
**TOTAL NUMBER AND WEIGHT OF PLASTIC WASTE BY SOURCE ON SURVEYED SITES IN VIETNAM 2020**




## Top 10 Plastic Waste Items

**The top 10 items of plastic waste found on combined river and coastal sites accounted for 83 percent of the total number, and 73 percent of the total weight of plastic items. Plastic bags and their fragments were the most common single-use items at survey locations in Vietnam.** *Soft plastic fragments* (mostly fragmented plastic bags) accounted for 17.4 percent in number and 15 percent in weight, and *plastic bags* size 1 (0-5kg) accounted for 8.5 percent in number and 9.1 percent in weight. *Fishing gear 1* (16.9 percent in number and 17.3 percent in weight), and *Fishing gear 2* (13 percent in number and 11.5 percent in weight) were the next highest. This was followed by Styrofoam food containers and hard plastic fragments. *Other plastics* (for example, pieces and fragments that were too small or damaged to be classified, or plastic shoes, and plastic traps) had the lowest count among the top 10 plastic items, in terms of the number of items, but this was fourth by weight (see Figure 8).

Figure 8:
**TOP 10 PLASTIC WASTE ITEMS AT RIVER AND COASTAL SITES IN VIETNAM**

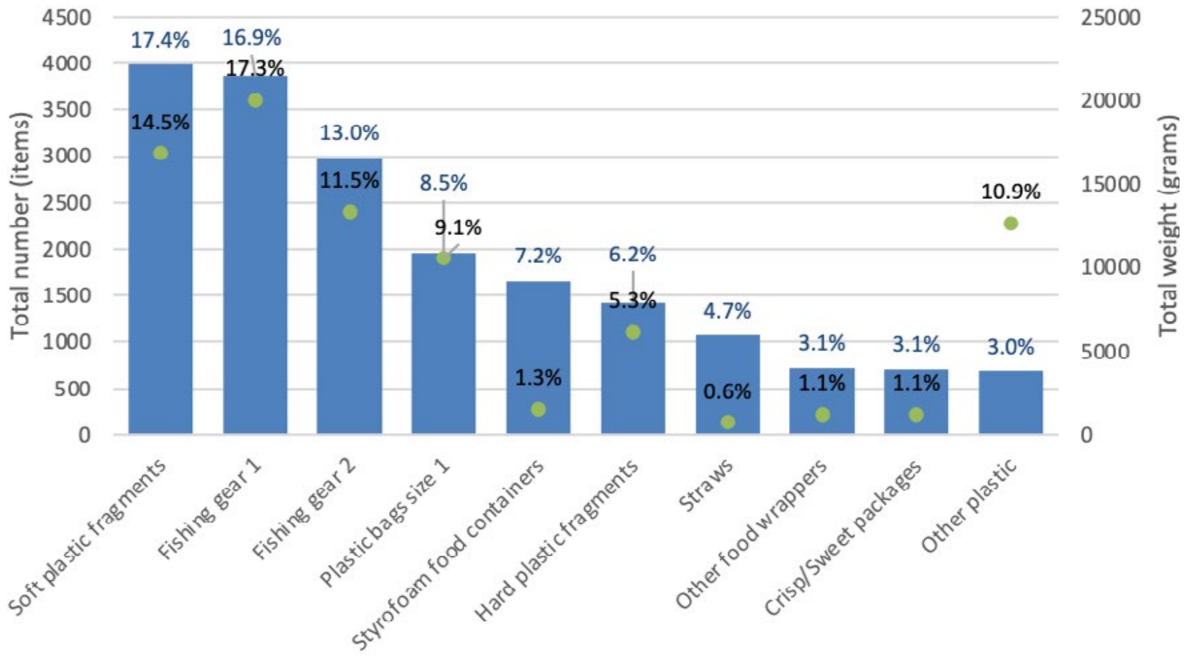



Figure 9:
**PHOTOS OF THE TOP 10 PLASTIC WASTE ITEMS AT RIVER AND COASTAL SITES IN VIETNAM**


Soft plastic fragments


Fishing gear 1


Fishing gear 2


Plastic bags 0-5kg


Styrofoam food containers


Straws

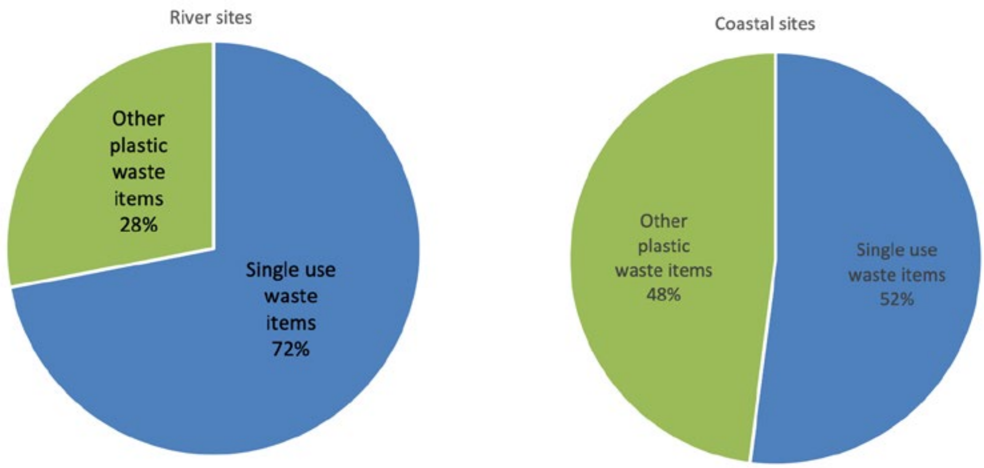

Other food wrappers


Other plastic


Hard plastic fragments


Crip/sweet packages

Figure 10:
**PERCENTAGE OF SINGLE-USE PLASTIC WASTE AT RIVER AND COASTAL SITES**




### Single-use Plastics

**Both at river and coastal sites, plastic waste was mainly single-use plastics.** In river areas, single-use plastics accounted for 72 percent in number, while in coastal areas, they account for 52 percent.

### Waste Brand Audit

**Of 24,461 waste items collected, 1,184 could be assigned to one of 266 brands.** Of the items assigned to a brand, the 21 top brands comprised about 56 percent of the total.

## 2.1.3.3 Results of the surveys conducted at river sites

### Major Waste Categories

**A total of 24 river sites (120 quadrats) in 10 locations were surveyed and sampled, with 2,707 waste items and 27.2 kg quantified. The most common category on riverbanks was *plastic waste* (79.7 percent in number and 57.2 percent in weight).** This was followed by *mixed waste* (7 percent in number and 9 percent in weight), and *glass* (6 percent in number and 10 percent in weight). Other categories represented less than 3 percent in number and 8 percent in weight, respectively (see Figure 11 and Figure 12).

Figure 11:
**TOTAL NUMBER OF WASTE ITEMS (PERCENTAGE) AT SURVEYED RIVER SITES**

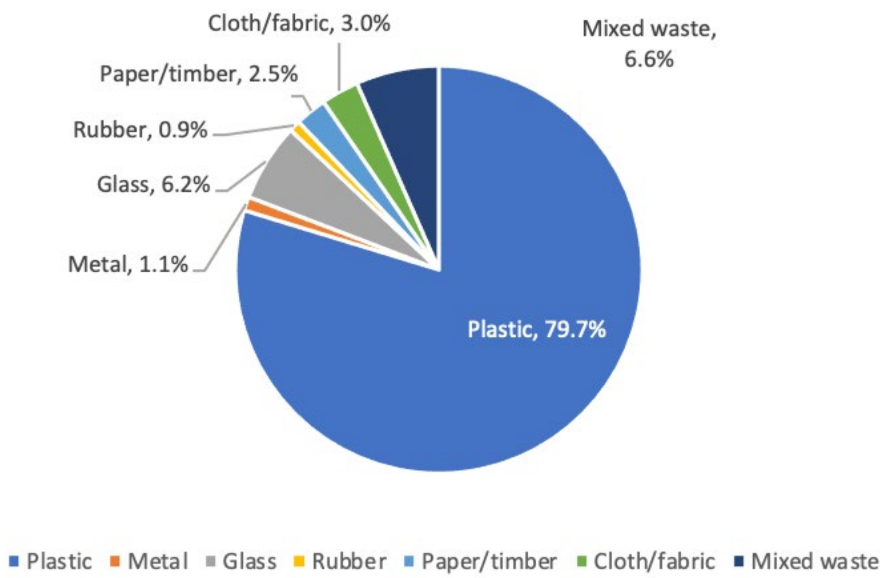
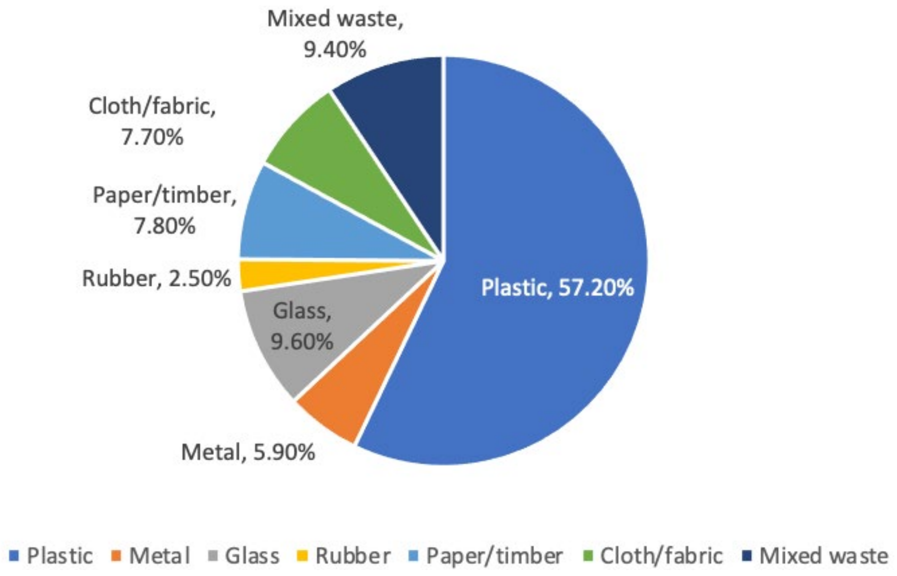



Photo: Praneat - Shutterstock

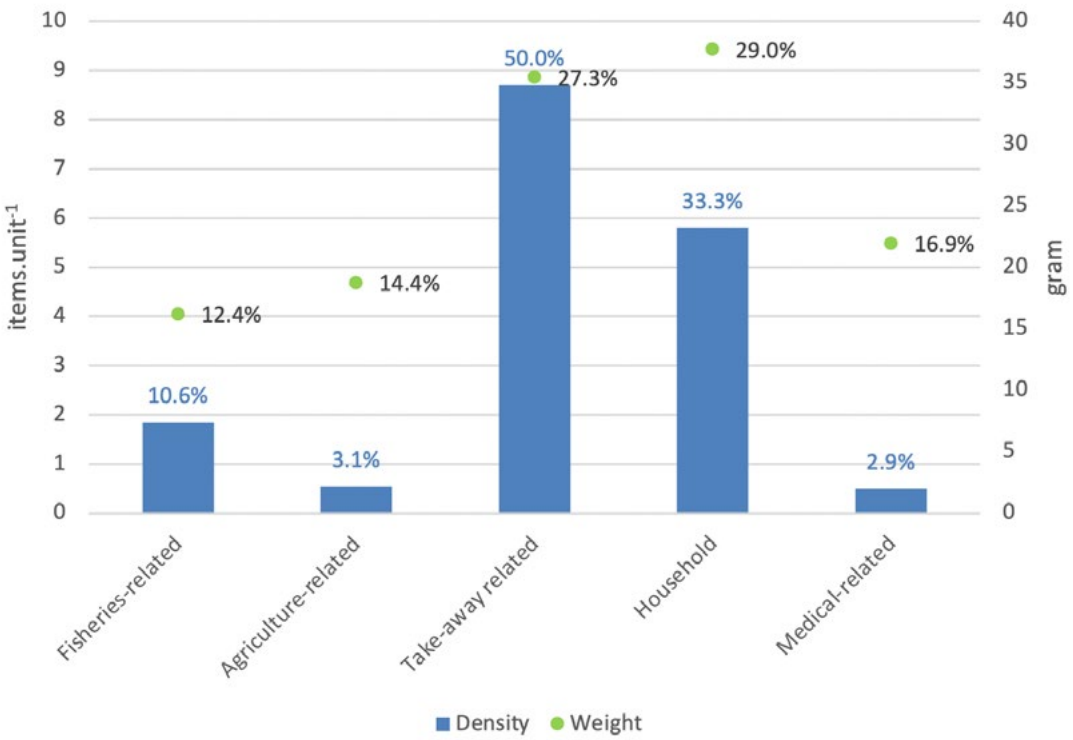
Figure 12:
**TOTAL WEIGHT OF WASTE (PERCENTAGE) AT SURVEYED RIVER SITES**




## Plastic Waste Sources

**Of the five main sources surveyed at river sites, take-away related waste dominated, representing 50 percent in density, but only 27.3 percent in weight**. *Household-related* waste was the second most important source (33.3 percent in density and 29 percent in weight), followed by f*isheries-related* waste (10.6 percent in density and 12.4 percent in weight). Agriculture-related and medical-related plastic waste both represented around 3 percent in number, and 14.4 percent and 16.9 percent in weight, respectively (see Figure 13).

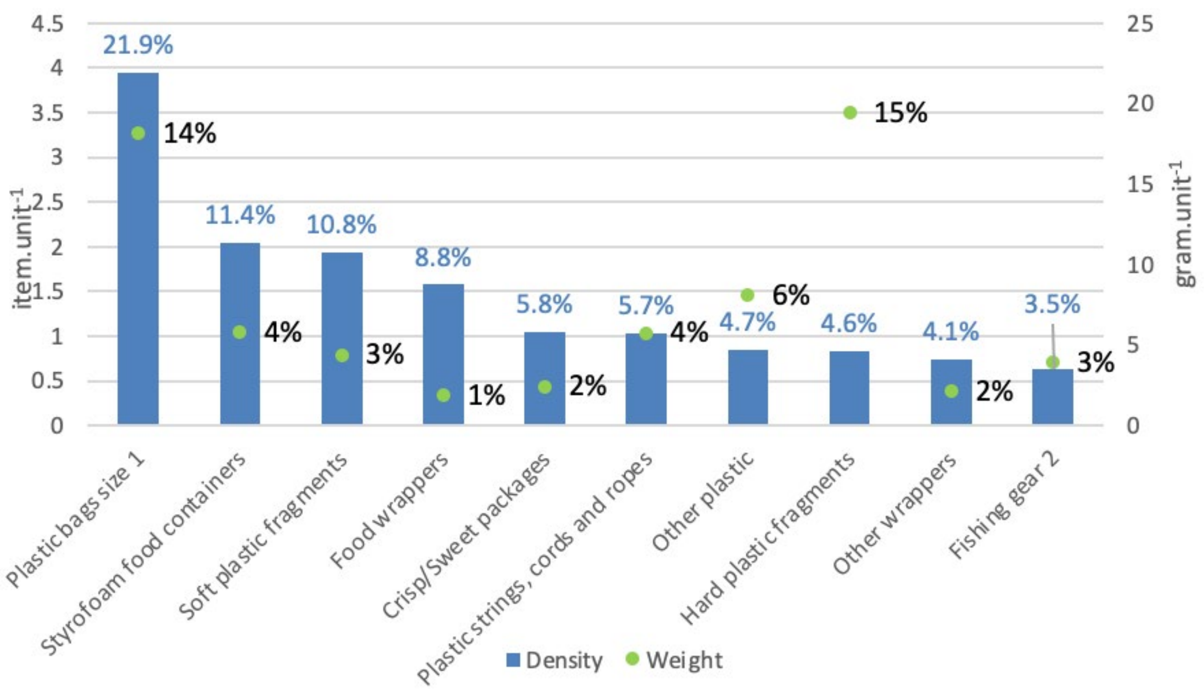
Figure 13:
**TOTAL DENSITY AND WEIGHT OF PLASTIC WASTE BY SOURCE ON SURVEYED RIVER SITES IN VIETNAM**



### Top 10 Plastic Waste Items

**The top 10 common plastic waste at river sites accounted for 81.3 percent in density and 54 percent in weight.** Among them, *plastic bags size 1* were the most common in density of waste (21.9 percent in density), followed by *Styrofoam food containers* (11.4 percent), and *soft plastic fragments* (10.8 percent). However, the top three categories in weight were: *hard plastic fragments* (15 percent), *plastic bags size* 1 (14 percent) and *other plastic* such as sanitary napkins, diapers, and plastic shoes (6 percent) (see Figure 14).

Figure 14:
**TOP 10 PLASTIC WASTE ITEMS AT RIVER SITES IN VIETNAM**




### Top 10 Plastic Waste Items in the Five River Areas

When comparing results between the five river areas where surveys took place (Central rivers, Phu Quoc rivers, Mekong River, Red River, and Dong Nai-Sai Gon River) these are the key findings:

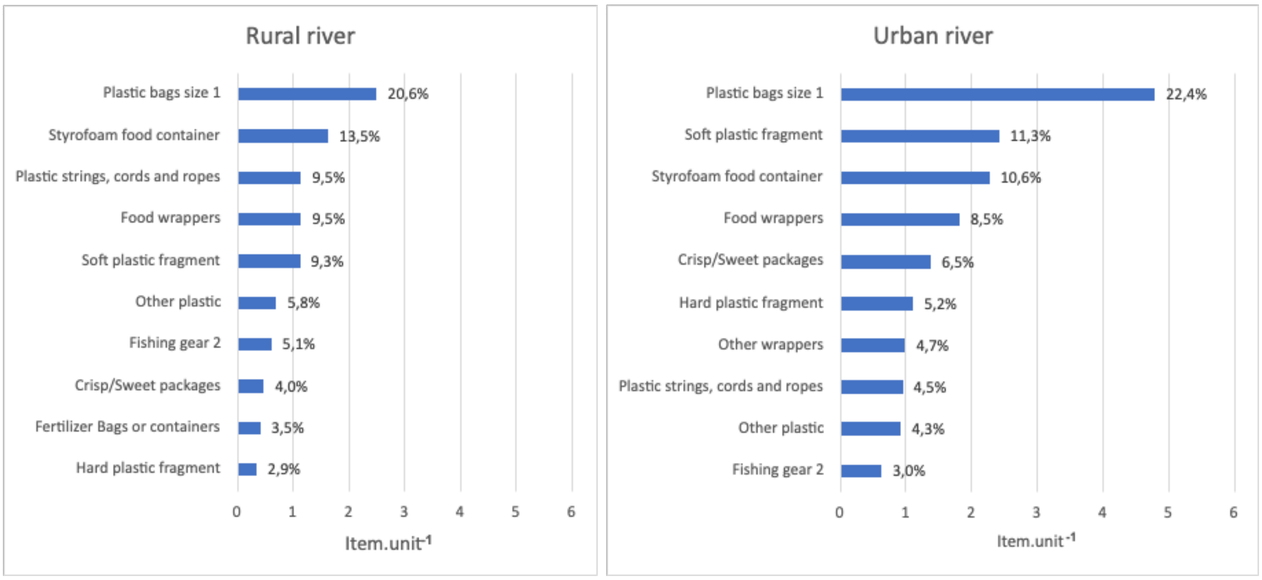
- **The top 10 plastic waste items accounted between 81.5 percent (Mekong River) and 93.4 percent (Red River) of total plastic waste found in terms of density.** This underlines the importance for finding solutions that effectively curb plastic pollution in Vietnam.
- ***Plastic bags* and *soft plastic fragments* (mostly from broken down plastic bags) play a dominant role among the top 10 plastic waste items.** For the Central and Phu Quoc rivers, *soft plastic fragments* was most prevalent item (25.9 percent and 32.3 percent, respectively). For the Red River, *plastic bags size 1* were found the most (44.7 percent), and for the Mekong River and the Dong Nai-Sai Gon River, *Styrofoam food containers* were most common (19.4 percent and 31.4 percent, respectively).
- **The average density of waste differed considerably across the surveyed river areas.** Locations along the Dong Nai-Sai Gon River (33 items/unit), Red River (24 items/unit), and Mekong River (22 items/unit) showed much higher densities than locations along the Central rivers (9 items/unit) and the Phu Quoc rivers (9 items/unit). The Red River had a much higher density of plastic bags than other rivers.

## Top 10 Plastic Waste Items – Rural versus Urban Areas

There was little difference when comparing rural and urban river sites by density (see Figure 15):

- **The top 10 plastic items by density accounted for 83.8 percent of plastic waste found at rural sites and 81 percent at urban sites.**
- **The top 10 plastic waste items at river sites were consistent across rural and urban sites.** *Fertilizer bags* (only among top 10 items at rural sites) and *other wrappers* (only among top 10 items at urban sites) were the exception.
- ***Plastic bag size 1* was the most frequently found item in both rural and urban environments.** *Styrofoam food containers, soft plastic fragments,* and *food wrappers* were among the top five types of plastic waste at both rural and urban river sites.

Figure 15:
**TOP 10 PLASTIC WASTE ITEMS AT RIVER SITES IN RURAL AND URBAN AREAS BY DENSITY**



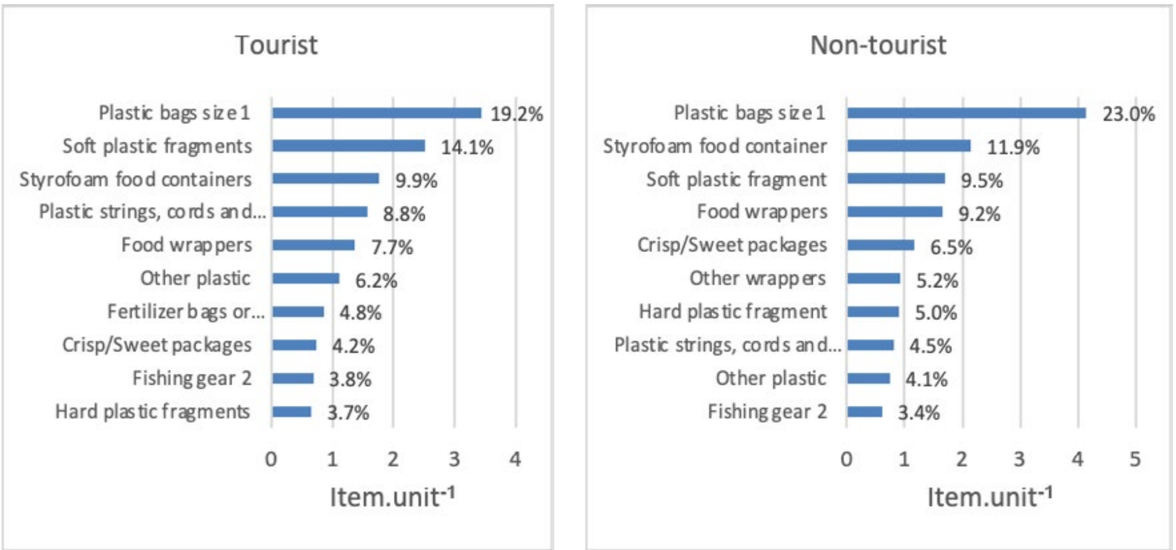

## The Top 10 Plastic Waste Items in Tourist Versus Non-tourist Areas

When comparing river sites in tourist and non-tourist areas (see Figure 16), these were the key findings, and they were quite similar:

- **In both tourist and non-tourist areas, the total density of the top three plastic waste items was 43.3 percent and 44 percent, respectively, while the total density of the top 10 plastic waste items was about 82 percent for both.**
- **The top three plastic waste items were *plastic bags size 1, Styrofoam food containers, and soft plastic fragments.***

It should be noted that, given that the surveys were carried during a global pandemic that severely affected international tourism, the surveys might yield different results if they were conducted when international tourism was similar to the pre-pandemic level.

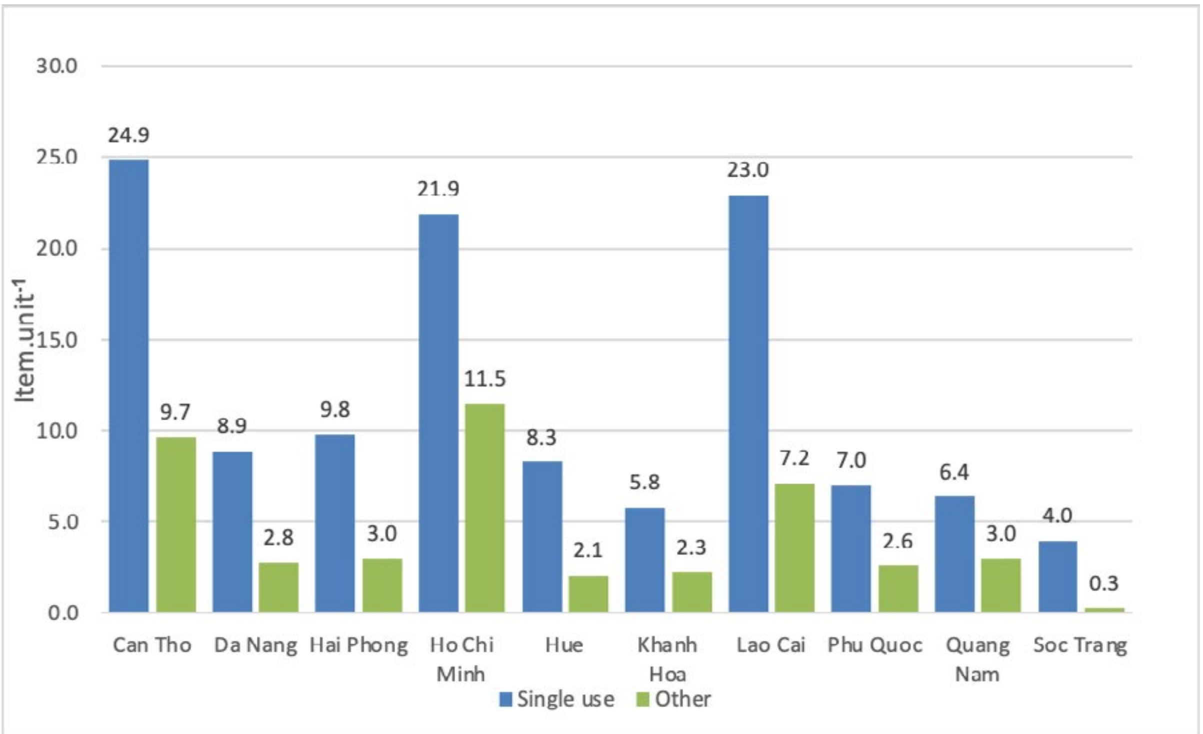
Figure 16:
**TOP 10 PLASTIC WASTE ITEMS AT TOURIST AND NON-TOURIST RIVER SITES BY DENSITY**




## Single-use Plastics

**At river sites, single-use plastics accounted for 72 percent of the total number of plastic waste items collected.** As shown in Figure 17 single-use plastic items made up between 53 percent and 93 percent of total plastic waste. The locations with the highest percentages of single-use plastic waste were Soc Trang (93 percent), Hue (80 percent), Hai Phong (76 percent), and Can Tho (72 percent).

Figure 17:
**SINGLE-USE PLASTIC WASTE BY DENSITY AT RIVER SITES IN SURVEYED LOCATIONS**




More detailed information on the survey results for river sites can be found in Annex 2.1.C.

### 2.1.3.4 Results of the survey conducted at coastal sites

#### Major Waste Categories

**A total of 54 transects at 14 coastal sites in eight locations were surveyed, and 21,749 pieces and 137 kg of debris were collected.** As Figure 18 shows, ***plastic*** items were the most numerous type of debris collected on the beaches during the survey period (95.4 percent), followed by *cloth/fabric* (1.3 percent), *glass,* and *mixed waste* (0.9 percent, each). *Plastic* waste was also most abundant in terms of weight (see Figure 19), and accounted for 73.4 percent of the total weight, followed by *glass* (8.7 percent), *mixed waste* (6.1 percent), and *cloth/fabric* (4.6 percent). Other materials such as *rubber, paper, wood,* and ***meta**l* had a very small percentage in both weight and the number of items.

Figure 18:
**TOTAL NUMBER OF WASTE ITEMS (PERCENTAGE) ON SURVEYED COASTAL SITES**

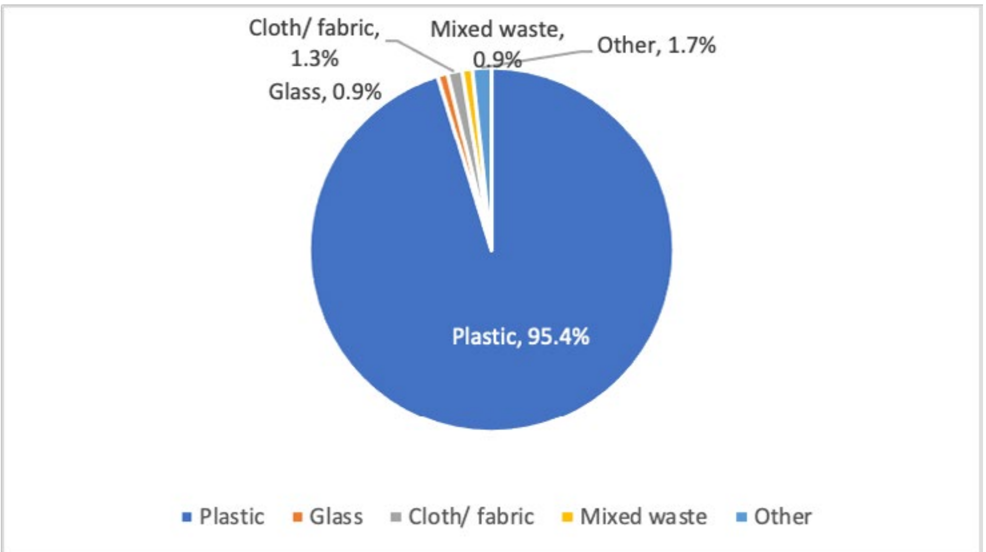
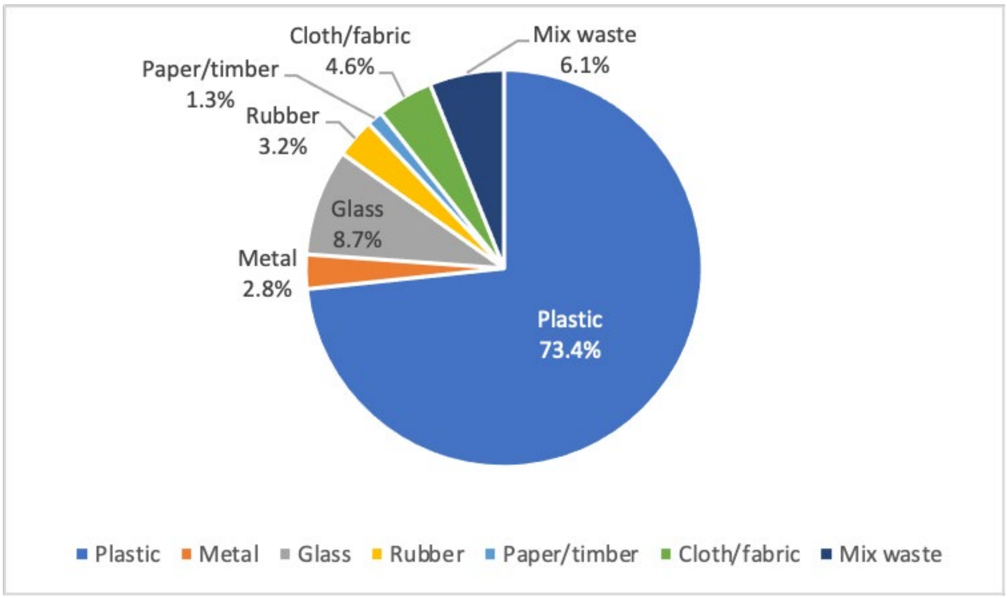



Figure 19:
**TOTAL WEIGHT OF WASTE (PERCENTAGE) ON SURVEYED OCEAN SITES**



### Plastic Waste Sources

**Coastal sites in Vietnam were polluted with plastic waste from take-away-related and fishery-related sources.** *Take-away-related waste* dominated on coastal sites, and represented 42.7 percent in number of items, and 36.3 percent in weight. Unlike river sites, *fishery-related* waste was the second most prevalent type (34.9 percent in number and 33.4 percent in weight), followed by *household-related waste* (20.4 percent in number and 21.9 percent in weight). *Agriculture–related and medical-related plastic waste* each represented around 1 percent in number and about 7 percent in weight.

### Top 10 Plastic Waste Items

As described above (2.1.2.2), this study surveyed both the standing stock at coastal sites and the daily accumulation rate.

**The standing stock survey showed that for total plastic waste, the top 10 plastic waste items at coastal sites accounted for 84 percent in density and 75.5 percent in weight.** *Fishing gear 1* was the most common (18.5 percent), followed by *soft plastic fragments* (18.1 percent), and *fishing gear 2* (14.0 percent). *Plastic bag size 1* and *Styrofoam food containers* ranked fourth and fifth in weight, with 7.1 percent and 6.8 percent, respectively (see Figure 21).

Figure 20:
**TOTAL DENSITY AND WEIGHT OF PLASTIC WASTE BY SOURCE ON SURVEYED OCEAN SITES IN VIETNAM IN 2020**

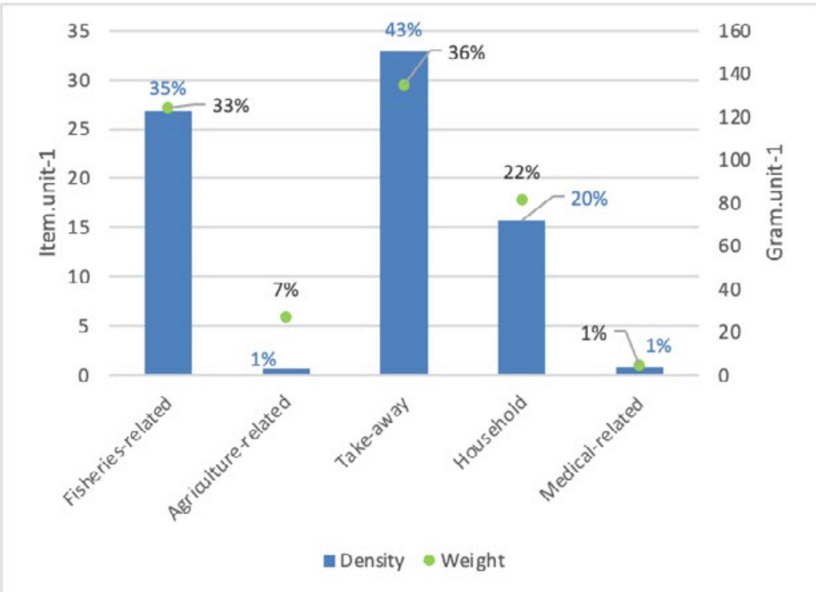



Figure 21:
**TOP 10 PLASTIC WASTE ITEMS (STANDING STOCK) AT COASTAL SITES**

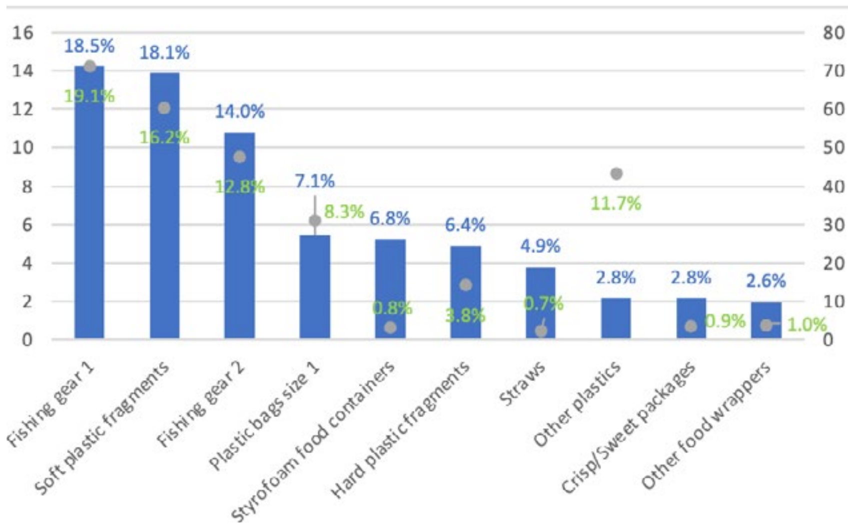
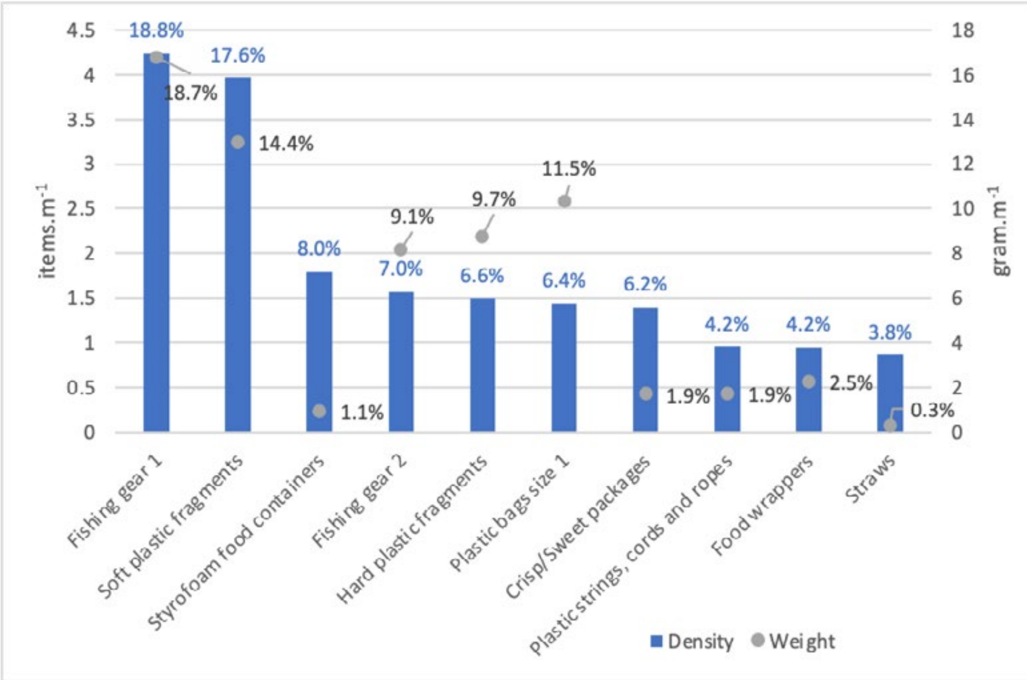


Figure 22:
**TOP 10 PLASTIC WASTE ITEMS (DAILY ACCUMULATION) AT COASTAL SITES**




**The daily plastic debris accumulated at coastal sites was high, accounting for 29.4 percent of the standing stock number.** This percentage was highly variable and influenced by a number of factors such as dynamics of the sea, wind, and human activities such as tourism and litter collection. Given the limitations of the survey process (see above), including the limited number of days that survey activities took place, daily accumulation rates should be viewed with caution. As Figure 22 shows, the top three items—*fishing gear 1*, *Styrofoam food containers*, and *soft plastic fragments*—were the top three types of plastic waste that accumulated on a daily basis.

## Top 10 Plastic Waste Items at Coastal Sites: A Comparison of Subzones

- **Ocean sites in the Northern subzone (Hai Phong and Thua Thien Hue) had a substantial amount of *fishing gear 1* (22.3 percent).** Other important plastic waste items included *hard plastic fragments* (12.4 percent) and *straws* (12.3 percent).[11]
- **Coastal sites in the transitional subzone (Da Nang, Quang Nam, and Khanh Hoa), and the Southern subzone (Ho Chi Minh City, Soc Trang, and Phu Quoc) had *soft plastic fragments* as the single highest plastic waste item (21.7 percent and 19.9 percent, respectively).** However, fishing gear was also an important pollution factor—*fishing gear 1* (15.8 percent and 19.2 percent, respectively) and *fishing gear 2* (15.7 percent and 14.2 percent, respectively). In the transitional subzone, these three waste items comprised around 53 percent of total standing stock and 46 percent of daily accumulation. In the Southern subzone, these three waste items comprised also around 53 percent of total standing stock and 52.6 percent of daily accumulation.
- ***Styrofoam food containers* are common in the Southern subzone (10.1 percent, which ranked fourth among the top 10 plastic waste items) and in transitional subzone (4.4 percent, which ranked sixth among the top 10 plastic waste items).** However, this plastic waste item was found less in the Northern subzone, and was not even included in the top 10 list, as *Styrofoam food containers* accounted for only 1.4 percent.

11 Unless otherwise stated, all following stated figures concern standing stock, by density.

### Top 10 Plastic Waste Items at Coastal Sites—Rural versus Urban Areas

- **Of total plastic waste, the top 10 plastic waste items accounted for 84 percent in rural sites and 87 percent in urban sites.** Even though the density of plastic waste could differ considerably between rural and urban areas (in rural areas, the coastal top 10 items made up between 3 and 21 item.m$^{-1}$, and in urban areas, the top 10 items only made up between 1 to 13 item.m$^{-1}$), the composition of plastic waste was very similar in the two environments.
- **In rural sites, *soft plastic fragments* was the most frequently found item (20.6 percent). The second most abundant items *were fishing gear 2* (15.4 percent) and *fishing gear 1* (14.9 percent). The same plastic waste items were also ranked in the top three in urban areas.**

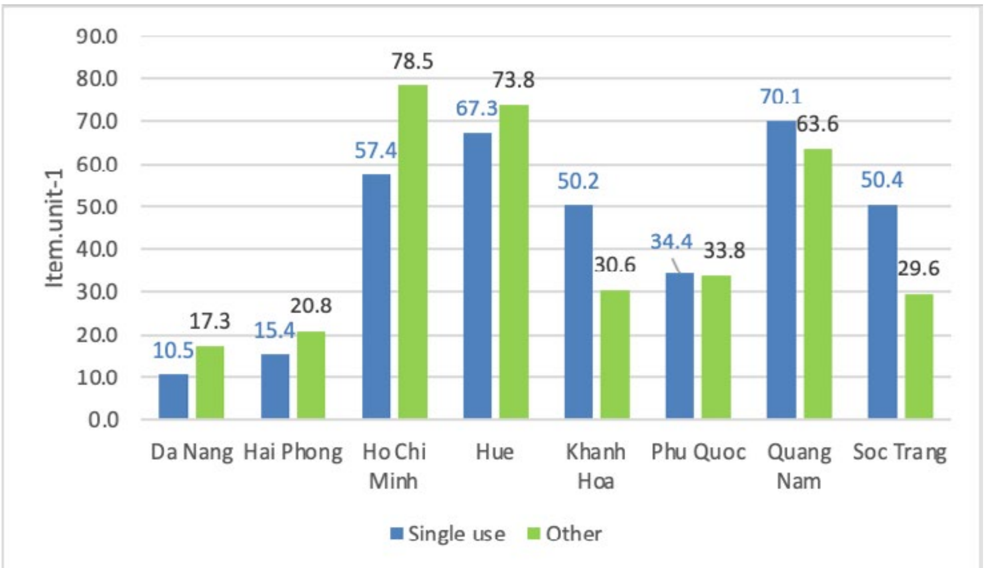
### Top 10 Plastic Waste Items in Coastal Sites—Tourist versus Non-tourist Areas

- **The top 10 plastic waste items accounted for 87 percent in non-tourist sites, and 85 percent in tourist sites.** Similar plastic waste items were found in the top 10 in both areas, but the percentages differed.
- **In non-tourist areas, *soft plastic fragments* were the most frequently found (31 percent), and accounted for 42.8 percent when combined with *plastic bags size 1*.** The next most abundant types of plastic waste were *fishing gear 1* and *fishing gear 2*, which together accounted for around 30 percent.
- **In tourist areas, fishing gear was even more prevalent.** *Fishing gear 1* (18.4 percent) and *fishing gear 2* (16.2 percent), together, accounted for 34.6 percent.
- **In tourist areas, a higher number of *straws* were found (6.7 percent) than in non-tourist areas (2.4 percent).** *Styrofoam food containers* presented a similar picture: in non-tourist areas, the standing stock was only 2.9 percent, compared to 9.6 percent in tourist areas.

### Single-use Plastics

**At coastal sites, plastic waste was often single-use, accounting for 52 percent of total plastic waste in number.** As shown in Figure 23, single-use plastic items made up between 38 percent and 63 percent of total plastic waste. Some tourist destinations such as Soc Trang (63 percent), Khanh Hoa (62 percent), Quang Nam (52 percent), and Phu Quoc (50 percent) had higher percentages than other coastal sites.

Figure 23:
**SINGLE-USE PLASTIC WASTE DENSITY AT COASTAL SITES IN SURVEYED LOCATIONS**




### Clean-Coast Index (CCI)

Of the 14 coastal sites, 10 sites (71.4 percent) were extremely dirty (with a CCI higher than 20 percent), two sites were dirty (14.3 percent), and two sites had a moderate pollution level (14.3 percent).

Table 6:
**CLEAN-COAST INDEX FOR SURVEYED COASTAL SITES**

| | Survey sites | Surveyed area ($m^2$) | Density | CCI | |
|---|---|---|---|---|---|
| | Hai Phong | | | | |
| 1 | Do Son | 4,220 | 0.46 | 9.28 | Moderate |
| 2 | Got Ferry | 1,440 | 3.67 | 73.41 | Extremely Dirty |
| | Hue | | | | |
| 3 | Thuan An | 4,000 | 3.53 | 70.6 | Extremely Dirty |
| | Da Nang | | | | |
| 4 | Dong | 1,835 | 0.64 | 12.80 | Dirty |
| 5 | Nam O | 1,850 | 2.38 | 47.56 | Extremely Dirty |
| | Quang Nam | | | | |
| 6 | Rang | 5,000 | 2.67 | 53.44 | Extremely Dirty |
| | Nha Trang | | | | |
| 7 | Vinh Nguyen | 1,000 | 1.65 | 33.12 | Extremely Dirty |
| 8 | Binh Lap | 880 | 18.9 | 379.8 | Extremely Dirty |
| 9 | My Ca | 1060 | 9.6 | 192.1 | Extremely Dirty |
| | Ho Chi Minh City | | | | |
| 10 | April 30 | 17,150 | 0.79 | 15.81 | Dirty |
| | Soc Trang | | | | |
| 11 | Ho Be | 3,025 | 0.39 | 7.80 | Moderate |
| 12 | Lai Hoa | 1,675 | 8.84 | 176.95 | Extremely Dirty |
| | Phu Quoc | | | | |
| 13 | Truong | 1,187.6 | 8.18 | 163.69 | Extremely Dirty |
| 14 | Sao | 3,072.6 | 1.28 | 25.62 | Extremely Dirty |

A more detailed presentation of survey results from coastal sites can be found in Annex 2.1.D.

### 2.1.4. Highlights and Discussion

#### Highlights

**In total, 38 sites in 10 locations across Vietnam were surveyed between October 2020 and January 2021,** and 24,461 items and 164 kg of waste were collected and classified.

**For the river and coastal sites, the surveys assessed the overall density of waste as a measure of cleanliness.** For the river sites, the average density of waste at sites along the Dong Nai River (33 items/unit), Red River (24 items/unit), and Mekong River (22 items/unit) was considerably higher than along the Central rivers (9 items/unit) and Phu Quoc rivers (9 items/unit). For coastal sites, the Clean Coast Index (CCI) was calculated. For 14 coastal sites in eight locations, the CCI calculations showed that 10 sites (71.4 percent of all coastal sites) were *extremely dirty* (with a CCI higher than 20); two sites were *dirty* (14.3 percent of all coastal sites); and two sites were *moderate* (14.3 percent of all coastal sites).

**For all surveyed sites, plastic waste items accounted for 93.6 percent in number (70.7 percent in weight).** At river sites, plastics accounted for 79.6 percent in number (57.2 percent in weight), and at coastal sites, plastics accounted for 95.4 percent in number (73.3 percent in weight).

**Take-away related waste, fisheries-related waste, and household waste were the three biggest sources of plastic pollution identified through the surveys.** At river sites, take-away related waste (43.6 percent), fisheries-related waste (32.6 percent), and household waste (21.6 percent) accounted for 97.8 percent of the total number of plastic waste items. At coastal sites, take-away related waste (42.7 percent), fisheries-related waste (35 percent), and household waste (20 percent) made up 97.7 percent of the total number of plastic waste items.

**At all locations, the top 10 plastic waste items accounted for 83.2 percent of the total number of plastic waste items, and 72.7 percent in weight.** With regard to river and coastal sites, the top 10 plastic waste items at river sites accounted for 81.3 percent (55 percent in weight) versus 84 percent at coastal sites (75.5 percent in weight).

**The majority of plastic waste items collected during all the surveys were single-use plastics (SUPs):** at river sites, 72 percent were SUPs; at coastal sites, 52 percent were SUPs.

**Table 7 presents the top 10 plastic waste items by number at river and coastal sites.** At river sites, take-away related plastic waste dominated the list, with *plastic bags size 1* and *soft plastic fragments* (mostly fragmented plastic bags) accounting for 32.7 percent of total combined plastic waste (coastal sites: 25 percent, combined). At coastal sites, *fishing gear 1* and *fishing gear 2* played a larger role, with a combined total of 32.5 percent. *Styrofoam food containers* also need to be highlighted, as they ranked second (11.4 percent) at river sites and fifth (6.8 percent) at coastal sites.

Table 7:
**TOP 10 PLASTIC WASTE ITEMS AT RIVER AND COASTAL SITES, BY NUMBER**

| River Sites | | | Coastal Sites | | |
|---|---|---|---|---|---|
| Rank | Top 10 Items River Sites | % Number | Rank | Top 10 Items Coastal Sites | % Number |
| 1 | Plastic bags size 1 | 21.9% | 1 | Fishing gear 1 | 18.5 |
| 2 | Styrofoam food containers | 11.4% | 2 | Soft plastic fragments | 18.1 |
| 3 | Soft plastic fragments | 10.8% | 3 | Fishing gear 2 | 14.0 |
| 4 | Food wrappers | 8.8% | 4 | Plastic bags size 1 | 7.1 |
| 5 | Crisp/Sweet packages | 5.8% | 5 | Styrofoam food containers | 6.8 |
| 6 | Plastic strings, cords, and ropes | 5.7% | 6 | Hard plastic fragments | 6.4 |
| 7 | Other plastic | 4.7% | 7 | Straws | 4.9 |
| 8 | Hard plastic fragments | 4.6% | 8 | Other plastic | 2.8 |
| 9 | Other wrappers | 4.1% | 9 | Crisp/Sweet packages | 2.8 |
| 10 | Fishing gear 2 | 3.5% | 10 | Food wrappers | 2.6 |

## Lessons Learned

The study provided a number of clear lessons for conducting future surveys, site selection, and engagement with stakeholders and participants.

**Survey Design: Site Selection and Implementation.** The survey design was developed to satisfy diverse objectives (investment inputs, plastics management, and development of alternatives). Locations and sites were pre-determined based on specific criteria such as population level, environmental impact, industry (tourism, fisheries, agriculture, and so on), and geography (specific water catchment areas and coasts). Site selection for future surveys could be improved by gathering more comprehensive information on the locations and sites to be surveyed. Data accuracy could also be improved by conducting surveys in both monsoon seasons.

**Stakeholder interaction: Information Gathering and Fieldwork Authorization.** Undertaking surveys required formal authorization by local authorities. The exercise revealed that it was easier to work with the provinces/ cities that have made environmental management a priority. Therefore, future approaches have to be tailored to the capabilities and commitment levels of local organizations and partners, while also maintaining rigor with the scientific methodologies.

**Volunteer Mobilization and Training.** While local volunteers required training on the field survey methodology, this also served as an effective way to increase local knowledge, capacity, and awareness-raising about plastic waste pollution. To build local capacity for long-term monitoring, the experience showed that it was advisable to recruit volunteers from local universities and work with local Departments of Natural Resources and Environment (DONREs). Recruiting volunteers should begin as early as possible, and as much as possible, communications media should suit the local site. Contact with volunteers, their universities, and the DONREs needs to be maintained after the surveys, including communicating about the survey results, and how the results are being used.

**Data Management.** The project team, partners, and volunteers need to be introduced to the survey design concept, and issues concerning data quality; data analysis techniques; data curation, management, and presentation; and use of the results. Induction activities for local stakeholders should be undertaken as soon as they are engaged, and ways to conduct virtual induction/trainings should be built in, and tested for future surveys.

Photo: Susie Hedberg - Shutterstock

# 2.2 INTEGRATED PLASTICS TRANSPORT RIVER MONITORING AND ANALYSIS

### 2.2.1 Objectives of Integrated Plastics Transport Monitoring and Analysis

Section 2.1 described the findings of the field surveys that were conducted using established methods at various river and coastal sites in Vietnam. This Section 2.2 on integrated plastics transport river monitoring and analysis is based on new survey methods that were piloted in a selected number of locations. The objective of the analysis was, therefore, not only to increase knowledge about plastic waste quantities, types, and leakage locations in Vietnam, but also about the suitability of new methodologies for plastic monitoring in Vietnam.

More specifically, the objectives of the integrated plastics transport monitoring and analysis were to:

1. Deepen knowledge about the different plastic waste types leaking into rivers and the ocean.
2. Increase knowledge about the plastic waste quantities and key locations for plastic waste leakage into waterways.
3. Develop and pilot an integrated plastics transport monitoring concept for rivers.
4. Inform the policies and investment programs intended to reduce marine plastic pollution.

### 2.2.2 Study Area

Plastics transport monitoring was carried out in three locations in Vietnam—**Hai Phong, Lao Cai/Sa Pa,** and **Hai Duong**—with three survey sites in each location. The Vietnam Administration of Sea and Islands (VASI) and the Vietnam Environment Administration (VEA), both of which are under the Ministry of Natural Resources and Environment (MONRE); the World Bank; and other relevant stakeholders mutually agreed on the survey locations and sites, and on the criteria set out in Table 8.

**The study locations needed to meet a diverse set of criteria.** These ranged from the relevance of the location (population level, and the environmental and economic impact of plastic pollution) to the enabling conditions such as existing plastic reduction policies and local political interest and commitment to take action to reduce plastic pollution. Study sites also needed to satisfy technical and practical requirements such as the availability of bridges or other structures to allow the installation of monitoring equipment.

Table 8:
**LOCATION AND SITE SELECTION CRITERIA AND INFORMATION ON SELECTED STUDY LOCATIONS**

| | | 1 | 2 | 3 |
|---|---|---|---|---|
| | **Criteria** | **Hai Phong City** | **Lao Cai/Sapa** | **Hai Duong Province** |
| Population level | **People impacted from good/bad waste management, including plastic pollution (city's population number)** | 2 million people | Lao Cai city—25% of province's population (173,840) | About 2 million people |
| Environmental impact | **Near river/coast, urban and upstream, impacting ocean plastic pollution** | Urban, coastal, river location | Urban, river upstream | Urban, river location |
| | **Waste treatment facilities** | 6–8 treatment facilities (one new); landfills | One treatment facility; landfills | Two treatment facilities; landfills |
| | **Waste collection rate** | 90% | 85% | 80–85% |
| | **Critical ecosystem protection proximity** | Biosphere Reserve (Cat Ba Island) | Hoàng Liên National Park | x |
| | **Potential for blocking waterways, causing flooding, and associated negative health impacts** | High impact potential | High impact potential | High impact potential |
| Economic impact | **Tourism's share of local economy/tourism development prioritized (21 national tourism cities/areas)** | Significant tourism, including adjacent Cat Ba Island | Significant rural and community tourism | High priority heritage tourism site |
| | **Potential impact on revenue from fisheries and aquaculture** | Medium fisheries and coastal aquaculture impact | Low fisheries and aquaculture impacts | Low fisheries and aquaculture impacts |

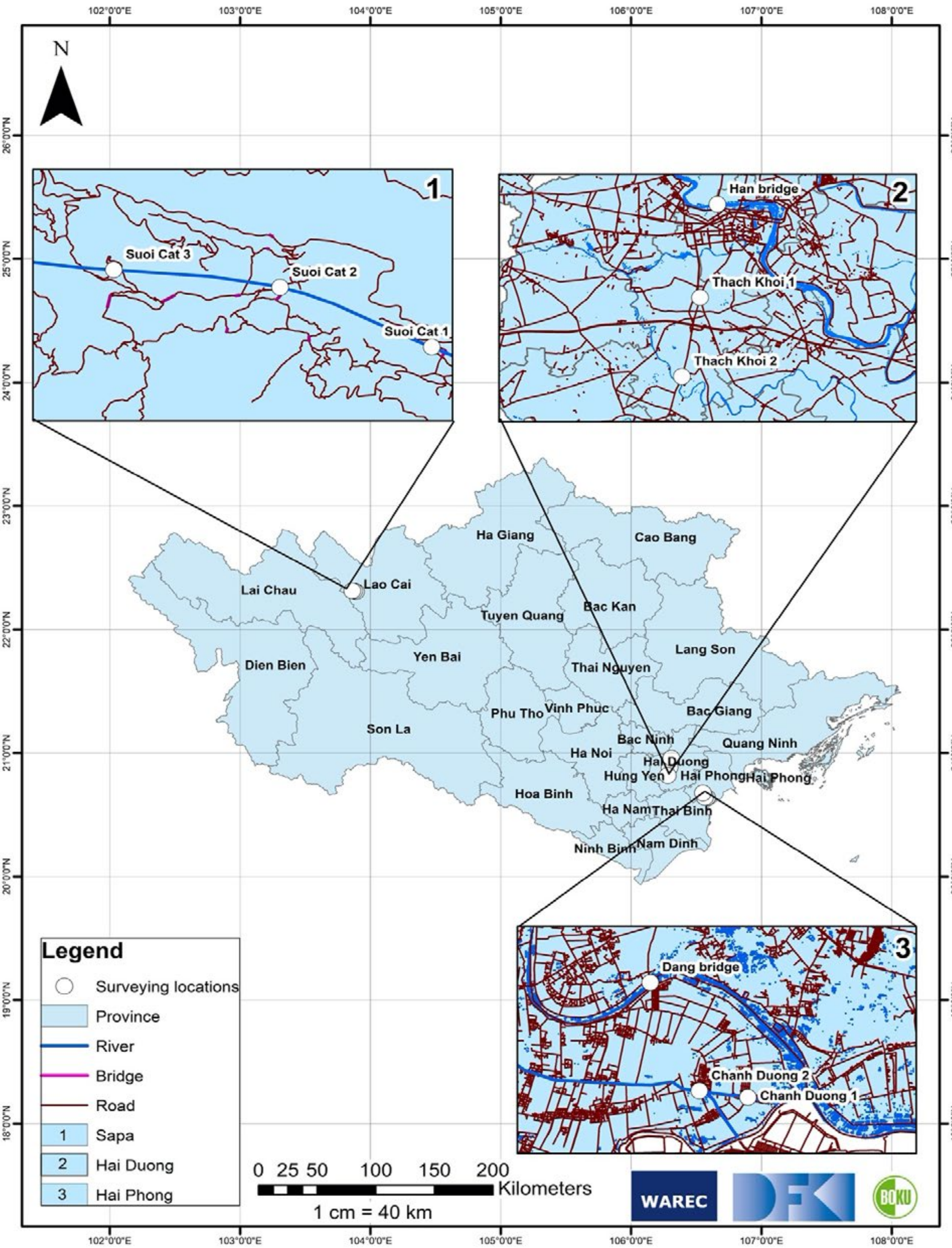
| | | 1 | 2 | 3 |
|---|---|---|---|---|
| | **Criteria** | **Hai Phong City** | **Lao Cai/Sapa** | **Hai Duong Province** |
| Choosing study river | **Selected rivers are within the vicinity of provinces (cities) of interest, or most (≥ 70%) of the river length is within a province (city);** | Chanh Duong tributary river | Cat stream (Sapa town/Cat Cat village) | Thach Khoi – Doan Thuong tributary river |
| | **River with low to medium flow velocity** | Flow velocity ranges from 0.5–1.5m/s | Flow velocity ranges from 0.5–1.5m/s | Flow velocity ranges from 0.5–1.5m/s |
| | **River should have light vessel traffic** | Mainly people living along the river in small boats | x | x |
| | **Availability of bridges or structures (syphon, water pipes etc.) along the river or accessible via road to the river's banks** | There are 5 locations where waste monitoring equipment can be installed | There are 3 locations where waste monitoring equipment can be installed | There are 3 locations where waste monitoring equipment can be installed |
| Law formulation & enforcement | **Plastic reduction action plan & implementation** | Plan for plastic reduction | Plan for plastic reduction | Plan for plastic reduction |
| | **Data available** | Low | High | Low |
| | **Law enforcement** | Medium | Medium | Medium |
| Political commitment | **Local government support** | Government interest: High | Government interest: High | Government interest: High |
| | **Local funding sources available** | Low | Information not yet available | Medium |

Table 9 provides an overview of all survey sites' coordinates, and Figure 24 shows survey sites on a map.

Table 9:
**SURVEY SITES' COORDINATES**

| ID | Survey Site | Location | Coordinates | |
|---|---|---|---|---|
| | | | Latitude | Longitude |
| 1 | Chanh Duong 1 | Vinh Bao - Hai Phong | 20.639106 | 106.582464 |
| 2 | Chanh Duong 2 | Vinh Bao - Hai Phong | 20.641278 | 106.566986 |
| 3 | Dang bridge | Tien Lang - Hai Phong | 20.677672 | 106.551364 |
| 4 | Thach Khoi 1 | Hai Duong | 20.882731 | 106.296247 |
| 5 | Thach Khoi 2 | Hai Duong | 20.818602 | 106.282264 |
| 6 | Han bridge | Hai Duong | 20.958615 | 106.309602 |
| 7 | Suoi Cat 1 | Sa Pa - Lao Cai | 22.3052 | 103.889653 |
| 8 | Suoi Cat 2 | Sa Pa - Lao Cai | 22.309917 | 103.875822 |
| 9 | Suoi Cat 3 | Sa Pa - Lao Cai | 22.310181 | 103.86015 |

Figure 24:
**MAP OF SURVEY LOCATIONS AND SURVEY SITES**



Data were analyzed for only a selection of sites (see Table 10). The COVID-19 pandemic resulted in a delayed start for the surveys with drones and bridge cameras, and prevented the survey team from travelling to Vietnam, and from remediating data collection issues that occurred on site (i.e. the damaging of sensors due to high humidity, and the low speed of data transfer for the data-volume-intensive river monitoring time-lapse imagery). Similarly, due to COVID-19, international experts were not able to conduct the net trawl surveys in person. In addition, detailed site assessments showed that most of the selected survey sites were not suitable for net trawl surveys due to low water levels, high bridges, the presence of rocks in the river, and river traffic. However, given the pandemic's restrictions and the fact that the bridge camera surveys and net trawl surveys were conducted as pilots, conducting of the surveys in all three targeted locations (Hai Phong, Hai Duong, and Sa Pa) provided a useful basis for assessing their feasibility as tools for monitoring plastic waste.

Table 10:
**DATA ANALYSIS CARRIED OUT BY SURVEY SITE**

| ID | Survey Site | Location | Results available for this study | | | |
|---|---|---|---|---|---|---|
| | | | Waste Quantities (drone surveys) | Waste Types (drone surveys) | Transport (bridge cameras) | Waste Types (net sampling) |
| 1 | Chanh Duong 1 | Vinh Bao - Hai Phong | Y | Y | Y | |
| 2 | Chanh Duong 2 | Vinh Bao - Hai Phong | Y | Y | Y* | Y |
| 3 | Dang bridge | Tien Lang - Hai Phong | | | Y | |
| 4 | Thach Khoi 1 | Hai Duong | Y | Y | | |
| 5 | Thach Khoi 2 | Hai Duong | | | Y | |
| 6 | Han bridge | Hai Duong | | | | |
| 7 | Suoi Cat 1 | Sa Pa - Lao Cai | Y | Y | | |
| 8 | Suoi Cat 2 | Sa Pa - Lao Cai | | | Y | |
| 9 | Suoi Cat 3 | Sa Pa - Lao Cai | | | | |

*Note: * At Chang Duong 2, two bridge camera surveys were conducted.*

## 2.2.3 Key Methodologies and Limitations

**In order to understand the different plastic waste types and quantities that leak into waterways, the assessment looked at plastics that are located on the water's surface but also plastics submerged in the water column.** Thus, the project used two complementary approaches to analyze the different plastic types with respect to their location either on the surface, or in the water column.

**With respect to surface plastics, a plastic analytics system based on machine learning technology called APLASTIC-Q was developed.** APLASTIC-Q took images as input data and was deployed to i) detect plastic pollution and estimate a given area's waste volume, ii) identify what type of plastics were present in the polluted area, and iii) quantify the different plastic types in a polluted area.

**With respect to plastic debris in the water column, the transport of plastics at various vertical positions over a cross-section, and over the whole water column were measured.** The direct measurements in the water column also allowed for validation of the data obtained through the automated measurements taken by the camera. Thus, the amount of plastic detected by the camera in a certain area could be related to the overall profile, and a plastic yield for a given timeframe could be estimated.

Results from analyzing both approaches were combined to determine i) the number of items per plastic waste type, the total, and per survey location; ii) identification of the top 10 plastic items and their relative abundance; iii) the percentages of top 10 identified items in relation to the total identified plastic waste; and iv) an estimated yearly yield of plastics transport at the measurement site.

**The following section provides a brief summary of the key methodologies that were applied to collect, process, and analyze the data.**

### 2.2.3.1 Data Collection and Field Work

**For each survey site, data collection relied on a combination of desk research and field work:**

**Desk research** provided information on the river network, hydrological data (for example, the flow rate, discharge, and water quality), and topographical data such as cross sections and water infrastructure.

**Data collection in the field** utilized i) cameras that were installed at several cross sections along a given river to record floating plastics, ii) unmanned aerial vehicles (UAVs) to capture floating and deposited plastics along the river and riverbanks, and iii) net sampling devices to capture plastic waste in the water column and measure water flow rates and currents (see Figure 25).

Figure 25:
**DATA COLLECTION DEVICES UTILIZED IN THE FIELD WORK**

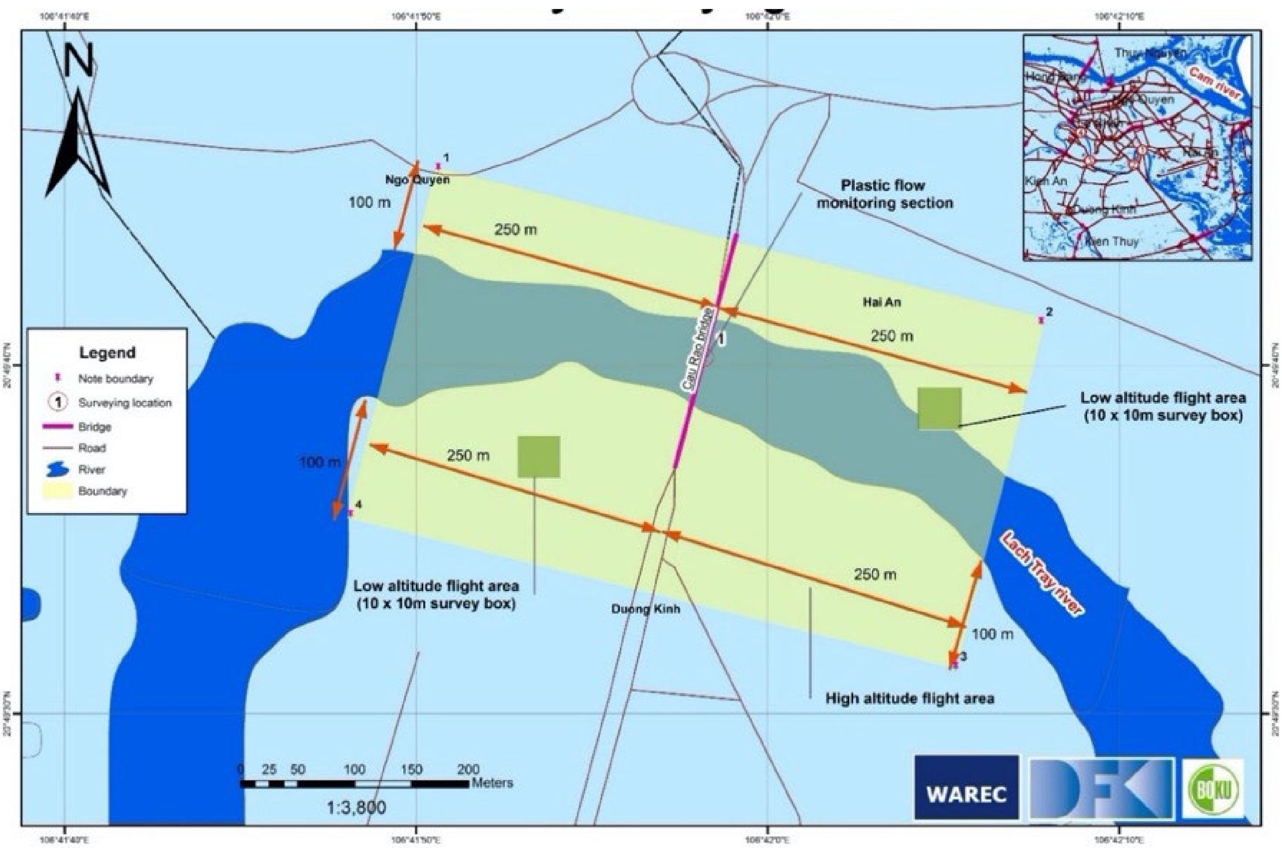
Figure 26 illustrates a typical survey protocol at a given river site:

**Two to three GoPro cameras were installed per bridge.** The number of installed devices depended on the width of the observed river.

**Net sampling was conducted at one survey site as a pilot (see Table 10 and Section 2.2.4.3).** Based on previous experience gained from measurements on the Danube River, a measuring device for macro plastic measurements was constructed. The objective was to construct a simple device that could be replicated as easily as possible anywhere in the world, and which could be used for sampling plastics transport in different river systems. For this purpose, with a view to optimize the sampling of macro plastics, the equipment carrier of the existing model was adapted, as well as the mesh and frame-sizes. The sampling was done in three vertical columns that corresponded with the camera locations on the bridge. Each net was exposed in the water for 120 minutes before its contents were collected, identified, and counted.

**The UAV took two sets of images: one high spatial resolution image captured at a high flight altitude of 60–100 meters to detect pollution hotspots; and very high spatial resolution images captured at a low flight altitude of 3–6 meters to analyze plastic pollution hotspots.** The area covered by the high-altitude flights comprised a distance of around 250 meters, upstream and downstream of the survey site. The upper and lower edges of the survey sites were fixed at 100 meters from the riverbanks or up to the river dike. The area covered by each low-altitude flight was approximately 10x10 meters, comprising areas where plastic waste had accumulated. Depending on the local features of a site, a number of low altitude flights were taken to ensure good representation of the plastic pollution.

Figure 26:
**EXAMPLE OF A TYPICAL SURVEY PROTOCOL**




*Note: The map shows Cau Rao Bridge in Hai Phong as an example of a typical survey protocol. No survey was undertaken at this site.*

Further information on data collection is presented in Annex 2.2.C, including drone survey positions and camera placement at survey sites, measured flow velocity and water flow, and the amount of data collected per site.

#### 2.2.3.2 Plastic Detection and Quantification

**The imagery produced through data collection was analyzed regarding (i) the abundance of quantities of waste, along with area and waste volume assessments; and (ii) the number of items per waste type, and the relative abundance of the top 10 identified plastic items.** The set of high-altitude overview imagery was used to identify plastic pollution hotspots and visually contextualize the study sites. The set of low-altitude, very high-resolution images for monitoring waste hotspots was analyzed regarding the statistics mentioned above in (i) and (ii). The images from the cameras installed on bridges were also analyzed with respect to these litter statistics.

The data analysis method is based on computer vision and machine learning algorithms (for more detail, see and Wolf et al. 2020). The method was developed for a World Bank-funded plastic diagnostics study in Cambodia in 2019, and further improved for this study.

#### 2.2.3.3 Plastic Flow Calculations and Modelling

**Plastic flow calculations and modelling utilized the imagery from the cameras installed on bridges, and the data obtained from the net sampling surveys.** The cameras installed on bridges at given study sites monitored the water flow (in cubic meters per second) and flow velocity (in meters per second). The analysis of these data allowed assessment of the plastic waste floating by a bridge, and from this, waste volumes could be deduced. Analysis of the net sampling surveys enabled determination of the transport of plastics under water, and the calibration of measurements by means of a camera, or to relate them to total transport.

#### 2.2.3.4 Limitations

**The variation between samples:** The focus of the surveys was on establishing sound knowledge on types of plastic waste, which could be achieved by sampling in rather short period of times in multiple locations. Results from World Bank studies in other countries (as well as other available global studies) show that while between different locations and times the ranking of plastic items can vary, the Top 10 items typically remain the same over different locations and times. Most of the methodologies (field surveys, drone surveys, trawl sampling) were thus focused on gaining a thorough understanding of priority plastic types, which was key for developing suitable policies and measures in addressing plastics pollution. Remote-sensing bridge surveys have shown promising results in quantification of plastics pollution over longer periods of time, however long-term studies over different seasons would be required to gain a thorough understanding and establishment of baselines.

**The size of the particles detected:** Available information from the region shows that typically, microplastics are a result of defragmentation of larger plastic items, thus targeting macro-plastics would also have significant impacts on microplastics. Targeting macro items also has generally higher feasibility in terms of short-term policy measures with low capacities and higher support amongst stakeholders and citizens. Impacts e.g. on reduced flooding, reduced waste amounts and related costs in collection, reduced open burning, and increased tourism value in tourism destinations are also generally higher with macro plastics. Specifically reducing micro-plastics in the environment may large require investments in appropriate technologies at water and wastewater treatment plants (World Bank surveys in the Philippines have shown that Manila wastewater treatment plants currently reduce microplastics in the range of 50-80%). Within the range of macro-items, the surveys carried out based on described technologies are a representative sample of plastic types leaking into the environment. This is particularly the case for field surveys as well as trawl surveys which capture the entire range of macro items. Drone surveys with applied technologies have limitations below ~5cm of items size (more costly equipment can improve this), while the piloted bridge surveys were more successful in quantification of plastics in general.

### 2.2.4 Results

The survey results gave an overview of the:

- waste quantities detected (that is how much waste was found at a pollution hotspot at a specific site?);
- proportion of waste types (that is what was the percentage of detected waste types?); and
- waste transport (that is how many plastic items passed by the survey point during the survey day?).

Depending on the data presented, the results were shown as combined results, results by location, and results by survey site.

### 2.2.4.1 Results of the Drone Surveys

#### Waste Quantities

The high-altitude imagery enabled analysis of a total of nine pollution hotspots across four survey sites with low altitude high-resolution imagery.

**The two most polluted hotspots were the Thach Khoi 1 site, Hai Duong, which had large accumulations of plastic waste in the tributary.** Over 5,000 waste items were found in two pollution hotspots with an estimated combined covered waste area of 45m².

**The tributary sites in Hai Phong and Sapa both contained rather low amounts of plastic waste.** In the five assessed pollution hotspots of Hai Phong, the drone monitoring detected and assessed around 700 items. Based on data analysis carried out to correct the original estimate, the actual number of items was estimated to be closer to 330 items for the Hai Phong pollution hotspots.[12] Given this rather low number, the drone monitoring covered an estimated a waste area of around 3m² for the Hai Phong pollution hotspots. The assessed waste area for the Suoi Cat survey sites (corrected) was also rather low for both hotspots, with an accumulation of just over 400 waste items (Table 11).

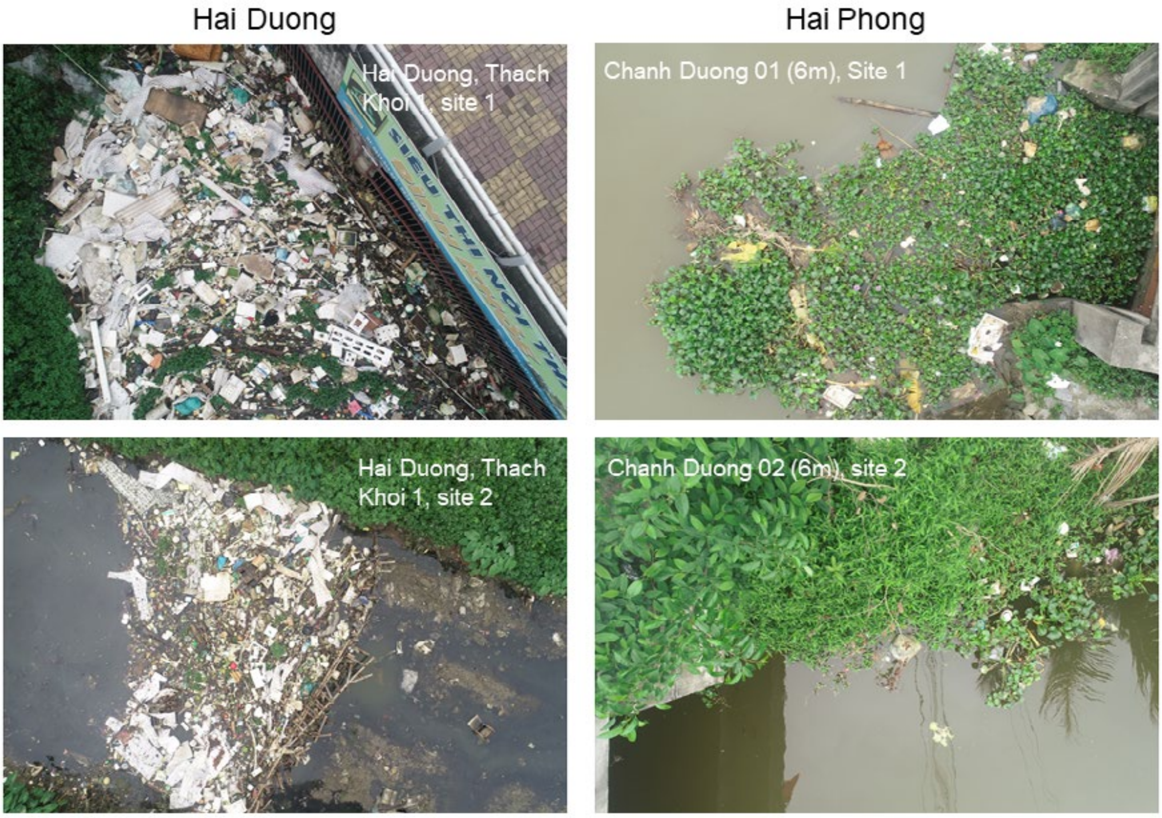
The significantly different pollution levels at the investigated hotspots were due to the types of obstacles immobilizing waste items (plastics washed ashore, trapped in vegetation, or accumulated in front of dams or other obstacles). The large variation reflected the waste situation on site for waste that was temporarily immobilized (mostly plastic waste). Figure 27 shows strongly polluted hotspots in Hai Duong (large waste accumulations), and the sites of Hai Phong (mostly plastic waste trapped in vegetation).

12 The correction was made through the classification of waste areas with two different algorithms; first, by the waste detection machine learning algorithm (PLD), and second, by the waste type classification algorithm (PLQ). The corrected results are expected to give more accurate waste assessments in site types with fewer waste items, as the effect of false positives is relatively higher in these sites, compared with heavily polluted sites; and these false positives will be reduced through the correction.

Table 11:
**WASTE QUANTITIES, AREAS, AND VOLUMES FOR POLLUTION HOTSPOTS AT THACH KHOI 1, CHANH DUNONG 1 & 2, AND SUOI CAT 1**

| Pollution hotspots | Assessed waste items | Waste area m2 | Volume area m3 | Corrected waste item numbers for sites with little pollution |
|---|---|---|---|---|
| Hai Duong, Thach Khoi 1, site 1 | 2,986 | 25 | 6 | |
| Hai Duong, Thach Khoi 1, site 2 | 2,521 | 20 | 5 | |
| Hai Phong, Chanh Duong 01, Site 1 | 192 | 1 | 0 | 101.5 |
| Hai Phong, Chanh Duong 01, Site 2 | 66 | 0 | 0 | 39.4 |
| Hai Phong, Chanh Duong 01, Site 3 | 103 | 0 | 0 | 60 |
| Hai Phong, Chanh Duong 02, site 1 | 214 | 1 | 0 | 82.4 |
| Hai Phong, Chanh Duong 02, site 2 | 163 | 1 | 0 | 51.5 |
| Suoi Cat 01_1 | 857 | 1 | 0 | 296 |
| Suoi Cat 01_2 | 378 | 0 | 0 | 116 |

Figure 27:
**PICTURES OF POLLUTION HOTSPOTS IN HAI DUONG AND HAI PHONG**




## Waste Types

Across all survey locations, from the highest to the lowest, the following items were identified as the most abundant:

1. Polystyrene, including food containers (40 percent)
2. Cup lids, caps, and small plastics (19 percent)
3. Other non-plastic waste (13 percent)
4. LDPE bags (6 percent)
5. Wrappers (6 percent)
6. PET bottles (6 percent)

**The most common waste type across all the locations, combined, was *polystyrene* (40 percent).** Polystyrene was detected over 1,800 times. This waste type included Styrofoam food packaging and larger Styrofoam or expanded polystyrene (EPS) foam objects. The drone analysis found that 93 percent of polystyrene objects were rather small, which implies that food packaging is a very common waste type.

**The second most occurring waste type across all locations, combined, was *cup lids,* caps, and *small plastics* (19 percent).** This comprised small waste items and plastic pieces, which, as a result of weathering, degrade into smaller waste items. The third most commonly occurring waste type was other non-plastic waste (13 percent). The five other waste types depicted in Figure 28 (graph D) made up 5 to 6 percent, respectively, in all the surveyed locations, combined, with at least 200 items for each type.

Given that the two hotspots in Thach Khoi 1 (Hai Duong) had the highest quantity of waste items, the combined data is skewed toward Hai Duong. Therefore, the results in Figure 28 show each location.

**In the two assessed hotspots of Hai Duong, the most common plastic type was polystyrene (43 percent).** The second most common type in these locations was *cup lids, caps,* and *small plastics* (21 percent), followed by *other non-plastics* (12 percent), **plastic wrappers** (7 percent), and *PET bottles* and *robust plastic bags* (5 percent for both).

**In the five Hai Phong pollution hotspots, the most common plastic type was also *polystyrene* (30 percent).** The second most common type was *LDPE bags* (26 percent), followed by *other non-plastics* (20 percent), *PET plastic bottles* (7 percent), and *robust plastic bags* (5 percent).

In the two Sapa pollution hotspots, the most common waste type was other non-plastic waste (19 percent), closely followed by polystyrene (18 percent). The third most common waste types were *LDPE bags* (17 percent), and *cup lids, caps* and s*mall plasti*cs (17 percent). The fourth most common waste type was PET *plastic bottles* (11 percent), followed by *robust plastic bags (*7 percent).

An investigation of the reasons for variations in waste composition at the different locations was outside the survey's scope. However, anecdotal evidence suggests that the variations were due to a mix of domestic waste littering, and economic activities in the survey areas, or upstream from the survey areas. Investigating the relationship between local littering behavior, waste management practices, and waste compositions should be seen as an opportunity to refine future diagnostics.

In addition to Figure 28, detailed proportional waste type assessments for each location are shown in Table 12. For detailed proportional waste type assessments by survey site and pollution hotspot, see Annex 2.2.D.

Figure 28:
**PROPORTIONS OF WASTE TYPES IN HAI DUONG, SAPA, AND HAI PHONG, AND THE NUMBER OF ITEMS BY WASTE TYPE, COMBINED, IN ALL SURVEYED CITIES**

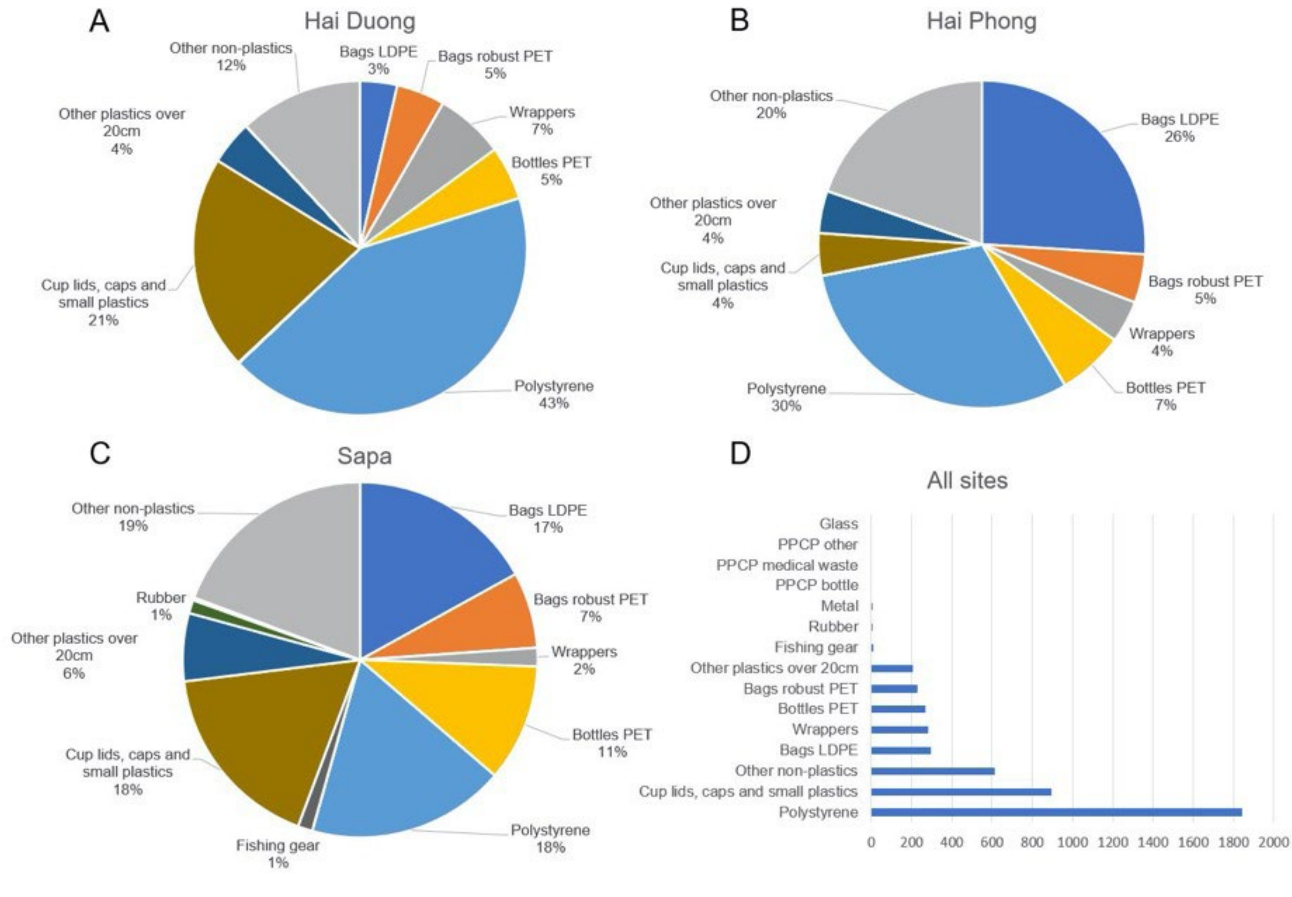


Table 12:
**DETAILED PROPORTIONAL WASTE TYPES, TOTALS, AND LOCATIONS**

| Waste types | All sites | Hai Duong | Hai Phong | Sapa |
|---|---|---|---|---|
| Polystyrene | 40% | 43% | 30% | 18% |
| Cup lids, caps, and small plastics | 19% | 21% | 4% | 17% |
| Other non-plastics | 13% | 12% | 20% | 19% |
| LDPE bags | 6% | 4% | 26% | 17% |
| Wrappers | 6% | 7% | 4% | 2% |
| PET bottles | 6% | 5% | 7% | 11% |
| Robust PET bags | 5% | 5% | 5% | 7% |
| Other plastics over 20cm | 4% | 4% | 4% | 6% |
| PPCP bottles | 0% | 0% | 0% | 0% |
| PPCP medical waste | 0% | 0% | 0% | 0% |
| PPCP other | 0% | 0% | 0% | 0% |
| Fishing gear | 0% | 0% | 0% | 1% |
| Rubber | 0% | 0% | 0% | 1% |
| Metal | 0% | 0% | 0% | 0% |
| Glass | 0% | 0% | 0% | 0% |

### 2.2.4.2 River Bridge Monitoring Surveys

**To record floating plastics, river monitoring surveys with cameras were carried out at several cross sections along the designated rivers in Hai Duong, Hai Phong, and Sapa. These surveys were carried out in tributaries, canals, and main rivers. Cameras were mounted on bridges to take images at defined time intervals for automated analysis. At the Chanh Duong bridges (Chanh Duong 1 & 2) over a canal in Hai Phong, the highest plastic waste transport (600 waste items per survey day) was observed.** The lowest plastic waste transport was observed on the main river in Hai Phong (140 plastic waste items per survey day).

**In Hai Duong,** river monitoring was carried out at the Thach Koi 1 site. The amounts identifed in the assessments ranged from 41 to 135 objects, with a total of 236 waste items per survey day. The plastic waste transport on the day of the survey was ~40 percent of that in the Hai Phong tributary, which transports large amounts of plastic waste.

**In Hai Phong,** river monitoring was carried out at the Chanh Duong 1 and 2, and Dang bridges. The tributary flowing below the two bridges, Chanh Duong 01 and Chanh Duong 02, is around 20 meters wide, whereas the river under the Dang bridge is around 100 meters wide. Some of the imagery analyzed for the Chanh Duong 01 and Chanh Duong 02 sites was compromised, and could not be used. Extrapolating data from the sucessful measurements, an estimated 600 waste items were detected for this tributary on the survey day.

**In Sapa,** analysis of the time-lapse imagery for the camera at the Suoi Cat 2 site identied a high number of objects (360) floating by on the survey day. Substantial waste transport of more than 10 waste items/half hour was estimated for long periods of the survey day.

Table 13 shows the plastics river monitoring results for the five sites across three locations.

Table 13:
**PLASTICS RIVER MONITORING RESULTS FOR HAI DUONG, HAI PHONG, AND SAPA**

| | Hai Duong, Thach Koi 2 | Hai Phong, Chanh Duong 01[1] | Hai Phong, Chanh Duong 02[2] | Hai Phong, Dang bridge | Sapa, Suoi Cat 2 (Cau Lao Chai) |
|---|---|---|---|---|---|
| 0h - 0.5h | 12 | 10 | 35 | 9 | 22 |
| 0.5h - 1h | 22 | 15 | 36 | 7 | 31 |
| 1h - 1.5h | 11 | 14 | 28 | 10 | 41 |
| 1.5h - 2h | 10 | 36 | 21 | 9 | 15 |
| 2h - 2.5h | 2 | 40 | 37 | 10 | 7 |
| 2.5h - 3h | 3 | 10 | 51 | 7 | 16 |
| 3h - 3.5h | 10 | 5 | 23 | 9 | 11 |
| 3.5h - 4h | 9 | 8 | 34 | 5 | 41 |
| 4h - 4.5h | 21 | 4 | 28 | 6 | 25 |
| 4.5h - 5h | 27 | 14 | 21 | 11 | 44 |
| 5h - 5.5h | 26 | 9 | 24 | 3 | 36 |
| 5.5h - 6h | 24 | 17 | 42 | 8 | 29 |
| 6h - 6.5h | 10 | 31 | 32 | 3 | 20 |
| 6.5h - 7h | 11 | 16 | 24 | 8 | 9 |
| 7h - 7.5h | 16 | 3 | 19 | 12 | 8 |
| 7.5h - 8h | 7 | 29 | 8 | 15 | 4 |
| 8h - 8.5h | 15 | 25 | 2 | 8 | 1 |
| 8.5h - 9h | 0 | | | | |
| SUM | 236 | 286 (600) | 465 (600) | 140 | 360 |

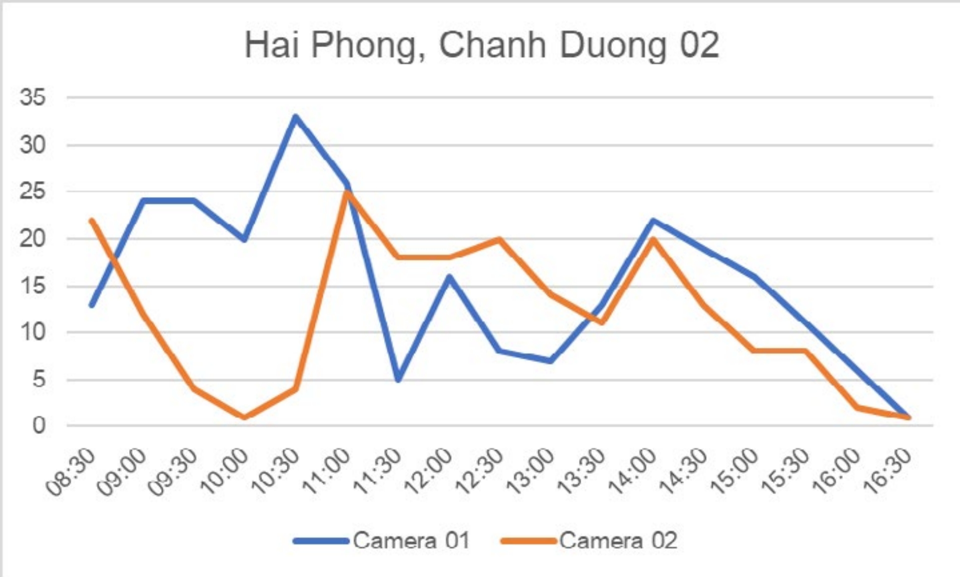
*Note: The survey day at Thach Koi 2 lasted 9 hours, while the survey days at other sites lasted 8.5 hours.*

*Since surveys at the different sites did not start at the same time of day, a comparison of sites at specific times of day should not be made.*

*[1] At this site, only one of the three cameras provided reliable data; the estimated number of waste items for this tributary on the survey day was 600 (shown by the sum in brackets).*

*[2] At this site, only two of the three cameras provided reliable data; the estimated number of waste items for this tributary on the survey day was 600 (shown by the sum in brackets).*

Figure 29:
**WASTE TRANSPORT OVER THE COURSE OF THE DAY FOR HAI PHONG, CHANH DUONG 02 BRIDGE**




### 2.2.4.3 Net Sampling Results

**Net sampling via mobile nets at several depths was used to determine plastics transport in a cross section.** Thus, all particle sizes (even small objects) could be collected, and the plastic concentration could be determined in connection with flow velocity measurements. With several recurring measurements, an annual load could be estimated. Net sampling also allowed calibration of the automated camera-based analyses.

**Net sampling results included data on i) flow velocity (see Annex 2.2.E), ii) quantity and weight of waste types, and iii) waste transport.**

**The total amount of collected waste was 121 pieces, of which *packages and other wrappers* accounted for the most (41.32 percent and 50 pieces).** *Plastic bags* ranked second (30.58 percent), followed by *other plastic* (18.18 percent), *single-use plastic products* (3.31 percent), *bottle caps* (2.48 percent), and straws (1.65 percent). Classification by weight gave a different result, with organic waste ranked first (58 percent).

Organic waste could not be counted by quantity because it was in the process of decomposition and contained too many small-sized items.

Figure 30:
**WASTE CLASSIFICATION BY QUANTITY FROM NET SAMPLING AT CHANH DUONG 2**

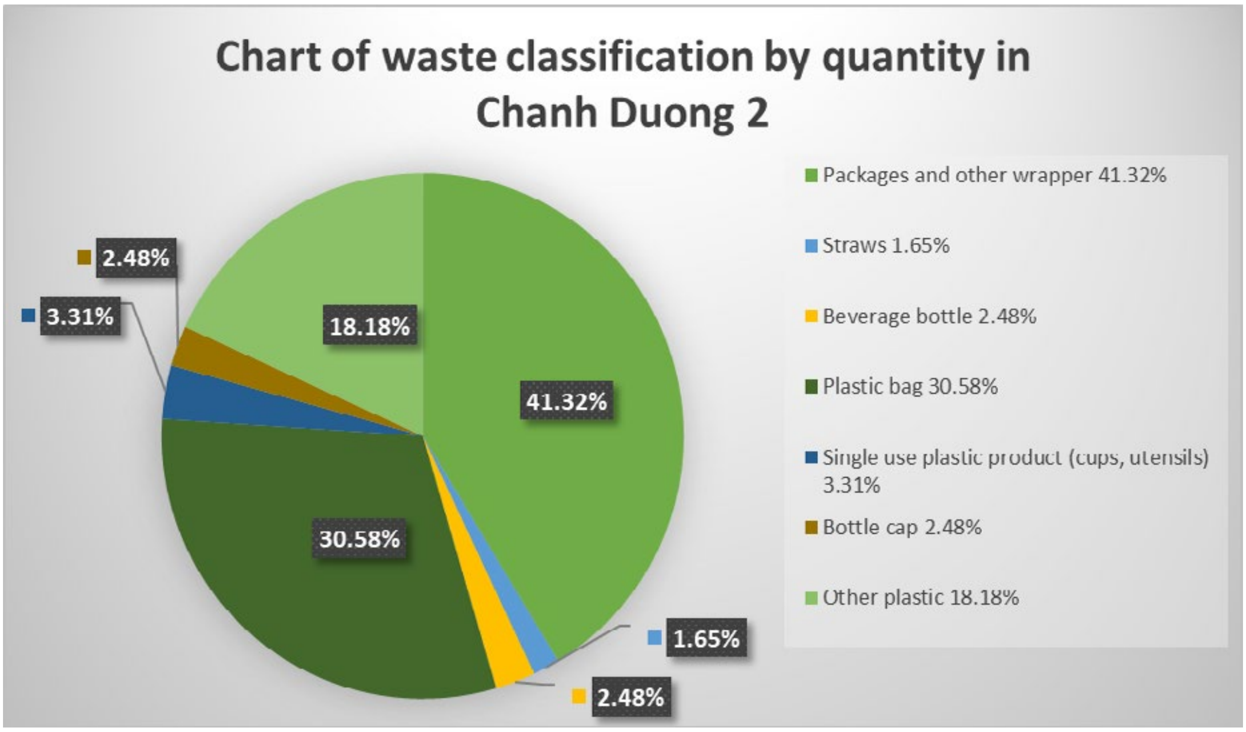
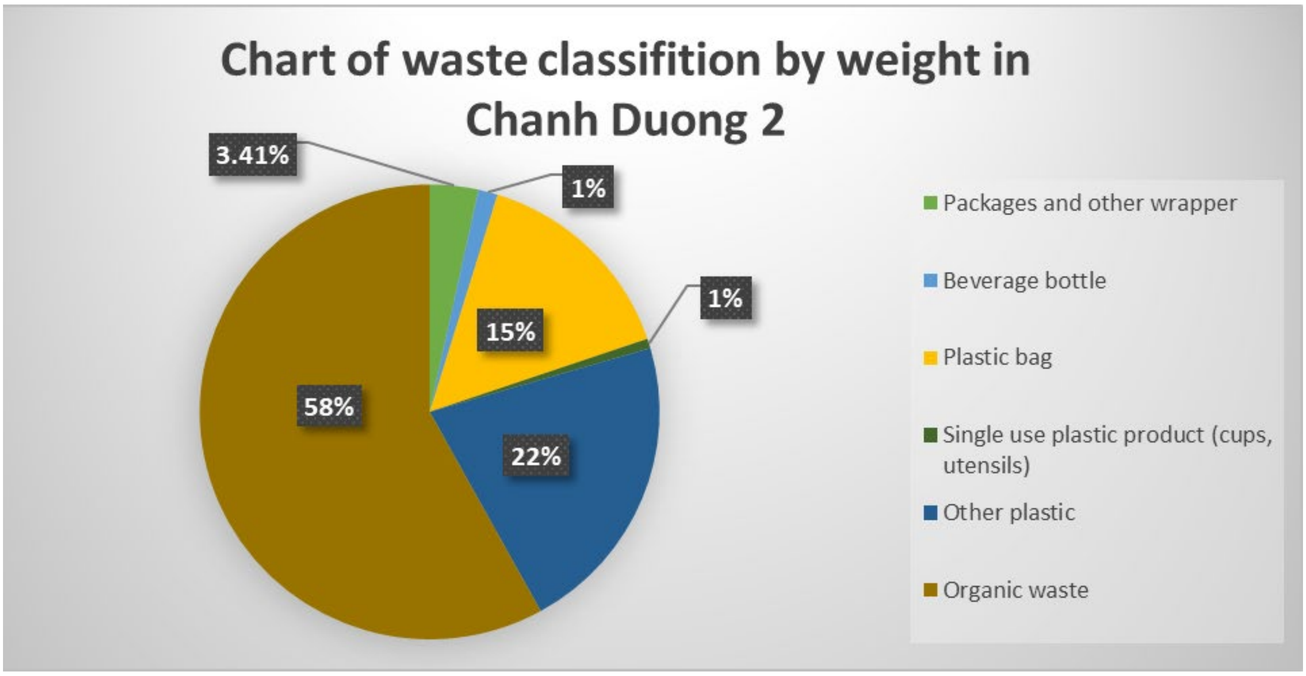



Figure 31:
**WASTE CLASSIFICATION BY WEIGHT FROM NET SAMPLING AT CHANH DUONG 2**




The number and weight of waste types collected during a survey day is shown in Table 14.

Table 14:
**NUMBER AND WEIGHT WASTE TYPES COLLECTED DURING NET SAMPLING**

| Order | Type of waste | Quantity (pieces) | | | Weight (g) | | |
|---|---|---|---|---|---|---|---|
| | | POS 01 | POS 02 | POS 03 | POS 01 | POS 02 | POS 03 |
| 01 | Packages and other wrappers | 18 | 27 | 06 | 40 | 50 | 10 |
| 02 | Straws | | 01 | 01 | | | |
| 03 | Fishing gear | | | | | | |
| 04 | Beverage bottles | | 01 | | | 40 | |
| 05 | Hard plastic fragments | | | | | | |
| 06 | Plastic bags | 18 | 21 | 02 | 200 | 220 | 20 |
| 07 | Single-use plastic products (cups, utensils) | 02 | 02 | 02 | 10 | | 10 |
| 08 | Bottle caps | 01 | 01 | 01 | | | |
| 09 | Other plastic (Styrofoam fragments, unrecognizable plastic waste) | 10 | 19 | 03 | 100 | 430 | 100 |
| 10 | Organic waste | | | | 1020 | 470 | 210 |
| | TOTAL | | | | **1370** | **1210** | **350** |

*Note: At each position, the survey lasted for two hours, after which waste samples were collected.*

**In conjunction with the flow velocity measurements, the concentration of plastics could be determined.** With this measurement, the concentration varied from 3 to 18 pieces of plastic per 1,000m³ of water. When extrapolated for the total profile, this resulted in the transport per hour of approximately 440 pieces of plastic, or approximately 4kg plastic.

**A comparison between the camera detection and the net measurement results was performed for one vertical water column. This measurement showed that about twice the number of plastic particles were registered over the total depth of the column than were detected by the camera in the uppermost layer of the water.** This was primarily due to the small size of plastic particles and the submersion of particles. The results indicate that with additional trawl surveys at different locations and times, a relationship between the two methodologies could be established that would enable better extrapolation for the total amount of plastics. This would comprise the measurement of submerged plastics, and those recorded by the automated camera measurements of plastics floating on the surface.

**Several observations were made during the survey:**

- Waste was mainly domestic, which is produced by people living on the banks on both sides of the river.[13]

13 At the time the survey was conducted, Hai Phong had closed the Tran Duong sluice gate. This resulted in an unchanged water level at the two survey locations, Chanh Duong 1 and Chanh Duong. Little waste was transported through the two survey sites, and the waste was mainly domestic waste from residential areas near the canal.

- Near the bottom of the net, there was almost no trash.
- There were many water hyacinths, which caused gridlock at the sites.
- Dead and rotting poultry were thrown into the river, which caused heavy pollution and a bad odor.
- Pineapple sacks and large plastic bags could not be picked up by net due to their large size.

### 2.2.5 Discussion

#### 2.2.5.1 Survey Results

**Most common plastic items:** Drone surveys were carried out in Hai Phong (five sites), Hai Duong (two sites), and Sa Pa (two sites) to determine the most common plastic items. Across all survey locations, the following items were identified as most abundant (from the highest to the lowest percent): *Polystyrene, including food containers* (40 percent), *Cup lids, caps,* and *small plastics* (19 percent), *LDPE bags, Wrappers,* and *PET bottles.* The net trawl pilot carried out at Chanh Duong 2 bridge, in Hai Phuong, revealed the most abundant plastic items in the total waste collected. These were *food packages and other wrappers* (41.32 percent), *plastic bags* (30.58 percent), *other plastic* (18.18 percent), *single-use cups/utensils* (3.31 percent), *bottle caps* (2.48 percent) and *straws* (accounting for 1.65 percent). The results of the study for the different waste type compositions in the cities of Hai Duong, Sapa, and Hai Phong were noteworthy. In Hai Duong there was more *polystyrene food packaging,* and in Hai Phong and Sapa there were comparatively more LDPE plastic bags. This may indicate that Hai Duong is likely a plastics source site type, and the shores of Hai Phong are more likely an aggregation site type, where plastic waste was not dumped, directly.

**Plastic waste quantities:** Plastics river monitoring surveys were conducted in all three surveyed cities: Hai Duong, Hai Phong, and Sapa, and tributaries, canals, and main rivers were surveyed. At the Chanh Duong bridges over a canal in Hai Phong, the highest plastic waste transport was observed (600 plastic waste items per day). The plastics river monitoring for Suoi Cat (Cau Lao Chai) bridge in Sapa found a high number of objects floating by per survey day (360 items), and for long periods during the survey day, substantial waste transport per half hour (over 10 waste items). The lowest plastic waste transport was observed on the main river of Hai Phong—140 plastic waste items per survey day.

**Plastic waste locations/hotspots:** Plastic waste was found in all the surveyed sites, but the abundance varied across the sites. Large waste accumulations were found in Hai Duong, with a ~10-fold higher waste abundance observed in that city, compared to the other surveyed cities. This is due to the different types of obstacles at specific sites immobilizing waste items (for example, vegetation or dams) and also likely related to local littering behavior and waste management practices (outside the survey scope).

**Lessons learned and development of proven concept for plastics monitoring on rivers:** Under this study, the globally novel approach on remote-sensing-based plastics monitoring was successfully piloted in Vietnam. This positive outcome of this survey can provide the foundation for the Government of Vietnam for carrying out longer-term plastics monitoring for enhancing knowledge on plastics pollution, establishing baselines, and measuring impacts of policies or other measures over time. A high number of very valuable technical lessons were learned in this first pilot which can provide the foundation for upscaling of plastics monitoring (see 2.2.5.2).

#### 2.2.5.2 Methodologies

**The monitoring activities have shown that drone surveys and bridge camera monitoring are suitable to monitor plastic waste in Vietnam. Together with net trawl surveys, detailed information on plastics transport could be gathered. To carry out plastic waste monitoring by these methods, good coordination is necessary with the responsible provinces and/or cities on:**

- Applying for a survey license,
- Coordinating with the Department of Natural Resources and Environment, the Sub-department of Environmental Protection, and the district Division of Natural Resources and Environment to identify locations to be monitored;
- Liaising with the provincial Departments of Natural Resources and Environment, and the People's Committees of districts and communes to set up fixed monitoring stations; and
- Liaising with local police to ensure the safety of people and vehicles during the installation of the equipment and the monitoring process.

### Data Collection with Drone Surveys

**Using UAVs had many advantages, including the short amount of time required to survey a site (1–2 hours), and the opportunity to visualize data in an easy, yet accurate way, with large spatial resolution.** In addition, UAVs allowed access to areas or viewpoints that were previously inaccessible. However, the use of UAVs also comes with a number of challenges such as lower image quality due to the fogging of lenses in the humid environment, and restricted access to areas with objects such as trees, utility poles, and power lines. A diligent assessment of future survey sites, and planning for survey breaks to clean lenses, will be crucial in future surveys in Vietnam.

### Data Collection with River Monitoring Cameras

**Using GoPro cameras for monitoring the environment is a relatively new method in Vietnam.** In this project, GoPro cameras mounted to a bridge recorded videos that were analyzed to estimate baseline waste transport in the rivers. The cameras used in this study were easy to install, handle, and relatively inexpensive, yet highly precise. However, during the surveys, the cameras had to be lowered after two hours to change the camera batteries. Thus, to avoid interruptions, survey sessions should be planned in accordance with the battery life. This method is flexible and can be used both for shorter surveys (1–3 days) and long-time monitoring. Also, through the installation of fixed monitoring stations to monitor seasonal variations, bridge cameras allow for monitoring rivers for one to two months or longer. River monitoring can be carried out, too, on a (bi-)monthly schedule at selected bridges for 1-day measurements—an approach that will enable municipalities or policymakers to assess annual plastic waste transport.

When selecting monitoring sites, rivers, tributaries, and canals should be selected by applying the following criteria: (i) the distance between the bridge and water should stay about the same on a given bridge, (ii) the distance from the bridge railing to the water surface should be at least 4m, and at most 10m, and (iii) the river should not be too steep or rocky, and ideally the water's movement is calm. These factors will enable successful data analysis.

### Data Collection by Means of Net Trawl Devices

**The use of nets at several depths to sample plastics transport is complex, and involves higher costs. However, this has the advantage of determining the total plastics transport in a river, including the small and submerged particles.** Complementing river monitoring via cameras with net sampling promises a substantial gain in knowledge. Sampling the measurement profile three to five times per year with simultaneous, continuous sampling using cameras could ensure that a relatively accurate statement about the annual load (total plastics) would be obtained.

**Due to low water levels at the survey site, the survey team used long steel bars to fix the equipment and the mesh to the bridge instead of using a crane.** For larger rivers, implementation of the whole device's configuration needs to be considered. In addition, the team encountered some challenges in procuring the right mesh materials and other equipment; however, these difficulties can be attributed to the fact that net sampling was carried out as a pilot.

### Data Analysis of Drone Imagery

**The monitoring results regarding waste quantities and waste types are estimations produced by the plastic waste analysis software, and should be understood as approximate statistics, rather than exact measurements.** The key factors, which increase or decrease the accuracy of artificial intelligence-based analysis are:

- **Underestimation of waste items** in the imagery because many plastics can be found below the surface of the water, and in waste dumps whose depth is not considered by the software.
- **Overestimation of waste items** due to non-waste-objects in the imagery that can cause the analysis algorithm to falsely classify image tiles as plastic.
- **Higher data uncertainty in less polluted sites** due to the fact that a false classification in a small sample has a higher impact on the output statistic.
- **Difficult detection of weathered waste items.**
- **False classification of waste items that are submerged in the water or mud.**

### Data Analysis of River Monitoring Imagery

**The river monitoring with GoPro cameras, combined with a machine learning method such as APLASTIC-Q, was carried out as a pilot in Vietnam. The initial results indicate its applicability for stationary river monitoring, detecting floating plastic waste objects on the river surface with sizes of >10cm, with reasonable accuracy.** During this study, the software was improved to be based on a larger knowledge base, and be more applicable for river monitoring surveys. In future, with further development of the methodology, it is expected to quantify waste types as well.

**However, the method is still at a piloting stage and needs to be further developed.** Specifically:

- Rivers with very high flow velocity, water movement, foam, and sun reflection are a challenge for data analysis, and lead to **overestimation of the waste quantity.** This can be reduced by analyzing the image sections that do not contain these problematic images.
- Distances of around 10 meters from cameras to the water's surface can cause low image quality, leading to an **underestimation of the total amount waste items that are passing.** Careful selection of survey sites can help mitigate this challenge.

Passing boats caused false positive classifications. This problem did not occur very often, and mitigation measures were taken such as only allowing a maximal waste count for a single analysis. As a result, this effect caused only a slight overestimation of the waste quantities.

### Relationship Between Drone Survey Results, River Monitoring, and Net Trawl Surveys

**The drone surveys and river monitoring surveys with cameras and net trawl devices generated different** information. Drone monitoring captured immobilized plastic waste such as accumulated plastic waste, waste trapped in vegetation, or plastics washed ashore. The installed cameras and the net trawl devices measured mobilized plastic waste on the river surface, and in the vertical river column, respectively.

**The results of both methodologies are expected to correlate. To better understand the correlation between the two methodologies, however, further studies are necessary.** For example, although no large accumulations of immobilized plastic waste were found at surveyed sites in Hai Phong, the high volume of plastic waste transport found through river monitoring suggested the presence of plastic waste hotspots in Hai Phong. Further studies could better explain the relationship/exchanges between immobilized and mobilized plastics in the riverine environment. Inspecting survey locations and their surroundings by using an interdisciplinary team to assess littering behaviors and waste management systems at surveyed locations could help to gather further insights about these exchanges, and the factors that influence them.

### Prospects on the Costs of Various Monitoring Systems

**The equipment costs varied with the different monitoring methods.** The drone surveys used equipment worth, approximately, $250 to $1,000 for drones, and $300 to $800 for cameras. The bridge surveys used GoPro cameras worth approximately $500. To cover the entire width of a river, several cameras can be mounted on one bridge.

Recent research in Germany by Escobar-Sánchez et al. (2021) explored the cost efficiency of beach monitoring using UAV and OSPAR (field survey) methods. These authors concluded that the OSPAR methods yielded a higher efficiency score for beach litter monitoring on the Baltic Sea in Germany, but they also suggested that UAV monitoring could perform better at other sites ("non-accessible sites, fragile ecosystems, floating litter or heavily polluted beaches").

**In Vietnam's context, the parameters were different for beach litter monitoring than was the case with the beaches that Escobar-Sánchez et al. (2021) analyzed in Germany.** These differences were as follows:

- Personnel costs in Vietnam were far lower, in general;
- The consumer electronic UAVs, which were used in this study, were less expensive in Vietnam;
- Some parts of the studied rivers were harder to access by foot, but were easy to monitor using drones;
- Plastic waste was usually distributed very heterogeneously in Vietnam. The sites contained a large amount of dense plastics in a small area. With the monitoring strategy employed in Vietnam, the study team was able to monitor these hotspots, and provide assessments of the waste quantities and types. In these densely polluted areas, the drone monitoring method was expected to yield results significantly faster than field survey methods, as the drones could usually be deployed quickly, and the area of interest was usually less than 100m². However, for these riverine plastic hotspots, precise comparisons between the field surveys and drone surveys were not carried out; and
- In future, bridge monitoring costs should be lower if they are scaled up—for example, a permanently installed CCTV system would require fewer people to operate the cameras.

### Recommendations for the Development of Monitoring Systems

To develop effective policies and monitoring measures, having a solid understanding of the priority plastic types is essential. Surveys in Vietnam and other countries have shown that only a few plastic items are responsible for most of the pollution. Several of these items are either non-essential and/or already have good alternatives available in the market. By targeting these specific items, plastics pollution, overall, could be significantly reduced. Thus, the surveys and other methods applied in this study generally focused on identifying the priority plastic types.

In order to measure the impacts of any procedures put in place to reduce plastics pollution, good understanding of the quantities of plastics is a major benefit. For this reason, especially, bridge surveys were piloted, initially, and then combined with trawl surveys in order to better understand both the types and qualities of submerged plastics. This successfully tested method can be applied to automatically and continuously measure plastics pollution over longer periods of time. If such automated monitoring systems are installed in the desired locations, the main additional requirement is labor to guard the equipment. By carrying out further trawl samplings (which are labor and time intensive), and combining these with bridge monitoring, it should be feasible to establish a relationship between surface and submerged plastics. Thus, through continuous and automated monitoring of only the surface plastics, it should be possible to estimate the total plastics transport in a river. However, successfully establishing such an approach will require further testing.

In general, for all of the survey methods used in the study, a key component of the work is identifying the capacities in the country, concerned, and using locally available and affordable technologies so that the surveys can be replicated and upscaled to additional locations, based on the government's priorities and requirements.

Photo: Roman Striga - Shutterstock

# 2.3 ANALYSIS OF ALTERNATIVES

## 2.3.1 Objective

**The aim of this study was to provide an initial overview of the main importers and producers, production and consumption figures, and alternatives to, and/or the recyclability of plastic products that are most commonly found at river and coastal sites in Vietnam.** In addition, this study attempted to make a comparison of wholesale prices for plastic products and their alternatives.

## 2.3.2 Study Design, Data Sources, and Limitations

### Study Design

This assessment of plastic alternatives is based on Section 2.1 (Plastic Field Surveys), which identified the top 10 plastic waste items found at 40 river and coastal sites in Vietnam during surveys conducted in 2020 and 2021 (Table 15).

Table 15:
**TOP 10 PLASTIC WASTE ITEMS AT RIVER AND COASTAL SITES IN VIETNAM**

| Rank | Top 10 Plastic Waste Items | % |
|---|---|---|
| 1 | Soft plastic fragments (LDPE) | 17.4 |
| 2 | Fishing gear 1: rope, net pieces, lures, lines, hard plastic floats (PE & PP) | 16.6 |
| 3 | Fishing gear 2: Polystyrenes-ESP, buoys, floats (PS & EPS) | 13.0 |
| 4 | Plastic bags size 1 (0-5kg) | 8.4 |
| 5 | Styrofoam food containers (PS) | 7.4 |
| 6 | Hard plastic fragments (HDPE) | 6.1 |
| 7 | Straws (mainly PP) | 4.6 |
| 8 | Other food wrappers | 3.2 |
| 9 | Other plastic (plastic slippers, diapers, etc.) | 3.2 |
| 10 | Crisp/Sweet packages (PP & PS) | 3.1 |

*Note: Percent was calculated by dividing the number of specific plastic waste items by the number for all plastic waste items sampled during the surveys.*

**For analyzing alternatives, the list of the top 10 plastic waste items was adjusted to reflect the fact that plastic alternatives can be identified by product type (for example, bags) but not by waste item (for example, soft plastic fragments):**

- *Hard plastic fragments* (item 6) and *other plastics* (item 9) were excluded; these categories included a variety of different materials that, thereby, made areas of application, and the identification of potential alternatives too ambiguous.
- *Plastic bags size 1* (item 4) and *soft plastic fragments* (item 1) were combined for the market assessment since the latter category largely consisted of plastic bag fragments. Also, *other food wrappers* (item 8) and *crisp/sweet packages* (item 10) were combined into one category due to the similarities of these categories.
- Some plastic waste item categories were either simplified by focusing on specific products within the broader waste item category (for example, fishing nets under *fishing gear 1*) or by broadening the scope of the assessment (for example, different sizes of plastic bags were assessed).

Table 16 shows the six remaining plastic waste items that were assessed.

Table 16:
**CATEGORIES FOR MARKET ALTERNATIVES ANALYSIS**

| Product Type Categories for Alternatives' Analysis | Corresponding Top 10 Plastic Waste Items |
| --- | --- |
| Plastic bags (different sizes) | Plastic bags size 1 (0-5kg)<br>Soft plastic fragments (LDPE) |
| Fishing nets | Fishing gear 1: Plastic rope, net pieces, lures, lines, hard plastic floats (PE & PP) |
| Various foam floats | Fishing gear 2: Polystyrenes-ESP, buoys, floats (PS & EPS) |
| Styrofoam food containers | Styrofoam food containers (PS) |
| Straws | Straws (mainly PP) |
| Food packaging | Other food wrappers<br>Crisp/Sweet packages (PP & PS) |

For each of the six product type categories, this study:

- **identified the main importers and producers by product category,** both for plastic products and their alternatives,
- **defined product sub-categories** (for example, parachute fishing nets and aquaculture nets as a sub-set of fishing nets),
- **assessed the recyclability of each plastic sub-category,** and
- **estimated units sold per annum, and wholesale prices for each sub-category.**

## Data Sources

The study was based on both primary and secondary data:

- **Primary data**
  - From interviewing plastic item producers/importers, producers of alternative products, large consumers of single-use plastics such as food and beverage companies (see Annex 2.3.A).
  - From interviewing environmental experts, researchers, and public officials regarding recommendations for alternative products (see Annex 2.3.B).

- Secondary data
  - From reviewing publicly available plastic industry publications.
  - From synthesizing information about suppliers and markets for each product on company websites and business registration information pages such as Yellow Pages Vietnam, e-commerce sites, and import and export data on Trademap.org.

### Limitations

However, the assessment:

- **does not provide a comprehensive market overview** for all plastic products and producers/ importers per product category, but focused on the most important ones.
- **identified potential alternative/substitute products,** but did not evaluate their environmental impact, suitability for consumers, or the effects they would have on consumer behavior, producers, and the supply chain.
- **gave a rough estimate of wholesale prices** for specific products, but did not undertake an analysis of the economic effects that a change from plastic products to alternatives would have.

**As such, this study needs to be seen as a first attempt to identify alternatives to those plastic products that are most commonly found at river and coastal sites in Vietnam.** Several opportunities exist to refine, deepen, and extend the assessment, and these are discussed in Section 2.3.4.

## 2.3.3 Results

### Plastic bags (different sizes)

**Plastic bags come in a variety of sizes, weights, thicknesses, and colors.** What they have in common is a low collection and recycling rate due their low residual value, and a lack of adequate waste management infrastructure and logistics in Vietnam.

**There are around 10 major companies in Vietnam that produce, import, and sell wholesale plastic bags with a focus on the local market (see Annex 2.3.C).** The actual number of plastic bag producers in Vietnam is considerably higher, but their products are mainly for export. There are also a number of companies that can produce biodegradable plastic products[14] that meet European standards.

**The "standard" plastic bags listed in Table 17 were sold around five times more frequently (809,000 tons per year) than comparable alternatives (162,000 tons per year).** This means that there is certainly a market for the alternative bag types presented here. It should be noted, however, that the alternatives that make up the majority of the total units sold are also made from plastic, although they possess characteristics that make them somewhat favorable (for example, biodegradability under specific conditions in the case of compostable plastic bags, and reusability in the case of polypropylene woven bags). When comparing wholesale costs per unit, most "standard" plastic bags are considerably cheaper than the alternatives, even when accounting for different use cases (single-use versus re-use). For example, compostable plastic bags are roughly five times more expensive than "standard" plastic bags.

14 Biodegradable plastic is defined as material that completely decomposes into $CO_2$, water, and organic matter. Currently, in Vietnam, there are companies that produce biodegradable plastic products with certificates obtained from TUV OK compost INDUSTRIAL, TUV OK compost HOME, (BPI) Biodegradable Product Institute Compostable, and DIN CERTCO compostable. Oxo-biodegradable bags—plastic bags that break down into small pieces much faster than conventional plastic bags—are not included in the definition.

Table 17:
**PLASTIC BAGS AND ALTERNATIVES – UNITS SOLD AND WHOLESALE COSTS**

| Plastic Bag Type | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Bag Type | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| PE bag<br>(various sizes)<br> | 284,692 tons | 30,000 – 40,000 VND/ kg | Compostable plastic bag<br>(various sizes)<br> | 51,897 tons | 160,000 VND/ kg<br>(single-use) |
| | | | PP woven bag<br> | 86,400 tons | 19,000–25,000 VND/piece (pcs)<br>(use for 1–2 years) |
| | | | Non-woven bag<br> | 1,728 tons | 8,000–15,000–30,000 VND/ pcs<br>(use for 1–3 years) |
| | | | Wooden bag<br> | | 61,000–125,000 VND/ pcs<br>(use for 1–3 years) |
| | | | Ivory paper bag<br> | 20,976 tons | 2,000–20,000 VND/pcs<br>(use for 3–10 times) |

| Plastic Bag Type | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Bag Type | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| HDPE plastic bag<br>(various sizes)<br> | 360,000 tons | 36,000–48,000 VND/kg | Flat Non-woven Fabric Bag<br> | | 6,000–6,500 VND/pcs<br>(use for at least 5–10 times) |
| | | | Kraft paper bag<br> | | 1,000–9,000 VND/pcs<br>(use for 1–3 times) |
| Cup-bag<br>(various sizes)<br> | 1,584 tons | 42,000–60,000 VND/kg | Canvas bag for cup<br> | | 6,000–10,000 VND/pcs<br>(use for at least 1 year) |
| | | | T-shaped kraft paper bag for cup<br> | 16 tons | 700–1000 VND/pcs<br>(single-use) |
| Milktea cup-bag<br>(various sizes)<br> | 1,408 tons | 30,000–48,000 VND/kg | Compostable plastic cup-bag<br> | | 160,000 VND/kg<br>(single-use) |

| Plastic Bag Type | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Bag Type | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| Waste plastic bag (5kg carrying capacity)<br> | 69,458 tons | 17,000–23,000 VND/kg | Compostable waste plastic bag<br>(various sizes)<br> | 347 tons | 95,000–118,000 VND/kg<br>(single-use) |
| Food bags<br>(various sizes)<br> | 91,364 tons | 76,000–96,000 VND/kg | Compostable food bag<br> | 914 tons | 145,000 VND/ kg<br>(single-use) |

### Fishing Nets

**Fishing nets come in a variety of sizes and applications, ranging from nets for aquacultures to parachute nets or fishing gill nets.** After their typical lifetime of four to six years, fishing net products are rarely collected and recycled.

**Alternative products such as biodegradable fishing nets[15] are just being introduced in Vietnam and are considerably more expensive than plastic fishing nets** (see Table 18). The absence of commercially competitive substitute products also leads to a negligible number of manufacturers and importers of substitute products for fishing nets (see Annex 2.3.C).

15 Typically, base raw materials for biodegradable fishing nets are blended polybutylene succinate (PBS) and polybutylene adipate-co-tere-phthalate (PBAT), together with other biodegradable materials and additives. Biodegradable nets can completely decompose in seawater within six months (piloting stage).

Table 18:
**FISHING NETS AND ALTERNATIVES – UNITS SOLD AND WHOLESALE COSTS**

| Fishing Net Type | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Product Types | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| Parachute fishing net<br><br>Mesh size: 1.5 cm–40 cm | 45,054 tons | 20,800–25,000 VND/m2<br><br>(durability of 4–6 years) | Biodegradable net | N/A | 70,000–138,000 VND/$m^2$<br><br>(decomposes after 6 months in seawater)<br><br>(currently piloting) |
| Parachute braided fiber fishing net/ Rake net<br><br>Mesh size: 0.6 cm–40 cm | | 3,090–5,200 VND/m2<br><br>(durability of 4–5 years) | | | |
| Aquaculture nets<br><br>Mesh role size: 1–4m x100m | | 13,000–30,000 VND/m2<br><br>(durability of 4–5 years) | | | |
| Aquaculture nets<br><br>Mesh size:<br><br>0.3 cm–1.6cm | | 6,200–13,000 VND/m2<br><br>(durability of 4–5 years) | | | |
| Fishing Gill Net Monofilament<br><br>Mesh size 5–8 cm | | 2,200–3,000 VND/m2<br><br>(durability of 4–5 years) | | | |
| Fishing net (small fishing)<br><br>Mesh size: from 1.5 cm to 100 cm | | 1,439 VND–2,000 VND/m2<br><br>(durability of 4–5 years) | | | |

## Various Foam Floats

**Floating foam products are mainly used in riverside and coastal areas for aquaculture and fishing activities.** The number of companies producing or importing foam floats into Vietnam is quite large; a range of typical manufacturers is listed in Annex 2.3.C.

**As Table 19 shows, substitute floating products are mainly made from wood and have a higher price but are more durable.** Table 19 also lists plastic drums, and *Line-X* float coating (a coating applied to foam floats), as alternatives because these products may offer considerably higher durability than standard foam floats. The fact that these products are presented as alternatives, despite being made from plastics points to the challenge of identifying suitable non-plastic alternatives for this product category.

Table 19:
**VARIOUS FOAM FLOATS AND ALTERNATIVES – UNITS SOLD AND WHOLESALE COSTS**

| Foam Float Type | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Product Types | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| Porous floating fish cage | 8,334 tons | 350,000 VND/ pcs<br>(durability of 2–3 years) | Line X coating float (paint 0.5–0.6 mm thick) | | 1,300,000 VND/pcs<br>(in piloting, durability of 10 years) |
| | | | Drum float<br>160 lit–220 lit<br> | | 800,000–1,200,000 VND/pcs<br>(durability of 3–5 years) |
| EPS foam float Size 8–15cm<br> | 406 tons | 8,700–9,000 VND/unit<br>(durability of 1 year) | Wooden float<br>10–14cm<br> | | 25,000–40,000 VND/pcs<br>(durability of 3–5 years) |
| Small fishing float<br>Weight: 5g<br>Material: foam<br>Size: 1.8cm x 0.4cm<br> | | 860–1,500 VND/pcs<br>(for single-use) | Wooden float<br>Size: 0.8 cm; Length: 6.6 cm<br> | | 3,000–6,000 VND/pcs<br>(durability of 1 year) |
| PVC fishing float/pool marker Size 14x20 cm; 13x18 cm; 15x15 cm<br> | | 54,000–78,000 VND/pcs<br>(durability of 1 year) | Wooden float<br>12cm–40cm<br>45cm–80cm<br> | | 200,000–276,000 VND/ pcs<br>(durability of 2–3 years) |

## Styrofoam Food Container

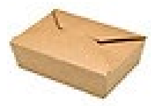
**Styrofoam food containers are a common packaging solution for take-away food.** Styrofoam cannot be recycled and it is not biodegradable. This plastic waste is discharged directly into the environment or disposed of together with other household waste.

The main producers and importers of this product are listed in Annex 2.3.C.

Most alternative products listed in Table 20 are substitutes with similar use cases to plastic products, but the list also contains products (for example, stainless steel trays, glass containers) that would require businesses and consumers to move away from a single-use, to a reusable model.

Table 20:
**STYROFOAM TRAYS AND ALTERNATIVES – UNITS SOLD AND WHOLESALE COSTS**

| Styrofoam tray types | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Product Types | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| Foam tray<br>Various sizes<br> | 5,133 million pcs | 700 VND–2,000VND/unit | Leaf tray<br> | 51 million pcs | 1,800–2,300 VND/unit<br>(for single-use) |
| | | | Bagasse tray<br> | | 1,300–3,200 VND/unit<br>(for single-use) |
| | | | PLA tray<br> | 4.2 million pcs | 2,300–3,500 VND/unit<br>(for single-use) |
| | | | Aluminum tray<br> | 3.6 million pcs | 3,800–5,320 9,600 VND/unit<br>(for single-use) |
| Food foam tray<br> | | 1,000–1,500 VND/unit | stainless steel tray<br> | | 42,000–65,000 VND/unit<br>(At least one year of use equals to 360 times) |

| Styrofoam tray types | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Product Types | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| Small sticky rice box  | 5,341 million pcs | 150–500 VND/ unit | Bagasse box  | 51.3 million pcs | 2,750–3,200 VND/unit<br>(for single-use) |
| Foam food box  | | 2,760 VND/unit | Kraft box  | 1,206 million pcs | 2,800 VND/unit<br>(for single-use) |
| Foam food box  | | 473–546 VND/ unit | Paper rice box  | | 5,700 VND–6,900 VND/unit<br>(for single-use) |
| | | | Glass box  | | 99,000 VND/ unit–180,000/ unit<br>(for single-use) |
| | | | Aluminum box  | | 5,000 VND/unit<br>(for single-use) |
| | | | Bagasse rice box  | | 2,300 – 5,500 VND/unit<br>(for single-use) |

## Straws

**In Vietnam, alternatives to plastic straws are well established and sold in volumes that, although smaller, are comparable to plastic straw volumes** (see Table 21). This is due customer acceptance, the availability of relatively cheap raw materials for alternatives, and a larger number of producers of substitute products (see Annex 2.3.C).

Table 21:
**PLASTIC STRAWS AND ALTERNATIVES – UNITS SOLD AND WHOLESALE COSTS**

| Straw type | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Product Types | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| Straight straw<br>PP plastic<br> | 1,257 million pcs. | 200 VND–1,000 VND/unit | Bamboo/ wooden straw<br> | 65 million pcs. | 600–1,000 VND/unit (for wholesales) or 1,000–6,000 VND/unit for retail<br>(use for 3–6 months) |
| | | | Paper/kraft straw<br> | 850 million pcs. | 200–500 VND/ unit<br>(single-use) |
| | | | Grass straw<br> | 85 million pcs. | 400–500 VND/ unit<br>(single-use) |
| | | | Compostable plastic straw<br> | | 3,200–3,800 VND/unit<br>(single-use) |
| | | | Rice straw/ vegetable straws<br> | 580 million pcs. | 300–800 VND/ unit<br>(single-use) |
| U-shaped straws for dairy factories<br>PP plastic<br> | 2,560 million pcs. | 100 VND–300 VND/unit | U-shaped paper straw/ sugar cane fibers<br> | 680 million pcs. | 400 VND/unit<br>(single-use) |

| Straw type | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Product Types | Units sold per year (estimate) | Avg. wholesale cost per unit |
|---|---|---|---|---|---|
| Curved straws<br>PP plastic<br> | 1,505 million pcs. | 1,200 VND–1,500 VND/units | Stainless steel straw<br> | | 7,000–15,000 VND/unit<br>(durability of 3–10 years) |
| | | | Glass straw<br> | | 4,000–10,000VND/ unit<br>(durability of 6 months–2 years) |

## Food packaging

**Food packaging waste is the product category with the greatest variety for specific products presented in this study. Different polymers and polymer blends, composite packaging, coloring, sizes, and organic contamination often make the recycling of food packaging waste very challenging.**

At the same time, alternative packaging products often have considerably different properties, which puts their suitability as substitutes into question. In the absence of specific regulation and change in business practices and consumer behavior, alternatives are unlikely to replace current food packaging on a larger scale.

| Food packaging type and size | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Product Types | Units sold per year (estimate) | Wholesale cost per unit (VND) |
|---|---|---|---|---|---|
| Packaging of agricultural Products;<br>Structure: PVC, PET, BOF;<br>Number of colors: from 1–9 colors<br>The largest size is 120 cm.<br> | 2,089,871 tons | 301–900 VND/ pcs | Kraft paper bag<br>Various sizes<br> | | 800– 4,350 VND/pcs |
| | | | Aluminium bag<br>Various sizes<br> | | 2,900– 9,600 VND/pcs |

| Food packaging type and size | Units sold per year (estimate) | Avg. wholesale cost per unit | Alternative Product Types | Units sold per year (estimate) | Wholesale cost per unit (VND) |
|---|---|---|---|---|---|
| Food Packaging<br>Structure: OPP/PE, OPP/ PP, OPP/MCPP, OPP/ LLDPE, PET/LLDPE, PET/ MPET/<br>LLDPE…<br>Number of colors: from 1–9 colors<br>The largest size is 120 cm.<br> | 2,089,871 tons | 6mic–30mic thickness PE bag price from 62 VND–1,383 VND/pcs | Tin box packaging<br>Various sizes<br> | | 10,500–55,000 VND/box |
| | | | Tin cans<br>Various sizes<br> | | 300–28,000 VND/ tin |
| | | | Glass jar with tin lid<br>Types from 15 ml–1000 ml<br> | | 4,000–25,000 VND/ box |
| Packaging of Frozen Food<br>Structure: PA/LLDPE, PA/ PE/LLDPE...<br>Number of colors: from 19 colors<br>The largest size is 120 cm<br> | | PA plastic membrane: 807,000 VND/ kg<br><br>LDPE bag 8x4x18 inch: 111–145 VND/ pcs | Stencils bags<br>38x50cm<br>weight 35–40gram<br> | | 1,200–2,000 VND/pcs |

## 2.3.4 Summary and Conclusions

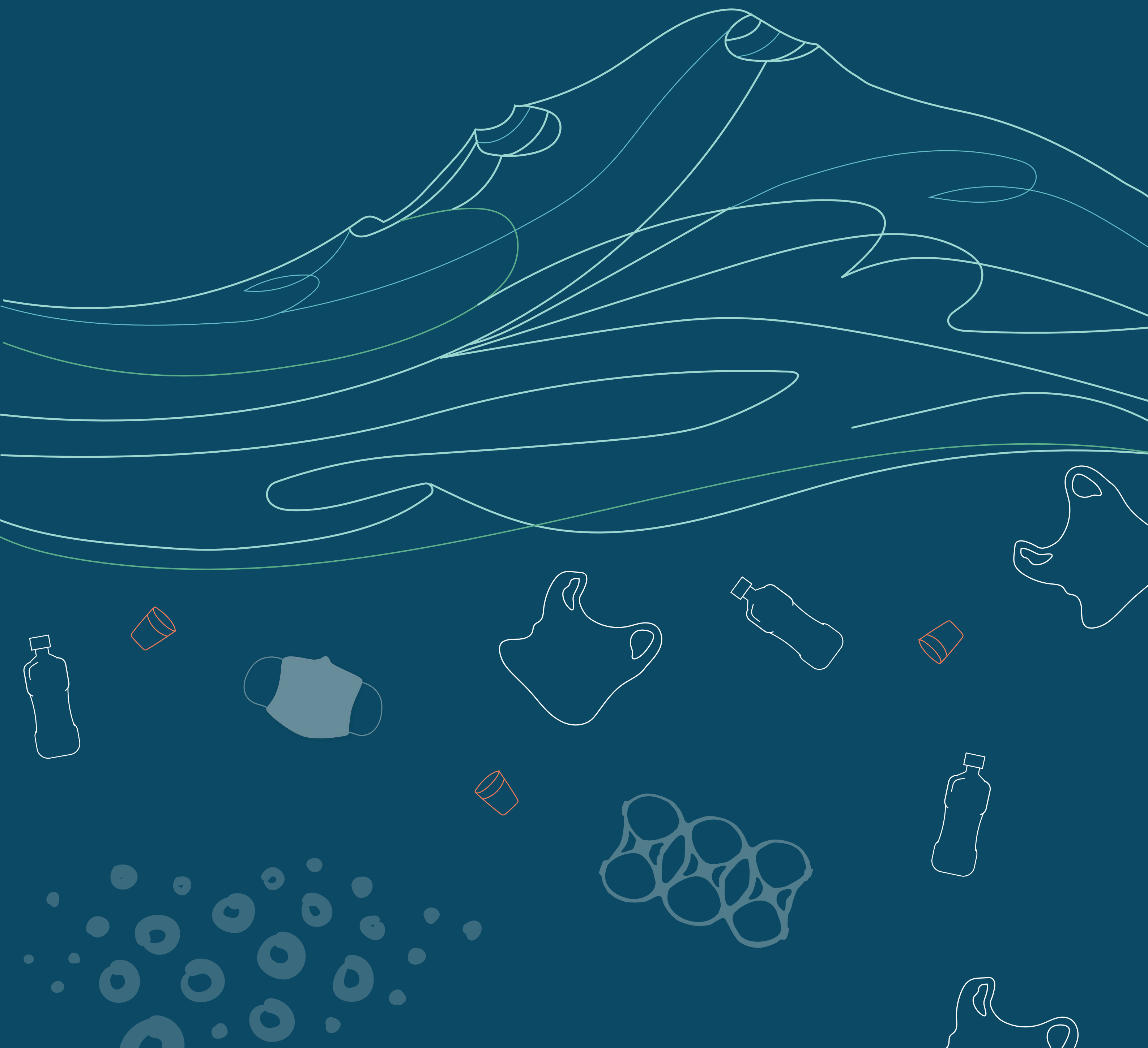
**This assessment of plastic alternatives was based on field surveys, which revealed the top 10 polluting plastic items at river and coastal sites in Vietnam.** The relevant data on alternatives available in the market were collected from primary sources via interviews, and from secondary sources reviewed in desk studies.

**The results of the preliminary plastic alternatives analysis showed that for most of the identified priority single-use plastics, alternative products were already available in the Vietnamese market.** This included alternatives that are mainly available for plastic bags and take-away-food related waste.

**While alternative products are currently often higher priced than their respective single-use plastic (SUP) product, most of the alternatives are reusable products.** In principal, the objective should not be to replace SUPs with non-plastic, single-use items, or with plastic multi-use items that may also have negative impacts, and would not be in line with a pathway toward a more circular economy.

**Thus, in promoting alternative products, the focus should be on the promotion of reusable, non-plastic items that support an overall reduction of waste generation.** Nonetheless, for plastic straws, in particular, due to the availability of relatively cheap raw materials for alternatives, high customer acceptance, and a larger number of producers of substitute products, single-use alternatives to plastic straws are already well established, and sold in volumes comparable to plastic straws. Promotion of other alternative products through policies and incentives, and supporting the transition to a reuse model to compensate for the higher unit price, will be crucial in further reducing the priority single-use plastic products that are responsible for, by far, the greatest amount of plastic pollution.

# 3. WAY FORWARD



**Improvements in plastic waste monitoring.** The studies summarized in this report illustrate the feasibility of undertaking low-cost surveys using different methodologies that can provide governments (both national and local) with a snapshot of plastic waste leakage with regard to volume, types, brands, flow, and hotspots. Depending on the policy objectives for monitoring, multiple methodologies could be employed, so location-specific protocols would need to be developed to determine the most appropriate survey types and frequency. Lessons learned from the different methodologies used in this study could feed into national guidelines on plastic monitoring that would support local governments in regularly tracking progress in implementing the policies concerned with plastics. To guide local-level monitoring, development of guidelines by MONRE will be necessary.

**The remote-sensing based plastics transport monitoring on rivers has provided valuable and promising results.** Remote-sensing based identification of plastics floating on rivers, combined with automated image analysis, is a very new approach at a global level, and is at an early stage of development. In this study, this approach was successfully piloted in Vietnam with plastic items that were automatically detected and analyzed over longer periods of time by cameras mounted on bridges. This positive outcome of the survey should provide the foundation for the Government of Vietnam to carry out longer-term plastic monitoring in order to increase knowledge about plastic pollution, establish baselines, and measure the impacts of policies and other measures over time. The simultaneous application of net trawls showed the potential to link results to remote sensing, and establish models to estimate total plastic loads, including of the load of submerged plastics, which is based on the automated detection of surface plastics. A high number of very valuable technical lessons were learned in this first pilot that could provide the foundation for the government to upscale plastic monitoring.

**Policies to address low-value and single-use plastic waste.** The survey results indicate that most of the plastic waste leakage at the studied sites was from a small number of items, many of which were single-use and low-value products. These included plastic bags and take-away plastic waste (for example, food packaging such as Styrofoam, plastic cutlery, plastic straws, and drink-stirrers). Therefore, policies are needed to reduce the input of low-value plastic products, as their use is becoming progressively restricted, worldwide, and Vietnam could benefit from other countries' experience in implementing waste reduction policies. A roadmap should be developed to phase-in the implementation of bans, restrictions, and taxes/fees on identified SUPs, which are very common in the tourism and retail sectors.

**Analyzing measures to address fisheries-related waste.** Given the extent to which fishing gear was identified in the field survey as one of the top two plastic items found in all coastal locations, in order to inform effective policy measures, further analysis is needed across the key sub-sectors (for example, ports, aquaculture, and capture fisheries). This would guide implementation of the Action Plan for Marine Plastic Waste Management in the Fisheries Sector, which was recently adopted by Vietnam's Ministry of Agriculture and Rural Development.

**Developing public awareness about the top 10 polluting plastic items.** The survey results, along with the preliminary market analysis of alternatives, highlighted the importance of improving public awareness about the negative impacts of plastic pollution. A substantial increase in educating citizens and youth about waste reduction, reuse, and the need to halt littering, is required to: reduce demand for low-utility plastic; support more cost-effective waste management infrastructure systems; and reduce littering, and the subsequent pollution of rivers and the ocean. In tandem with the previously mentioned plastic policy analysis and roadmap, the government should also develop an awareness-raising and communications strategy.

Other areas for further analysis include:

- a more extensive analysis of product alternatives that would include lifecycle costs and environmental impacts;
- an economic analysis in specific locations of the cost of the impact of plastic waste items;
- plastic ocean transport modelling/ocean current modeling to better understand the potential transboundary pathways of plastic waste; and
- up-scaling of integrated plastics river monitoring surveys through building on the lessons learned in this study's pilot surveys.


Photo: Katerina Morozova - Shutterstock

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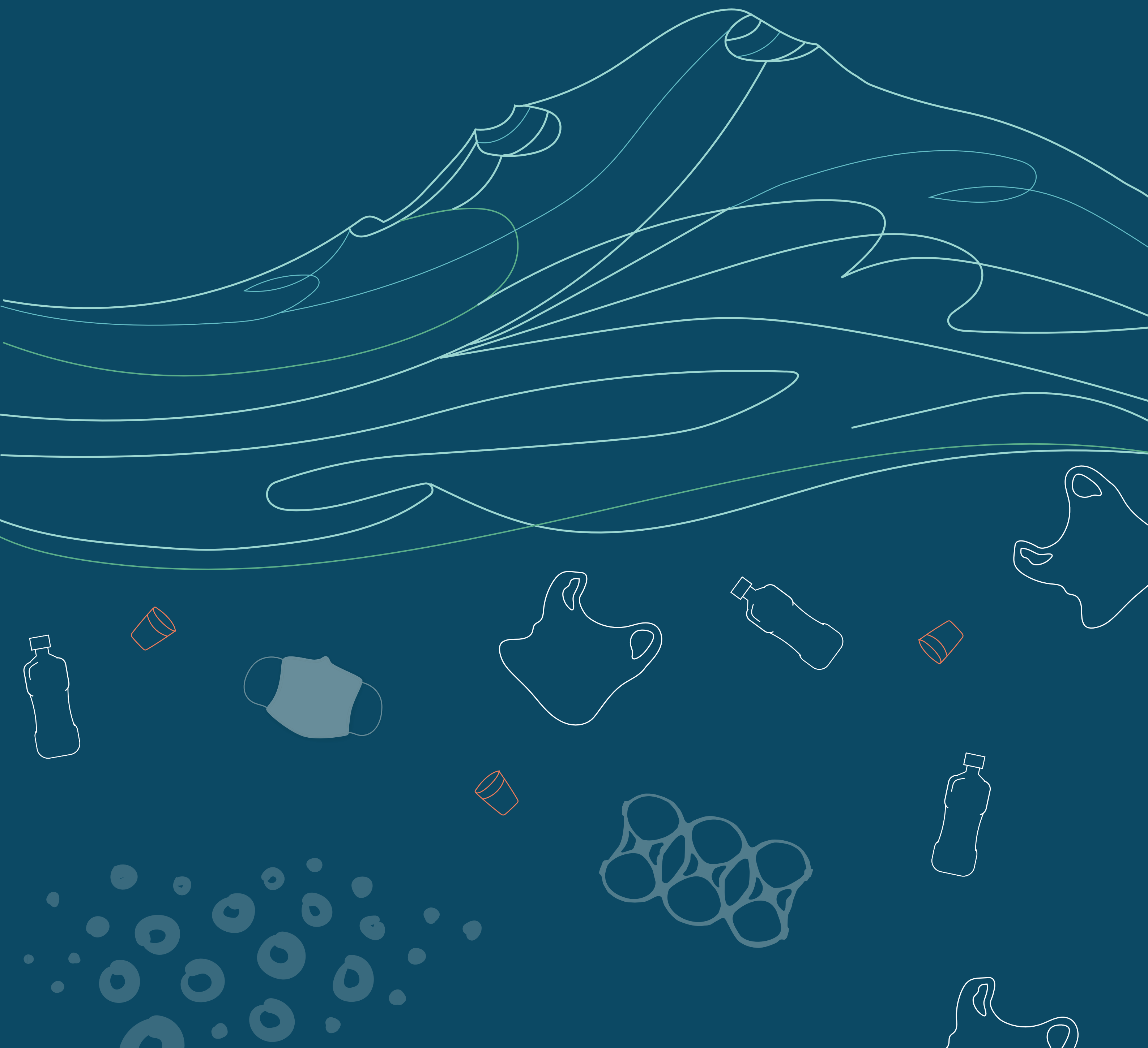

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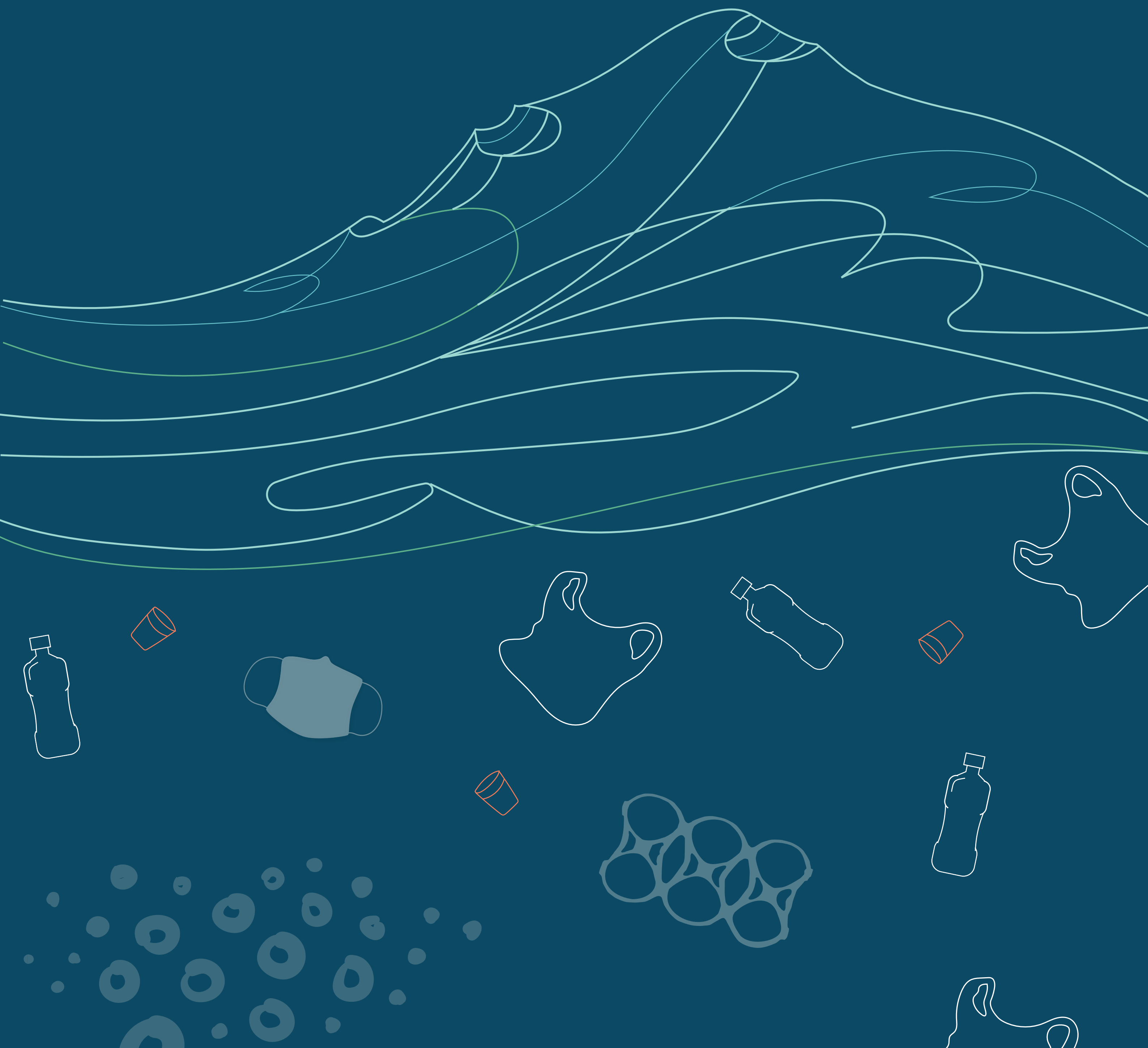
# 5. ANNEXES



## ANNEX 2.1.A:

# SURVEY DATA SHEET TEMPLATES

Table 22:
**SURVEY SITE CHARACTERIZATION SHEET**

| Overview of survey location | | | |
|---|---|---|---|
| Shoreline Debris<br>Debris density data sheet | Organization | | |
| | Surveyor name | | |
| | Phone number | | |
| | Date | | Date of this survey |
| | | | |
| Shoreline code (ID) | | | Unique code for a beach |
| Shoreline name | | | Name for section of shoreline (e.g, beach name, park) |
| Location | | | Ward, District, Province |
| Time start/end | Start | End | |
| Coordinates of start of shoreline site | Longitude | Latitude | Record in both corners if width > 6m. If transect, record at water's edge. |
| | | | |
| Coordinates of end of shoreline site | Longitude | Latitude | Record in both corners if width > 6m. If transect, record at back of shoreline. |
| | | | |
| Photo | | | Photo ID |
| Characteristics of shoreline | | | |
| Width of beach (100m) | | | Length measured along the midpoint of the coast (in metres) |
| Substratum type | | | Sand, Gravel, Coral,… |
| Substrate uniformity | | | Percent coverage of the main substrate type (%) |
| Tidal range | | | Maximum & Minimum vertical tidal range. Use tide chart (usually in feet) |

| Overview of survey location | | | |
|---|---|---|---|
| Tidal distance | | | Horizontal distance (in metres) from low – to high – tide line. Measure on beach at low and high tides or estimate based on wrack lines. |
| Back of shoreline | | | Describe landward limit (e.g; vegetation, rock wall, cliff dunes, parking lot). |
| Aspect | | | Direction you are facing when you look out at the water (e.g: northeast) |
| Location & land use | Resident | Not used yet | |
| | Tourist | | |
| | Agriculture | | |
| | Aquaculture | | |
| Nearest town | | | Name of nearest town |
| Nearest town distance | | | Distance to nearest town (km) |
| Nearest town direction | | | Direction to nearest town (cardinal direction) |
| Nearest river name | | | If applicable, name of nearest river or stream. If blank, assumed to mean no inputs nearby. |
| Nearest river distance | | | (km) |
| Nearest river direction | | | Direction to nearest river/stream |
| Rive/creek input to beach | Yes | No | Whether nearest river/stream has an outlet within this shoreline section |
| Pipe or drain input | Yes | No | If there is a storm drain or channelized outlet within shoreline section |

Source: *Lippiatt et al., 2013*

Table 23:
**FIELD SURVEY DATA SHEET**

| The name of the survey site | | | | |
|---|---|---|---|---|
| ID transect | | | | |
| Time | | Start | | End |
| Date: dd/mm/yy | | | | |
| Length of transect (m) | | | | |
| Width of transect (m) | | | | |
| **ID** | **Item** | **Size(1-2)** | **Number** | **Weight** |
| P | PLASTIC | | | |
| 1 | Hard plastic fragments | | | |
| 2 | Soft plastic fragments | | | |
| 3 | Film plastic fragments | | | |
| 4 | Crisp/Sweet packages | | | |
| 5 | Food wrappers | | | |
| 6 | Other wrappers | | | |
| 7 | Beverage bottles (PET) | Size 1 (0-500ml) | | |
| | | Size 2 (> 500ml) | | |
| 8 | Other Beverage bottles (HDPE,...) | | | |
| 9 | Containers and bottles | | | |
| 10 | Cleaner and cosmetics bottles (shampoo bottles, cosmetic jars, shower gel bottles e.g) | Size 1 (0-100ml) | | |
| | | Size 2 (>100ml) | | |
| 11 | Bottle caps (HDPE) | | | |
| 12 | Cigar/Cigarette butts | | | |
| 13 | Plastic bags | Size 1 (0-5kg) | | |
| | | Size 2 (>5kg) | | |

| | | | | |
|---|---|---|---|---|
| 14 | Styrofoam food containers | | | |
| 15 | Single-use plastic products (Cups, Utensils…) (PET) | | | |
| 16 | Single-use plastic products (Cups, Utensils…) (PP) | | | |
| 17 | Straws | | | |
| 18 | Fertilizer bags or containers | | | |
| 19 | Plastic strings, cords and ropes | | | |
| 20 | Personal hygiene products | | | |
| 21 | Medical products | | | |
| 22 | Fishing gear 1: Fishing plastic ropes, net pieces, fishing lures & lines, hard plastic floats | | | |
| 23 | Fishing gear 2: Polystyrenes - ESP, Buoys & Floats | | | |
| 24 | Other plastic | | | |
| 25 | Lighters | | | |
| M | METAL | | | |
| G | GLASS | | | |
| R | RUBBER | | | |
| P | PAPER | | | |
| C | CLOTH/FABRIC | | | |
| O | MIXED WASTE | | | |
| L | Large Debris items (>1m)/ Large Debris items (> foot of -0.3m) | | | |

| | | | | | |
|---|---|---|---|---|---|
| | Item type (vessel, net, etc.) | Status (sunken, stranded, buried) | Approximate width (m) | Approximate length (m) | Description/ photo ID # |
| | | | | | |

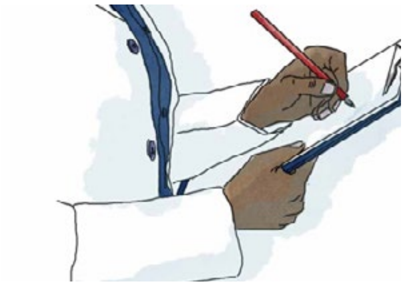
*Notes on debris items, description of "Other/unclassifiable" items, and so on.*

## ANNEX 2.1.B:

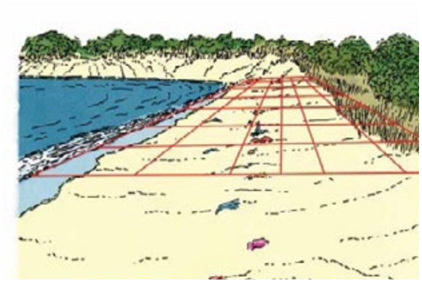
# SURVEY PROTOCOLS

### COASTAL SITES

- Before arriving at sites
  Surveying should take place at low tide. When planning the monitoring schedule, consult tidal charts to determine the correct time for low tide.
- Working at sites

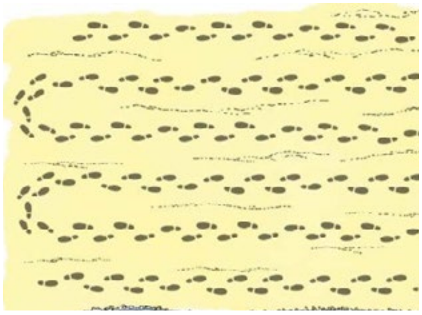


Step 1: Fill out the site characterization sheet



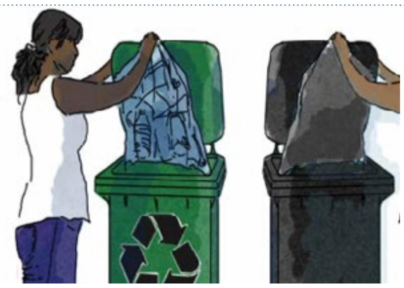
Step 2: Identify a section of 100m on each beach. Each 100m-section is divided into 20 equal sections, each with a width of 5m, and perpendicular to the shore.


Step 3: Select 4 randomly divided sections on the beach, herein called transects



Step 4: In each transect, walk from the water's edge to the back of the shoreline and collect waste items that are larger than 2.5cm (Plastic, metal, grass, rubber, cloth, wood, others)

Step 5: Sort, count, and weigh the waste items collected, and fill out the data sheet. Audit the brands of the waste and write these on the brand audit sheet

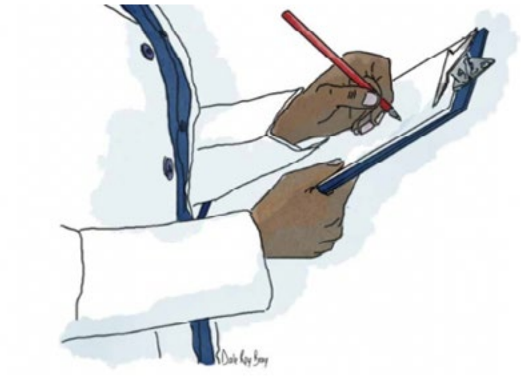


Step 6: Throw the waste collected into the trash bin

*Photo source: (Lippiatt, 2013; WIOMSA, n.d)*

## RIVER SITES

- Working at sites



**Step 1:** Fill out the site characteristics sheet

**Step 2:** Select quadrat: In the selected area, a one-square metre quadrat is placed every few (10 to 20) metres where digging is possible (for example: tidal flooded areas, areas of periodic flooding, and areas close to creek outlets). Pick up the waste on the surface of the quadrat.

**Step 3:** Collect the waste items which are larger than 2.5 cm (in at least one dimension) in the quadrat to a depth of 30cm

**Step 4:** Clean, sort, count, and weigh the waste items collected, and fill out the data sheet. Audit the brands in the waste, and write these on the brand audit sheet

**Step 6:** Throw the waste collected into the trash bin

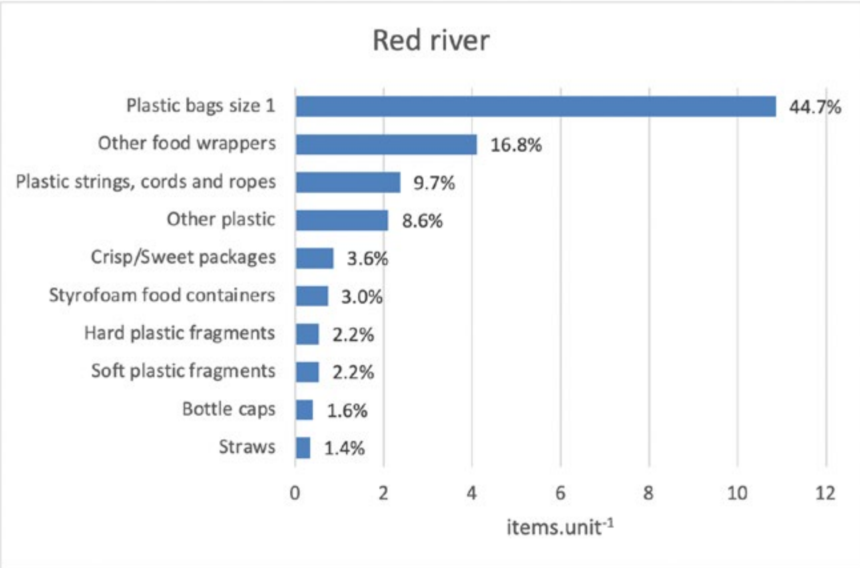
*Photo source: (Lippiatt, 2013; WIOMSA, n.d)*

## ANNEX 2.1.C:

# SURVEY RESULTS FROM RIVER SITES

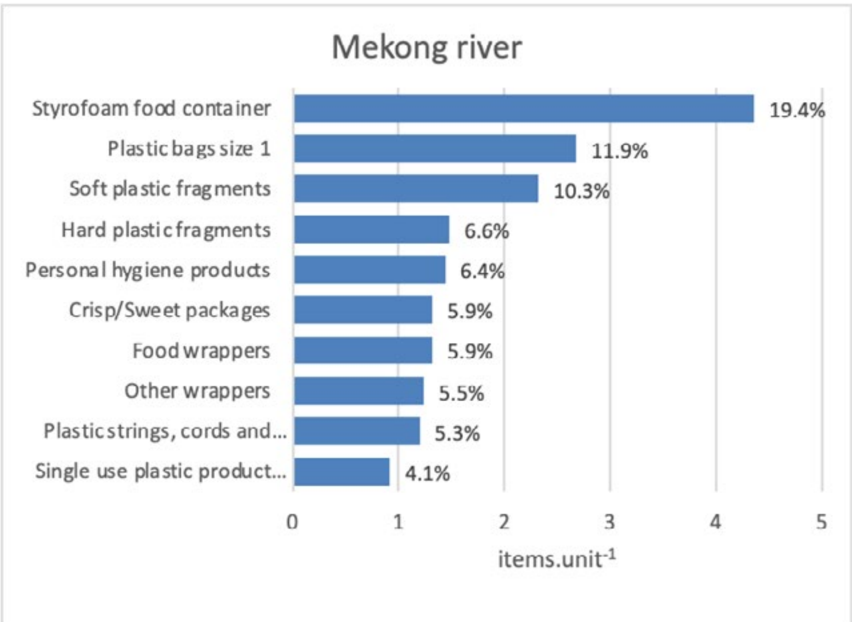
**In the Red river** (Lao Cai and Hai Phong), 20/28 subcategories of plastic were detected, and the top 10 items accounted for 93.4% of the total plastic waste.

Figure 32:
**TOP 10 PLASTIC WASTE ITEMS AT RED RIVER SITES**



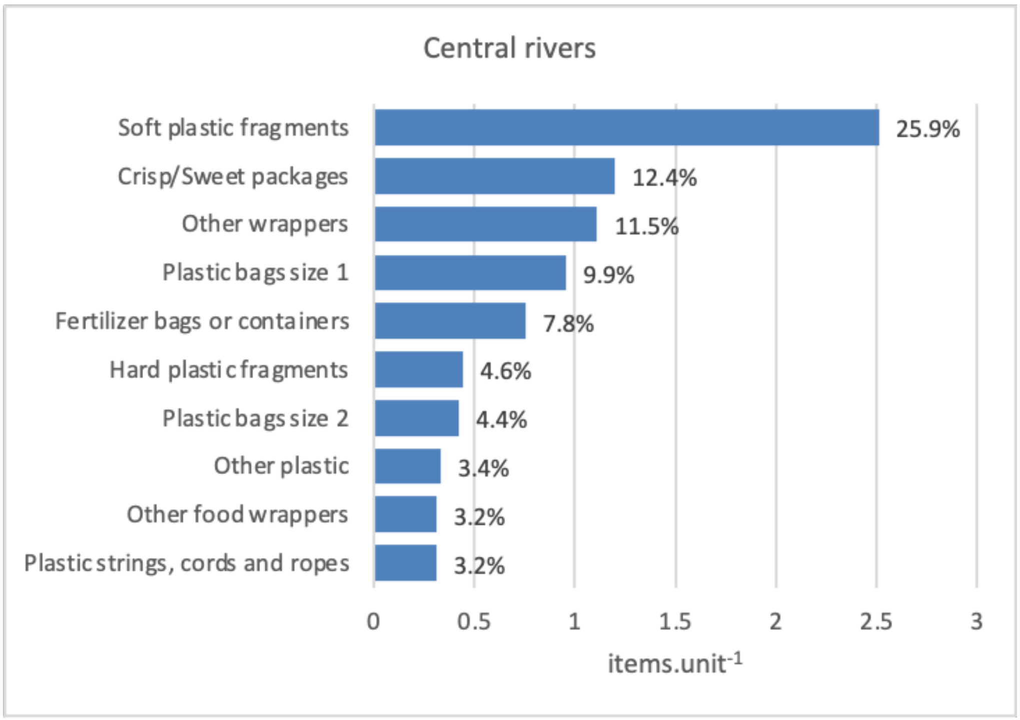

**In the Mekong river** (Can Tho and Soc Trang), there were 25/28 **plastic waste categories,** and the top 10 items accounted for 81.5% of all the plastic waste items recorded.

Figure 33:
**TOP 10 PLASTIC WASTE ITEMS AT MEKONG RIVER SITES**



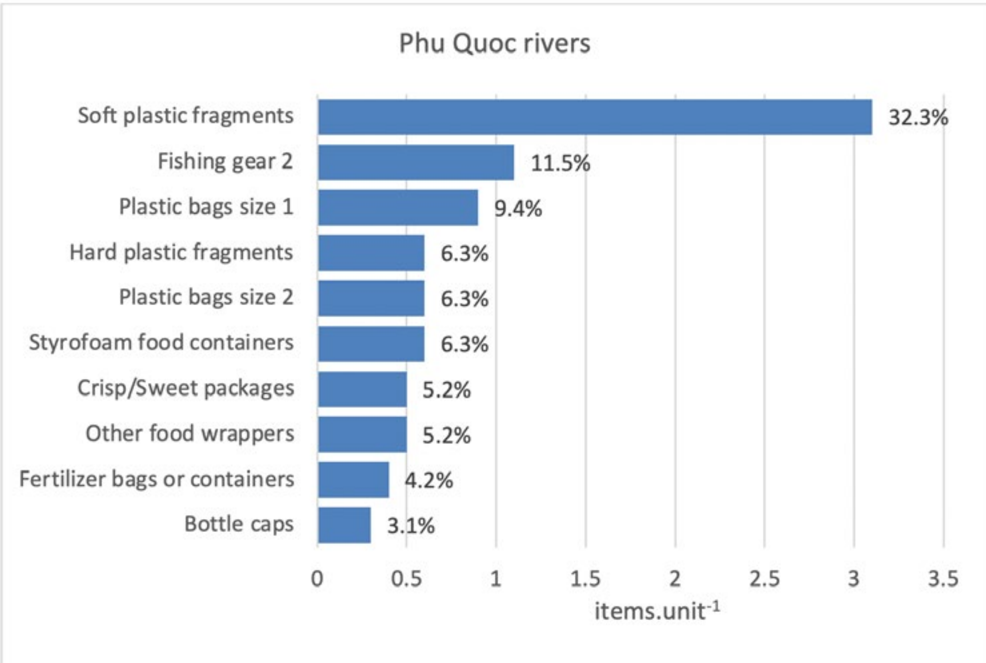
**Riverbanks in Central provinces** (Hue, Quang Nam, Da Nang, Khanh Hoa), 22/28 sub-categories of plastic waste were detected, and the top 10 items accounted for 86.2% of all items recorded.

Figure 34:
**TOP 10 PLASTIC WASTE ITEMS AT CENTRAL PROVINCES RIVER SITES**



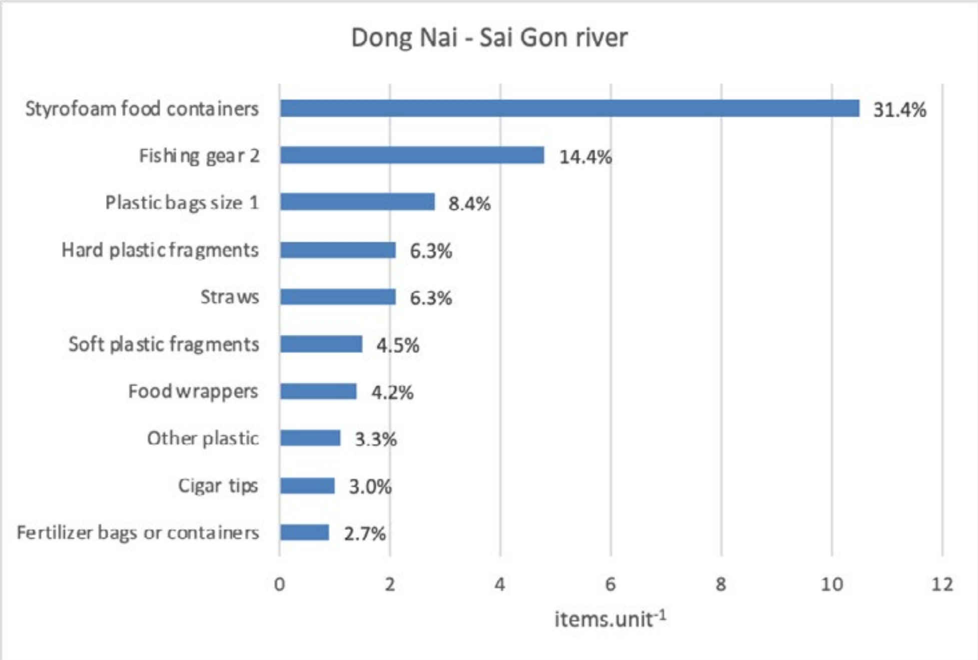

**Phu Quoc** rivers had 17/28 sub-categories of plastic **waste** and the top 10 items accounted for 89.6% in density.

Figure 35:
**TOP 10 PLASTIC WASTE ITEMS AT PHU QUOC RIVER SITES**



**Dong Nai – Sai Gon** river (Ho Chi Minh) had 21/28 subcategories of plastic and the top 10 items accounted for 84.4% in number.

Figure 36:
**TOP 10 PLASTIC WASTE ITEMS AT DONG NAI-SAI GON RIVERBANK SITES**




**At each river site location, single-use plastics (SUPs) account for a significant amount.** At the river sites, SUP items accounted for between 66% and 93% (although the amount of waste collected was different for each site). The percentage of SUP waste at river sites, by location, is presented in Figure . The locations with highest fractions of SUP waste were Soc Trang (93%), Thua Thien Hue (80%), Hai Phong (77%), and Da Nang (76%). The top three locations that had the highest density of SUP waste items were Can Tho (24.9 items/unit), Lao Cai (22.9 items/unit), and Ho Chi Minh City (21.9 items/unit).


Photo: xuanhuongho - Shutterstock

Figure 37:
**SINGLE-USE PLASTIC WASTE DENSITY AT EACH RIVERBANK LOCATION**

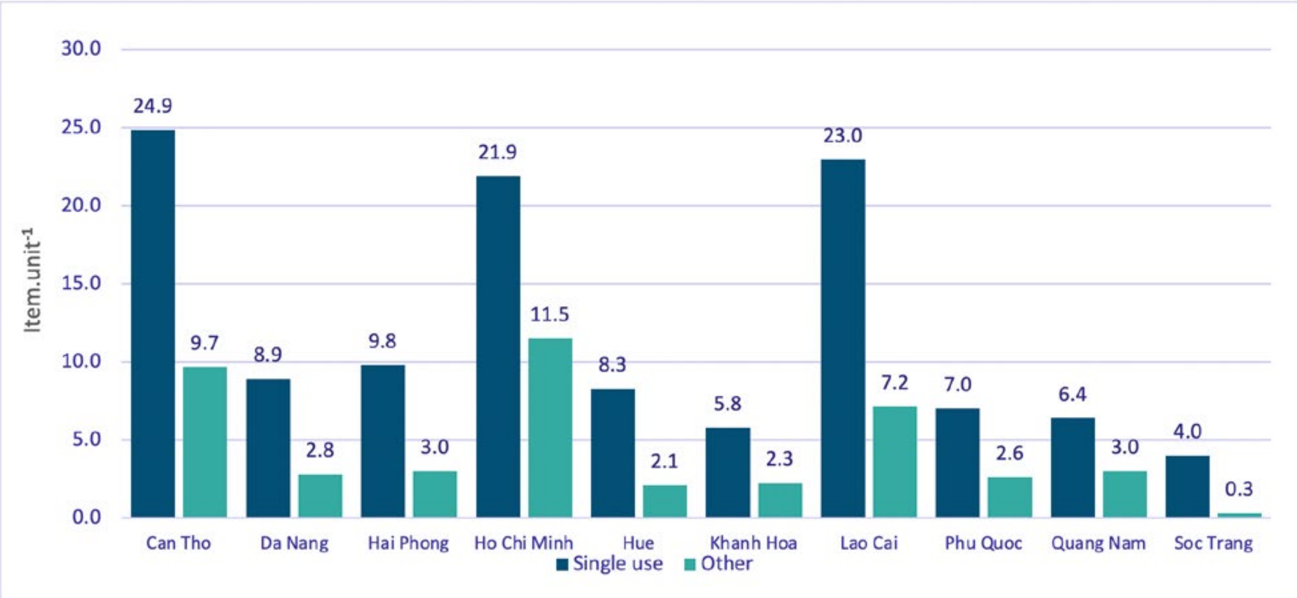



Table 24:
**SINGLE-USE PLASTIC WASTE DENSITY AT EACH RIVER SITE LOCATION**

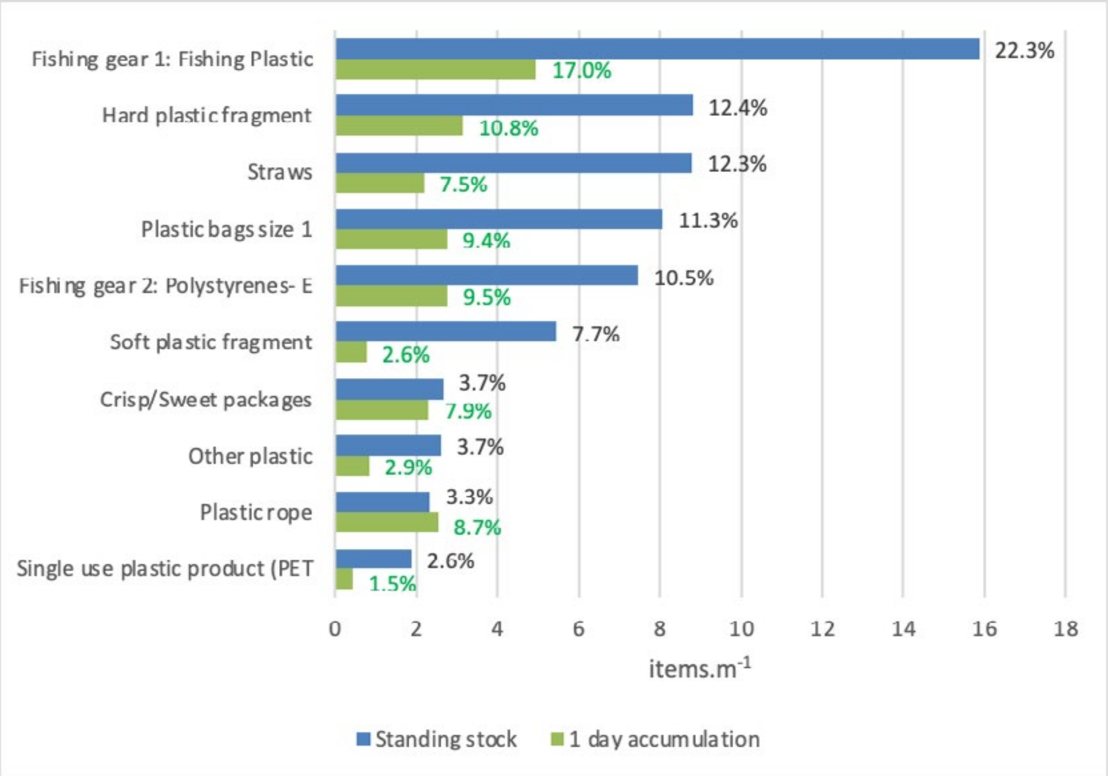
| Province | Single use (Density: item/unit) | Other (Density: item/unit | Total (Density: item/unit) |
|---|---|---|---|
| Can Tho | 24.9 | 9.7 | 34.5 |
| Da Nang | 8.9 | 2.8 | 11.7 |
| Hai Phong | 9.8 | 3 | 12.8 |
| Ho Chi Minh | 21.9 | 11.5 | 33.4 |
| Hue | 8.3 | 2.1 | 10.4 |
| Khanh Hoa | 5.8 | 2.3 | 8.1 |
| Lao Cai | 22.9 | 7.15 | 30.1 |
| Phu Quoc | 7 | 2.6 | 9.6 |
| Quang Nam | 6.4 | 3 | 9.4 |
| Soc Trang | 4 | 0.3 | 4.3 |

## ANNEX 2.1.D:

# SURVEY RESULTS FOR COASTAL SITES

Beaches in the **Northern subzone** (Hai Phong, Thua Thien Hue) were characterized by a large amount of *fishing gear 1* (standing stock: 22.3%, ), *hard plastic fragments* (12.4%, ranked second), and *straws* (12.3%, ranked third) (Figure 37).

Figure 38:
**STANDING STOCK AND DAILY ACCUMULATION OF THE TOP 10 PLASTIC WASTE ITEMS ON COASTAL SITES IN THE NORTHERN SUBZONE (DENSITY)**




At coastal sites in the **Transitional subzone** (Da Nang, Quang Nam, Khanh Hoa) and in the **Southern subzone** (Ho Chi Minh, Soc Trang, Phu Quoc), *soft plastic fragments* (21.7%, in the Transitional subzone, 19.9% in the Southern subzone) was the top plastic waste item, followed by *fishing gear 1* and *fishing gear 2.* These three plastic categories together comprised 53% of the total standing stock and 46% (Transitional subzone sites) and 52.6% (Southern subzone sites) of daily accumulation. Additionally, *Styrofoam food containers* were common in the Southern subzone sites (10.1%, ranked fourth) and the Transitional subzone (4.4%, ranked sixth). However, this plastic category was found less in the Northern subzone, and was not even in the top 10 list (accounting for only 1.4%).

Figure 39:
**STANDING STOCK AND DAILY ACCUMULATION OF THE TOP 10 PLASTIC WASTE ITEMS AT COASTAL SITES IN THE TRANSITIONAL SUBZONE (DENSITY)**

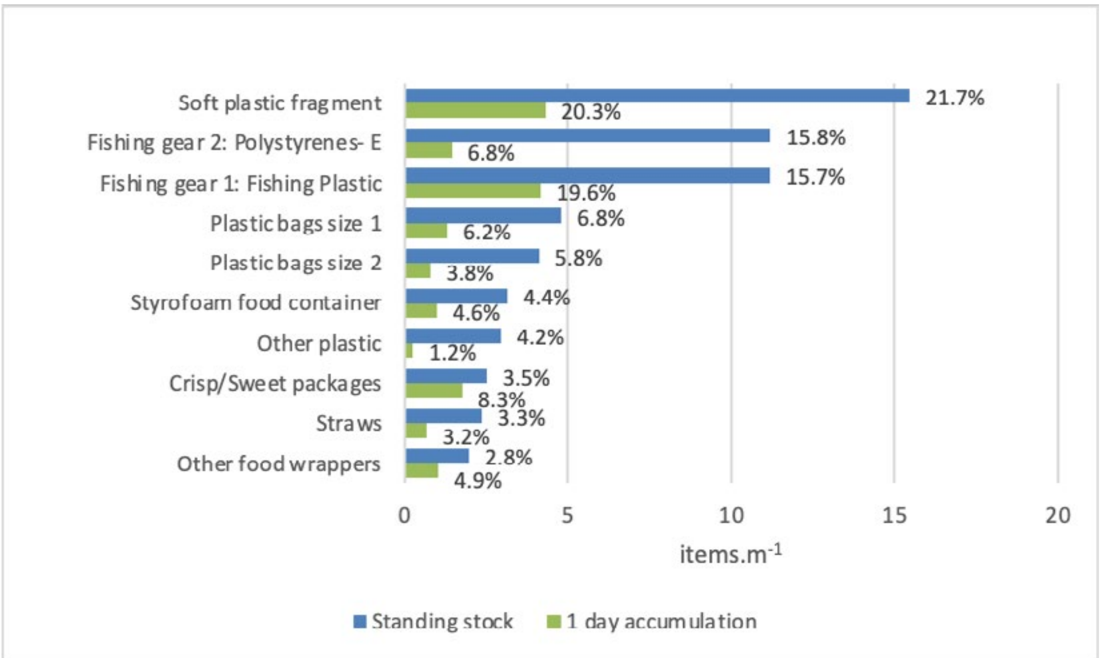
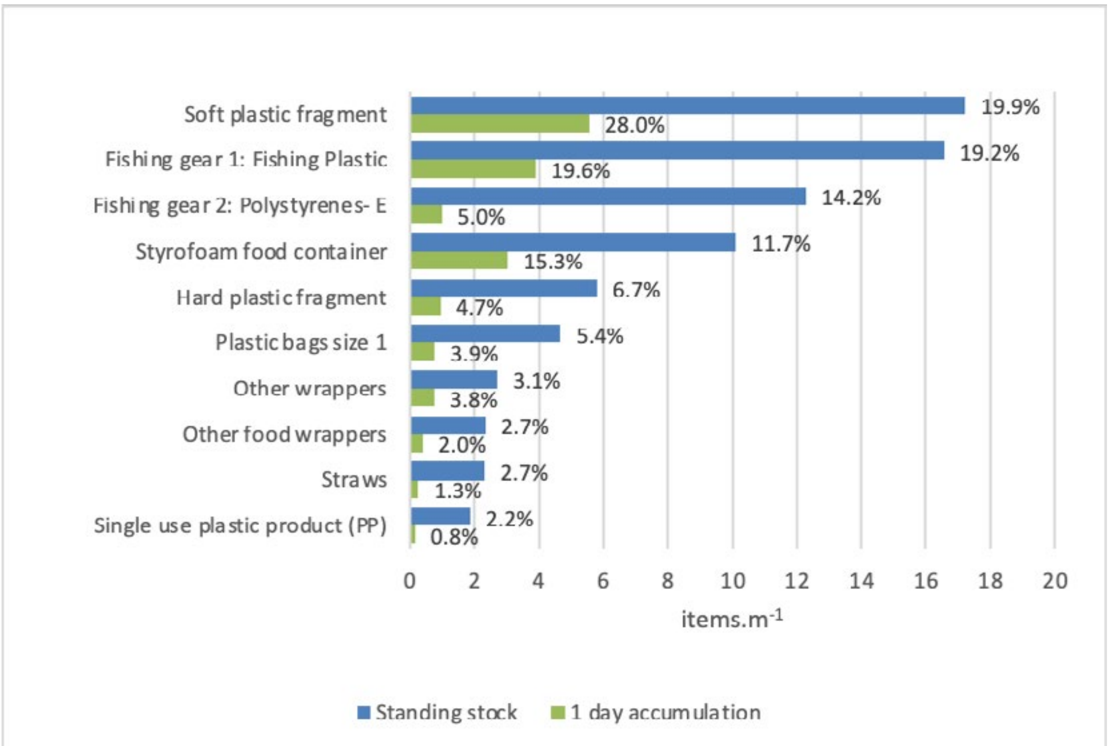



Figure 40:
**STANDING STOCK AND DAILY ACCUMULATION OF THE TOP 10 PLASTIC WASTE ITEMS AT COASTAL SITES IN THE SOUTHERN SUBZONE (DENSITY)**



**The top 10 items accounted for 84% in rural sites and 87% in urban sites.** The composition of plastic waste was also undifferentiated between rural and urban areas, but their fraction was different. In rural sites, *soft plastic fragments* were the most frequently found items (20.6%). The second most abundant sub-category was *fishing gear 2* (15.4%), followed by *fishing gear 1*. These sub-categories were also ranked in top three in urban areas. Even though there was a noticeable difference in the densities of plastic debris between the rural and urban areas (in rural coastal sites, the top 10 items accounted for from 3 to 21 item.m$^{-1}$, and in urban coastal sites, the top 10 items only accounted for from 1 to 13 item.m$^{-1}$). Also, the composition of plastic categories was very similar between the two environments.

Figure 41:
**STANDING STOCK AND DAILY ACCUMULATION OF THE TOP 10 PLASTIC WASTE ITEMS AT RURAL COASTAL SITES (DENSITY)**

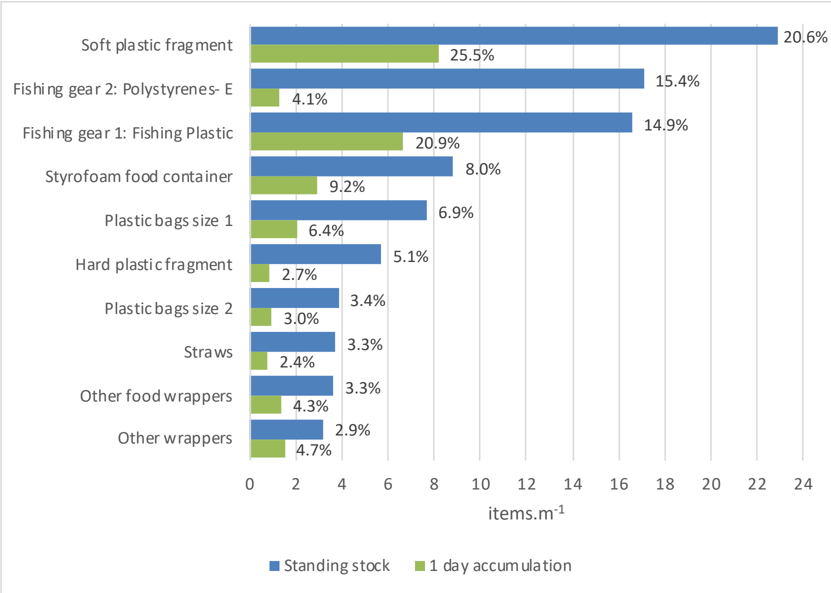
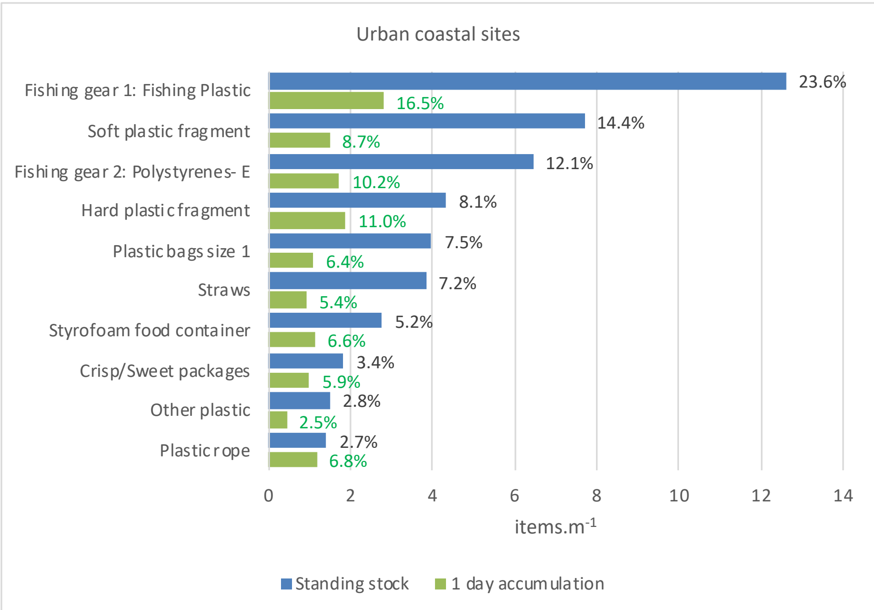



Figure 42:
**STANDING STOCK AND DAILY ACCUMULATION OF TOP 10 PLASTIC WASTE ITEMS AT URBAN COASTAL SITES (DENSITY)**



**The top 10 items accounted for 87% at non-tourism sites and 85% in tourism sites.** The composition of plastic waste was similar between tourism and non-tourism areas. In non-tourism sites, *soft plastic fragments* was the most frequently found category in density (31%). Combined with *plastic bags size 1*, these two categories added up to 42.8%. The subsequent most abundant types were *fishing gear 1 and 2*, both of which accounted for 30%. At tourism sites, *fishing gear 1* (18.4%) and *fishing gear 2* (16.2%) were the top two items, followed by *Styrofoam food containers* (9.6%, and 2.9% at non-tourism sites). At non-tourism sites, *straws* accounted for only 2.4% in standing stock, but at tourism sites, this percentage was 6.7%

Figure 43:
**STANDING STOCK AND DAILY ACCUMULATION OF THE TOP 10 PLASTIC ITEMS AT NON-TOURISM COASTAL SITES (DENSITY)**

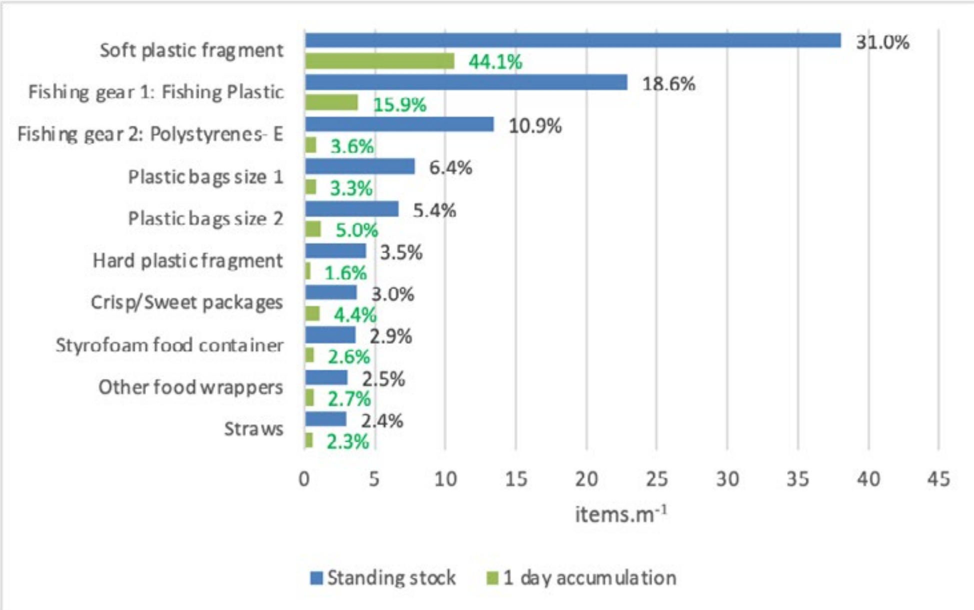
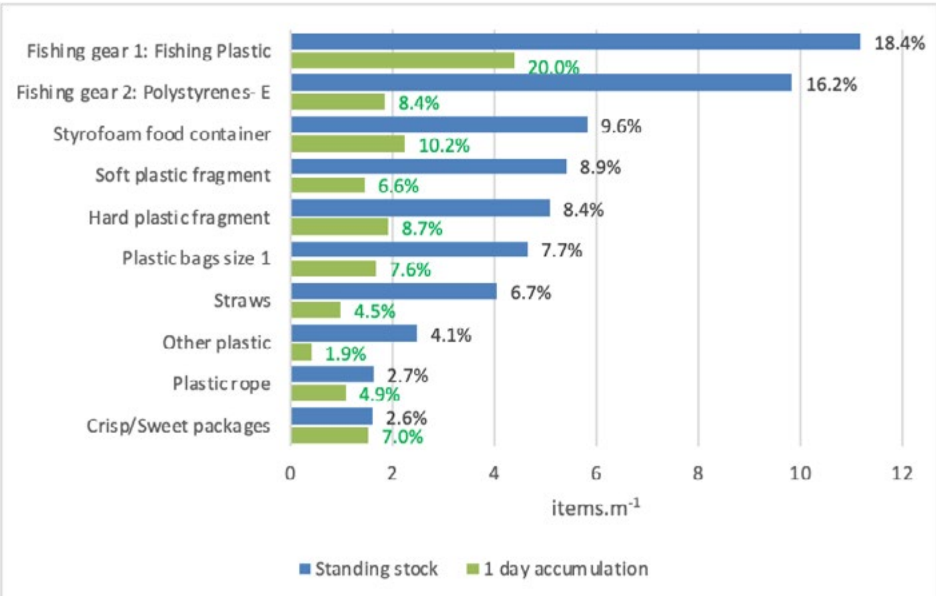



Figure 44:
**THE STANDING STOCK AND DAILY ACCUMULATION OF THE TOP 10 PLASTIC ITEMS AT TOURISM COASTAL SITES (DENSITY)**



## ANNEX 2.2.A:

# KEY METHODOLOGIES – DATA COLLECTION, PLASTIC DETECTION, CLASSIFICATION AND QUANTIFICATION, PLASTIC FLOW CALCULATIONS AND MODELLING

### Overview of methodologies adopted for data collection

**Monitoring of floating plastics on rivers through remote sensing:** This method utilized 3 GoPro cameras installed on bridges (Figure 45) to monitor plastic waste transportation at the selected rivers in three cities (Hai Phong, Hai Duong, and Sapa). Installed cameras survey lasted 8 hours each per camera yielding a 24-hour footage per survey site. Images were subsequently analyzed for waste quantities and types using an automated artificial intelligence (AI)-based approach.

Figure 45:
**CAMERA INSTALLATION AT THE BRIDGE.** CAMERAS WERE INSTALLED AT SEVERAL CROSS SECTIONS ALONG THE RIVERS TO RECORD FLOATING PLASTICS. RBG CAMERAS WITH DESIRED RESOLUTION OF 15-20 MO AND 4K VIDEO RECORDING WERE UTILIZED.

**Monitoring of plastics on rivers and riverbeds through unmanned aerial vehicles (UAV):** This method employs a two-step approach to monitor plastics on shore and larger waste accumulations. The first captures a high-level overview of the area of interest around the bridge location near each river survey site at a 60m height with an automated flight pattern. The second captures locations of waste accumulations using a drone pilot. After capturing, selected high-polluted locations are monitored in detail at 6m height at a geospatial resolution (GSD) of ~0.2cm. Obtained high-resolution imagery obtained at 6m were subsequently analyzed with an automated AI method.

For automated plastic quantification, a UAV was deployed to capture floating and deposited plastics along the river and riverbanks (Figure 46). Recorded imageries were fed into APLASTIC-Q model to detect and analyze of plastics pollution in terms of waste quantity and waste types.

Figure 46:
**UAV OPERATION AT A SURVEY LOCATION.** AT SELECTED LOCATIONS, 2 SETS OF IMAGES WERE TAKEN (1 HIGH SPATIAL RESOLUTION CAPTURED AT HIGH FLIGHT ALTITUDE OF 60 - 100M AND VERY HIGH SPATIAL RESOLUTION CAPTURED AT LOW FLIGHT ALTITUDE OF 6M) AS SHOWN.

The area size of the high-altitude flights covers ~250 meters each upstream and downstream of a survey location. The upper and lower edges of the survey locations are fixed at 100m from the riverbanks or up to the river dike.

The area size of each low-altitude flight covered approximately 10x10 meters with focus on the accumulated plastic waste areas. Depending on the local features of the site, a number of low altitude flight were taken to ensure a good representation of the plastic pollution.

These surveys included areas of high and medium density of plastic waste, and potential areas with visibly different types of plastic waste. The method possesses the robustness to detect and quantify waste in the imagery and classify waste types for the various wastes detected.

**Monitoring of submerged plastics in rivers through net trawls:** With this approach, multiple nets are exposed to the river in various depths. The nets (Figure 47) filter considerable volume of water over a timeframe (approximately 45 minutes in this study). A simultaneous flow velocity measurement was used to determine flow rate through the nets thus resulting in a plastic concentration. Repeated measurements under different conditions led to the determination of an annual load via the correlation between transport and discharge. The use of automated camera enables the correlation between detectable plastic (mostly surface floating) and total transported plastic (except very large particle). Thus, camera observations enabled calculation of total plastic transport.

Figure 47:
**FINAL DEVICE CONFIGURATION OF NET TRAWLS.** NETS ARE ARRANGED IN DIFFERENT DEPTHS. AT EACH RIVER CROSS-SECTION, 1-7 VERTICAL PROFILES ARE DISTRIBUTED OVER THE ENTIRE WETTED AREA, TO YIELD A MAXIMUM OF 35 SAMPLING POINTS FOR EVERY DEPLOYMENT. NET TYPES AND MESH SIZES ARE SELECTED ACCORDING TO PREVAILING BOUNDARY CONDITIONS AT THE MEASURING SITE.


## Additional considerations during data collection

To enhance river monitoring, relevant data on current status of the river network, hydrological data (such as flow rate, discharge, water quality), as well as topographical data (such as cross section of rivers, water infrastructure etc) were collected. The current use of water resources and waste discharge in Thai Binh, Thack Khoi, Chanh Duong River and Cat Stream were investigated. In addition, point-source discharges (both in flow and quality) were identified in the river basin and stream. Relevant local stakeholders were also identified, and institutional settings were mapped and included in later consultations.

## Data Analysis

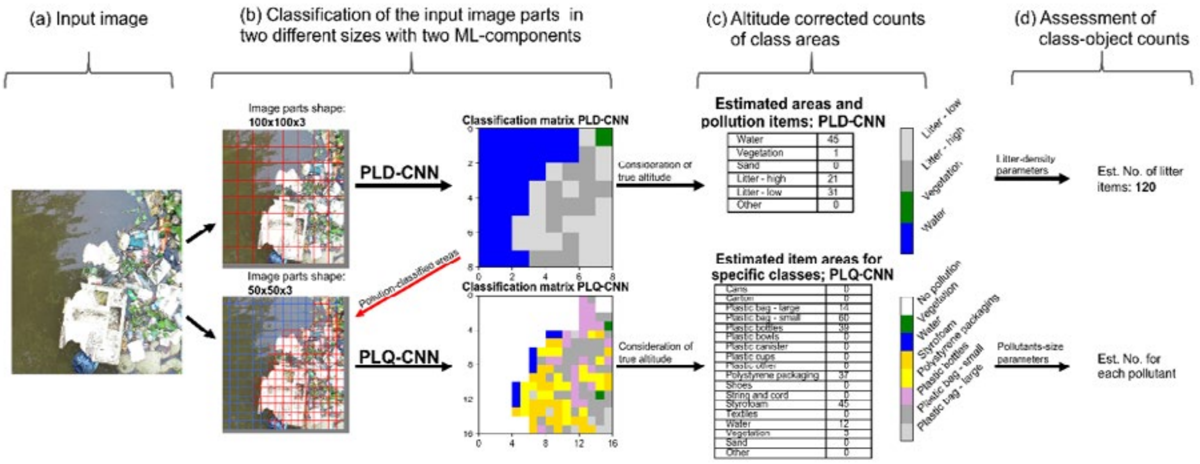
The method 'Machine learning for aquatic plastic litter detection, classification and quantification' (APLASTIC-Q) was utilized for data analysis. APLASTIC-Q is based on two convolutional neural networks [16] (CNNs). Input images from low altitudes (6m) with high resolution drone overflights. Subsequently, each image is partitioned into two different ways resulting in two different sets of image tiles. APLASTIC-Q can process images (file formats: JPG, PNG, TIFF), videos (MP4, MOV, AVI) and orthomosaics [17] (TIFF).

16 Convolutional neural network (CNN) is a class of deep neural networks, most applied to analyzing visual imagery. CNNs use relatively little pre-processing compared to other image classification algorithms. Which is why the network learns to optimize the filters or convolution kernels that in traditional algorithms are hand-engineered.

17 Orthomosaic, or Ortho-rectified photo mosaic is created with a set of drone survey images. The images have overlaps in between the set and are all geo referenced. The set gets processed with a photogrammetry software, common software's are Pix4D-mapper or Agisoft Metashape.

The first CNN comprises tiles with a shape of 128x128x128 pixels. It detects if there is plastic in a tile and labels them either as Water, vegetation, Litter-high, Litter-low, Sand and others. The classification of the first CNN restricts the application of the second CNN which comprises tiles with 64x64x3 pixels. The second CNN is restricted to evaluate only areas in which pollution was detected using the Litter-high and Litter-low labels. The two output classification maps are then used to estimate the number of different types of debris objects in the input image and the number of pollutants for each type of pollutant i.e. P – bottles PET (P for plastic, PET for Polyethylene terephthalate), P – polystyrene, P – bags LDPE (Low-density polyethylene), etc. Labels used for the second CNN do not only comprise plastic waste items but also non plastic (NP) waste like rubber, metal, and glass thus enabling assessment on the relative abundances of plastic waste over the analyzed study sites.

Figure 48:
**APLASTIC-Q (Wolf et al. 2020) ANALYSIS OF IMAGERY BASED ON CONVOLUTIONAL NEURAL NETWORKS TO QUANTIFY POLLUTANT ITEMS NUMBERS, WASTE TYPES, AREAS COVERED AND GIVE A VOLUME ESTIMATE.** APLASTIC-Q SOFTWARE CAN GIVE ASSESSMENTS FOR THE QUANTITIES AND FOR WASTE TYPES FOR SURVEY SITES, WHERE THE ASSESSMENTS CAN BE USED AS ACTIONABLE INFORMATION.




Waste area and waste volume assessment per input imagery is done with the two output classification maps, the consideration of altitude and litter parameters. The consideration of altitude assigns a real-world area, which one tile covers. The litter parameters consider areas which are classified as Litter-low and hence do not contain many waste items and areas which are classified as Litter-high and hence can often contain even piled up waste. For the waste area assessment, the tiles which are classified as Litter – low are considered 50% polluted, the tiles for Litter – high are considered as 100% polluted. For the waste volume assessment, the tiles which got classified as Litter – low have been estimated to be 7cm thick on average, the tiles for Litter – high are estimated to be 30cm thick on average. For example, if a tile with dimension 128x128x3 was detected as litter – high with the geospatial resolution (GSD) 0.2cm, the real-world area is 0.065m²: this leads to a waste area assessment for that tile of 0.065m² and a waste volume assessment for that tile of 0.019m³. These area and volume assessments are added up for all tiles analyzed of the input image.

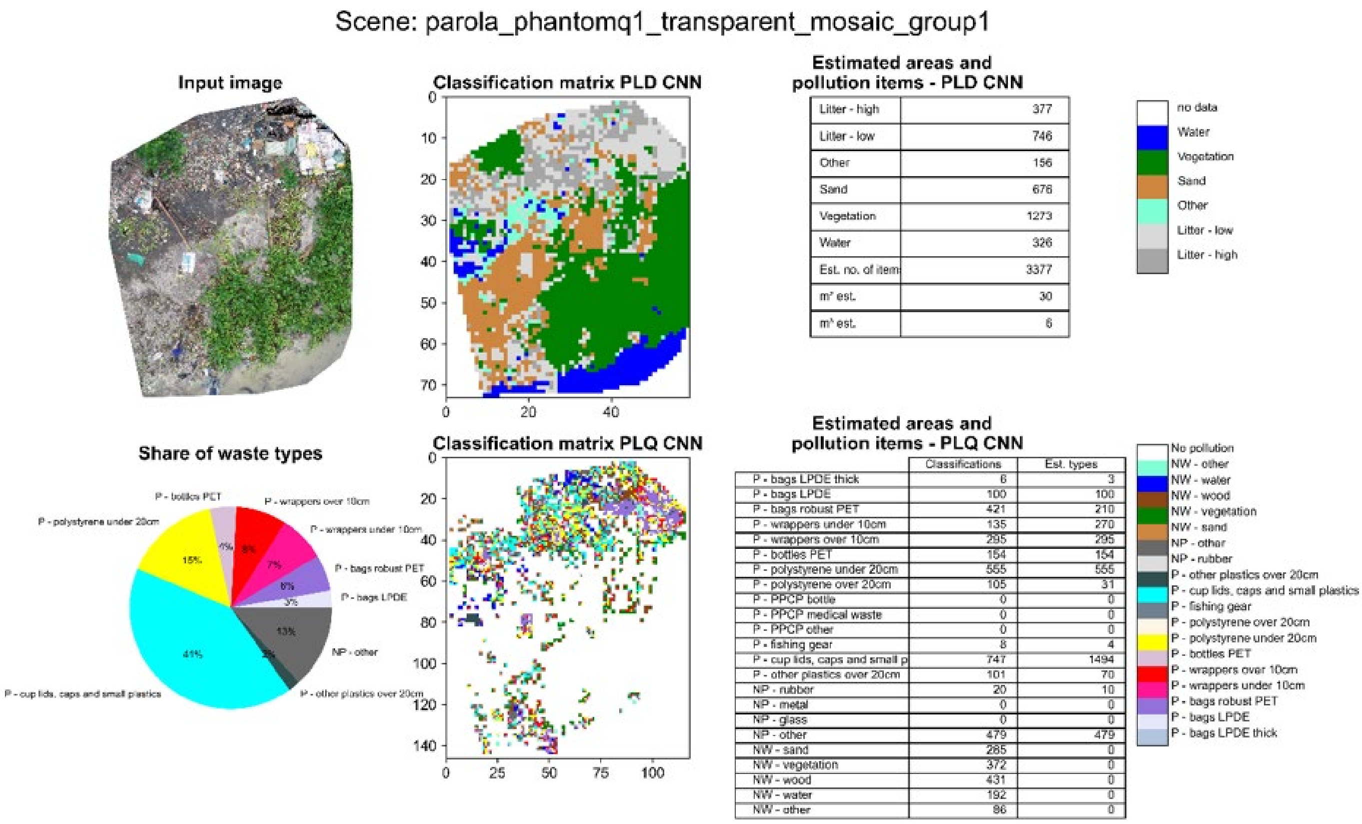
## Plastic Detection, Classification of plastic types, and Quantification of Plastics

The imagery produced by the data collection approaches are analyzed in terms of various plastic waste statistics. These statistics involve assessments for (i) waste quantities in terms of abundances along with areas and waste volume assessments for (ii) waste types in terms of numbers of items per waste type and top 10 identified plastic items with relative abundance.

Several types of imagery are collected as part of this plastics study. Each set of imagery has different advantages for data analysis. (1) The set of high-altitude overview imagery is used to identify plastic hotspots and visually contextualize the study sites. (2) The set of true-color low altitude with very high-resolution images to monitoring waste hotspots was analyzed regarding waste quantity and waste types. In addition, the images from the low-cost cameras installed on bridges are analyzed with respect to these litter statistics as well.

The data analysis method is based on computer vision and machine learning algorithms, it is briefly described in the following section, more details can be found in Wolf et al. (2020). The method was established for a World Bank-funded plastic diagnostics study in Cambodia (2019) (Wolf et al. 2020) and was further developed in this study. The data analysis method can detect and classify plastic debris in various aquatic environments including: River surfaces, banks near rivers, and beaches.

Figure 49:
**EXAMPLE OUTPUT OF APLASTIC-Q. IT GIVES AN ESTIMATE ON THE NUMBER OF WASTE ITEMS, AREA COVERED WITH WASTE, WASTE VOLUME ESTIMATE IN M3. MOREOVER, IT ESTIMATES THE WASTE TYPE ITEMS ALONG WITH THE PROPORTION OF THE WASTE TYPES FOR EACH IMAGE OR ORTHOMOSAIC**



## Assessment of plastic waste transportation based on data analysis

The assessment of waste emissions for the river monitoring is based on the methodology mentioned above as well. The waste assessment is in three steps:

1. Sections of the GoPro time-lapse images are analyzed according to the method above
2. The analysis results of the time-lapse images are processed using a plastic waste assessment approach mentioned below
3. Visualization of results bridge monitoring survey days

There are two methods how the plastic waste assessments have been processed at step (2), and the selection of these methods depend on local factors. When the waste transportation is on a high level, the method on assessment of plastic waste transportation through counting waste detections in single images was found to be more effective, as it also enables the detection of multiple plastic objects passing by at the same time. When only few items were transported by the river, the assessment of plastic waste transportation through clustering was found to be more effective, as it counts single plastics in a more accurate way, as multiple waste detections are necessary.

## Assessment of plastic waste transportation through clustering

Data from the monitoring analysis is saved in the form of large arrays. Each classes of both machine learning algorithms of the monitoring software are represented in its own array. Each entry in those arrays corresponds to the waste estimations of the Plastic Litter Detector (PLD) or Plastic Litter Quantifier (PLQ) respectively for one single image. The data from the PLD and the PLQ is divided into batches. The batch size depends on the time lapse interval, that is the time between the recording of two images and the chosen time resolution of the estimation. For Instance: The time lapse interval is 8 sec., it is estimated how many litter objects passed the river in one-hour intervals. In that case 1h/8s = 3600s/8s = 450 images are the batch size for the estimation. The waste analysis of the PLD is the focus of the estimation. The method looks for so-called clusters in the data. These are successive images, in which the PLD detected pollution. These clusters appear if a litter item was captured by the camera and is visible in multiple successive images and got classified successfully by the PLD. In the next step each cluster is analyzed individually. If the PLQ detected any kind of pollution in the images corresponding to the cluster, the waste litter counter for that data batch is increased by one. If not, the data from the PLD is assumed to be a false positive and the count does not increase.

## Assessment of plastic waste transportation through counting waste detections in single images

The waste analysis of the PLD is again the focus of the estimation. In this method, the data of each image is analyzed individually. If the PLD and the PLQ detected any kind of pollution in the image, the waste litter counter for that data batch is increased by the number of litter tiles the PLD detected. An upper limit constraint of maximally five litter objects per image is used. This is done that the effects of sun glitter, unsteady water or passing by boats are reduced to the waste estimations.

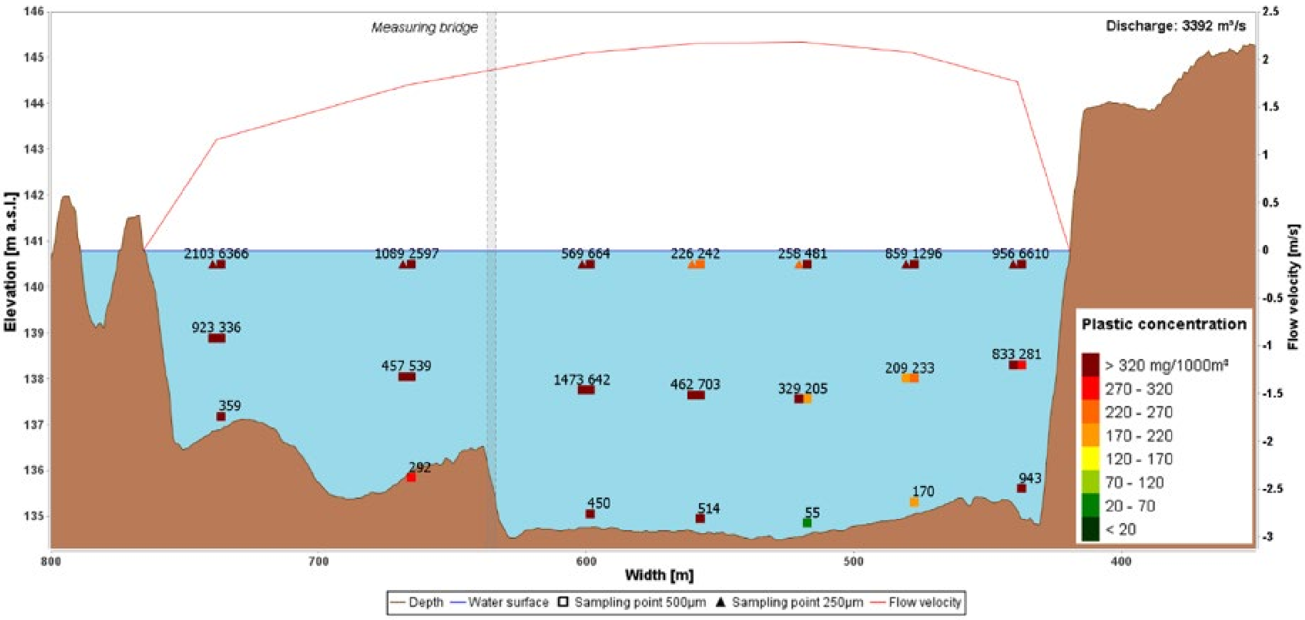
The best use case for that method is, if a continuous stream of a few small litter objects is present. This was the case for heavy polluted tributaries, like the Chanh Duong bridge at Hai Phong. This method is again independent of the flow speed, but it works well for rivers with continuous flow speeds.

The method cannot distinguish between on large litter object and many smaller ones. This may lead to an overestimation if larger objects float by, or it may lead to an underestimation if multiple objects float by and trigger the upper limit constrain. If a continuous waste detection is caused, in the form of a litter object that is trapped in the view of the camera or reflections in the surface of the water - this may lead to an overestimation, as the waste item is counted multiple times. This effect was mitigated by analyzing a section of the time lapse images. Through this, unwanted sections are cut out, like sun glitter, manmade buildings, and trapped waste items.

## Plastic Flow Calculations and Modelling

The calculated plastic concentration for an example coming from the Austrian Danube River can be seen in Figure 50. The measurements clearly show that plastic is not only found in the uppermost layer of the river but is distributed over the full water column.

Figure 50:
**EXAMPLE OF THE DATA GATHERED FOR ONE MULTI-POINT MEASUREMENT PERFORMED IN THE DANUBE RIVER NEAR HAINBURG**




Note*: The sampling was conducted on 13 January 2015 at a Danube discharge of 3.392 $m^3 s^{-1}$. The plastic concentration [mg/1000m³] is displayed for each net (Liedermann et al., 2018[18]).*

3 Liedermann, M; Gmeiner, P; Pessenlehner, S; Haimann, M; Hohenblum, P; Habersack, H. (2018): A Methodology for Measuring Microplastic Transport in Large or Medium Rivers WATER-SUI. 2018; 10(4)

A transport rate qi,j [g m-2 s-1] can then calculated as a product of plastic concentration Ci,j [g m-3] and the measured flow velocity vi,j [m s-1]:

$$q_{i,j} = C_{i,j}\, v_{i,j} \qquad (2)$$

A mean plastic transport value for the cross-section and an estimation of yearly yields based on a number of measurements at different discharge/seasonal conditions can then be determined, comparable to the analysis of suspended sediments in rivers, (e.g. Haimann et al., 2014[18]).

Hydrodynamic numerical models can be used for an upscaling process. If basic data (river geometry, water level) are available, numerical models can be used to model hydrological events that could not (not yet) be sampled. For this purpose, BOKU/IWA has developed its own model R-Sim3D (Tritthart and Gutknecht, 2007[19]). It solves the three-dimensional Reynolds-averaged Navier-Stokes equations using the Finite Volume Method on a mesh consisting of arbitrarily shaped polyhedra. This approach has the potential to deliver more accurate results than standard methods when applied to recirculating flows, as it can significantly reduce numerical diffusion (Tritthart, 2005). Convective fluxes at cell boundaries are interpolated using a second-order upwind scheme. Pressure–velocity coupling is performed using the SIMPLE algorithm in a generalized formulation. The hydrodynamic model implements both the standard **k-ε** and the improved **k-ω** turbulence closure models. The elevation of the free water surface is derived iteratively from the computed non-hydrostatic pressure field. This model can be used if required in the course of the project. The model also has a module for modelling particle paths (Tritthart et al., 2019[20]), which could be used to model plastic particles in the vicinity of the camera and to give probabilities for the location of the passage within the cross section.

19 Haimann, M; Liedermann, M; Lalk, P; Habersack, H. An integrated suspended sediment transport monitoring and analysis concept Int. Journal of Sediment Research 2014, 29(2), 135-148.

20 Tritthart, M; Gutknecht, D. (2007): THREE-DIMENSIONAL SIMULATION OF FREE-SURFACE FLOWS USING POLYHEDRAL FINITE VOLUMES ENG APPL COMP FLUID. 2007; 1(1): 1-14.

21 Tritthart, M; Gmeiner, P; Liedermann, M; Habersack, H. (2019): A meso-scale gravel tracer model for large gravel-bed rivers, Journal of Applied Water Engineering and Research, 7, 89-102; ISSN 2324-9676

## Advantages and Disadvantages of the different methodologies

| Methodology | Advantages/Strengths | Disadvantage/Weakness |
|---|---|---|
| Analysis of Drone Images | Accurate plastics counting and type identification;<br>Drone flights can cover large areas and therefore, more areas can be imaged, analyzed, and monitored;<br>With the combination of low-altitude and high-altitude flights, the waste accumulation and possible sources can be assessed. | Limited to visible wastes as optical cameras can only image surfaces;<br>Drone flights can be difficult in constricted places and those with significant signal interferences;<br>Require significantly high drone piloting skills;<br>Generation of orthomosaics is difficult to impossible for areas with moving features or objects. |
| Analysis of Images from Bridge-based Monitoring | Counting of plastics is accurate;<br>Identifications of plastic types can be accurate provided that the image resolution is high enough;<br>Method can be used for long term monitoring;<br>Method can also be used during nighttime provided that artificial illumination is available. | Cameras and peripherals can be expensive, particularly if the rivers is wide and the bridge is long;<br>Plastics type identification requires very high-resolution images;<br>Plastics partially hidden in vegetation and/or among debris may be missed or misclassified;<br>Factor such as rough water surface and sun glint might adversely affect the automated counting and plastics identification. |
| Net trawl survey | Can catch even small floating plastics <5cm<br>Capable of identifying submerged plastics under the water surface<br>Results can be used to compare them with other plastics monitoring results<br>Immanent flow velocities enable more accurate monthly / yearly extrapolations of plastics freight | Method is not really build for detection of larger plastics, as they can clog the net<br>Device weights over 20kg and survey needs at least two persons to carry out<br>Postprocessing of the cought plastics can include steps of drying out the material – this can pose problems to regions with very high humidity |

## Lesson learned:

Firstly, it is necessary to closely coordinate with the parties in the consortium to come up with a detailed survey process for each work item. Secondly, it is necessary to update accurate information about weather, COVID-19 epidemic, tidal schedule of survey areas affected by tides. The last survey, due to not updating detailed information about the weather, led to the camera with failed drone sensor, making the image blurry due to too high humidity (85-90%) in Sa Pa - Lao Cai at the survey time. And finally, better coordination with the field survey team is needed.

## ANNEX 2.2.B:

# DEVELOPMENT OF A NET SAMPLING DEVICE APPLICABLE FOR VIETNAMESE RIVERS

Although terrestrial environments and freshwaters are recognized as the origins and transport paths of plastics, the majority of research to date focuses on the marine environment (Horton et al., 2017). However, studies in freshwater environments have been rapidly advancing over recent years. Horton et al. (2017) gave a detailed overview of freshwater studies ranging from lakes, (e.g. Imhof et al., 2016; Fischer et al., 2016), to rivers (Baldwin et al., 2016; Dris et al., 2015; Faure et al., 2015; Lechner et al., 2014; Mani et al., 2015; McCormick et al., 2014 and Yonkos et al., 2014) and river sediments, (e.g. Klein et al., 2015; Horton et al., 2017). A number of studies have been performed that addressed the transport of microplastics in riverine systems. Measurements were undertaken in recent years in tributaries of the Great Lakes (Baldwin et al., 2016), the Seine River (Dris et al., 2015; Dris et al., 2018), various rivers in Switzerland (Faure et al., 2015), the Rhine River (Mani et al., 2015), various river sites near Chicago (McCormick et al., 2014) and the Danube River (Lechner et al., 2014). The researchers all used benthic nets (Lechner et al., 2014) or surface trawls as first used by Carpenter et al. (1972), described by Brown and Cheng (1981) and proposed as a standard methodology for surface waters by Lippiat et al. (2013). Moore et al. (2011) tried to address multiple depths by using different devices including a modified large Helley Smith sampler in concrete-lined creeks near Los Angeles. Also, Dris et al. (2018) addressed different depths in one point in the center of the Seine River by coupling a plankton net (addressing fibres) with a propeller-type current meter to sample down to 2 meters. But so far, only Liedermann et al. (2018) sampled the entire cross-section with a multi-point method to address microplastic transport in medium and large rivers.

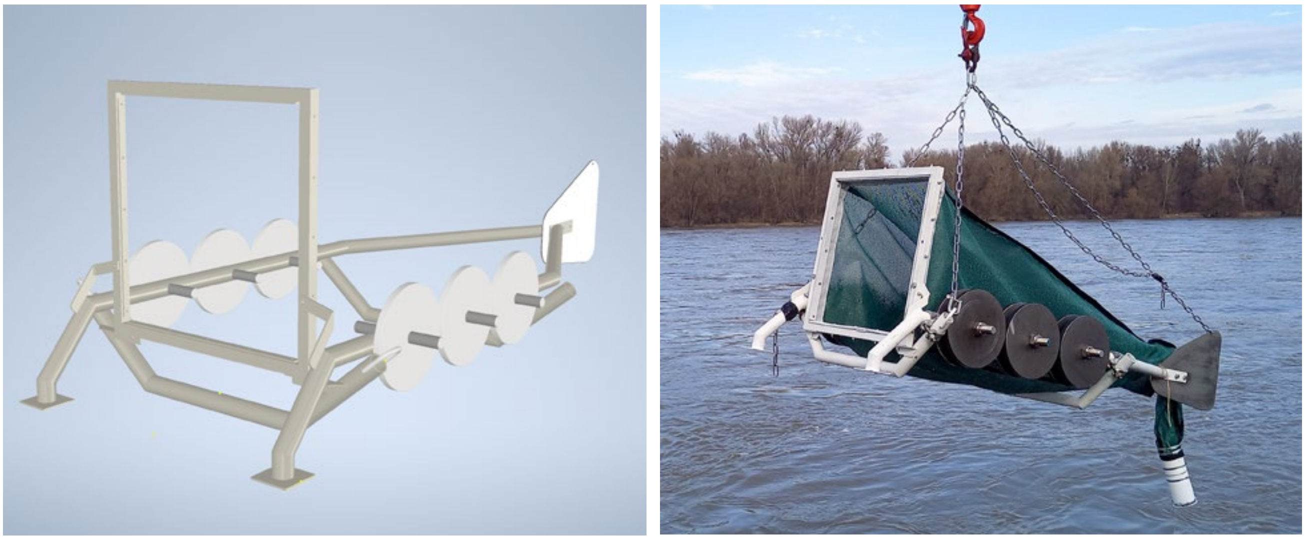
Within the framework of the project, it was therefore planned to construct a simplified measuring device for macro plastic, based on the experience gained from measurements on the Danube, which could be replicated as easily as possible anywhere in the world and which could be used for sampling plastic transport in different river systems. For this purpose, particularly the equipment carrier had to be adapted. But also mesh and frame-sizes were optimized as now mainly macro plastic is targeted.

### Equipment carrier

The modified BfG sampler as used for plastic measurements by Liedermann et al. (2018) built the basis for the newly developed equipment carrier within the project. Facing some advantages of the modified BfG sampler when addressing plastic measurements like the smooth positioning in the water and its usability up to high hydraulic forces, there are also disadvantages. Due to its construction only a very small net could be attached within the frame to measure bed near concentrations. Also, it was aimed to get a more flexible system towards the used weights in order to a better adaption to the hydraulic boundary conditions of any river in the world. Furthermore, it was aimed to develop a much easier equipment carrier compared to the complex constriction of the BfG sampler in order o get the needed material easily under the prevailing circumstances in other countries.

The resulting device is depicted in Figure 51 as sketch and during a field test. The frame consists of 48 mm steel pipes. Two cross beams connect the net frame at the bottom. In the rear the frame is connected at the fin, giving stability in the water column. The dimensions of the used frame for the macro plastic measurement net are 600x600 mm. Connections between the parts (e.g. net frame and cross beams) are not welded in order to be able to disassemble the device quickly. To attach the weights, 12 threaded bars are welded to the frame. Each bar can be attached with 2 weights of approximately 10 kg, so in total 240 kg additionally to the weight of the carrier itself.

Figure 51:
**VISUALIZATION OF THE CONSTRUCTION PLAN OF THE EQUIPMENT CARRIER (LEFT); FIELD TEST OF THE NEWLY DEVELOPED EQUIPMENT CARRIER (RIGHT)**



## Mesh size

As mesh sizes varied throughout the previous studies, different sizes were used within the project, to also address the differences between larger and smaller mesh types. The following mesh sizes were tested during measurements:

- 250 µm with 34 % porosity
- 500 µm with 38 % porosity
- 2,43 mm with 44 % porosity
- 8 mm with very high but undefined porosity

Based on the porosity values and to reach the required "open area ratio" of three (Tranter and Smith, 1968), the net length was calculated. Calculations were performed for the 250 µm and the 500 µm nets, resulting in a used length of 2,5 m. The two bigger meshes characterized by a higher porosity were produced with the same dimensions and therefore fulfill the required "open area ratio".

For the evaluation of the performance of the different mesh types towards macro plastic measurement 2 major aspects are relevant, (i) the sampling efficiency and (ii) the filtration efficiency.

Towards macro plastic, no clear trend in terms of sampling efficiency was found during field tests for the mentioned net types, since depending on the vertical, either the one or the other net had a higher concentration. In terms of filtration efficiency, Liedermann et al (2018) compared the 250 µm and 500 µm nets and found that the 500 µm net had a better efficiency. The comparison with the 2.43 mm and 8 mm nets shows that both nets have a significantly better filtration efficiency. When using the coarser nets for macro plastics, a significantly longer measuring time can be achieved under different boundary conditions (higher suspended matter load). Therefore, the coarser meshes should be preferred when addressing macro plastics. However, since the 8 mm net does not cover the complete range of macro plastic, the 2.43 mm net is recommended for sampling.

## Frame size

For the frame size, the aim was to use the largest possible net dimensions in order to get the highest possible discharge through the nets. For the used device, the nets are positioned at the surface, in the middle of the water column and at the bottom of the river. At the center and surface layer two nets are attached parallel, at the bottom layer one net is directly attached at the equipment carrier. The uppermost net assemblage was equipped with a buoyant body to ensure that these nets are skimming the water surface. As previously mentioned, the frame size is directly influenced and is vice versa influencing the mesh dimensions (due to its open area ratio) as well as the length of the used net.

Hence, during the tests, double frames with the dimensions of 600x600 mm as well as 900x900 mm were evaluated. For the final device assemblage 600x600 mm were used.

## Macro plastic measurement device and assemblage

The net frame was equipped with a fin on each side to assure streamwise alignment and another 1.6 m-long fin was added in the middle of the frame to ensure good positioning within the water column. The uppermost frame carrying buoyant bodies is only fixed by a stopper; to avoid dropping too low during handling samples. The center nets can be adjusted in height according to the prevailing water depth by using a displaceable stopper. For the lowermost net assemblage, a single centered net was applied to the sampler near the bed instead of the basket. An inclination rack is used, which allows the nets to have an upright position when deployed. The sampling container of Liedermann et al. (2018) is used to reduce the emptying time. A mechanical flow meter is attached to measure the discharge through the nets, which is required for calculating plastic concentration.

Figure 52:
**ASSEMBLAGE OF THE MACRO PLASTIC MEASUREMENT DEVICE; TOP: OLD ASSEMBLAGE ON THE LEFT AND NEWLY DEVELOPED CONFIGURATION ON THE RIGHT. BOTTOM: NETS WITH INCLINATION RACK AND NETS IN THE UPPERMOST LAYER ASSEMBLED WITH BUOYANT BODIES.**

Figure 53:
**SAMPLING CONTAINER USED FOR EMPTYING THE NETS**

Figure 54:
**MECHANICAL FLOW METER ATTACHED AT THE INLET OF THE NET TO MEASURE THE DISCHARGE**

## ANNEX 2.2.C:

# DETAILED PROPORTIONAL WASTE TYPES BY SITE

Table 25:
**DETAILED PROPORTIONAL WASTE TYPES BY SITE**

| Waste types | Hai Duong, Thach Khoi 1, site 1 | Hai Duong, Thach Khoi 1, site 2 | Hai Phong, Chanh Duong 01, Site 1 | Hai Phong, Chanh Duong 01, Site 2 | Hai Phong, Chanh Duong 01, Site 3 | Hai Phong, Chanh Duong 02, site 1 | Hai Phong, Chanh Duong 02, site 2 | Suoi Cat 01_1 | Suoi Cat 01_2 |
|---|---|---|---|---|---|---|---|---|---|
| Bags LDPE thick | 0% | 0% | 0% | 0% | 2% | 10% | 3% | 5% | 0% |
| Bags LDPE | 4% | 2% | 11% | 15% | 38% | 13% | 49% | 16% | 7% |
| Bags robust PET | 7% | 2% | 10% | 0% | 3% | 2% | 4% | 8% | 4% |
| Wrappers under 10cm | 2% | 7% | 0% | 0% | 3% | 2% | 4% | 0% | 0% |
| Wrappers over 10cm | 3% | 2% | 2% | 0% | 5% | 1% | 4% | 2% | 0% |
| Bottles PET | 7% | 4% | 7% | 10% | 8% | 6% | 2% | 9% | 16% |
| Polystyrene under 20cm, including food containers | 36% | 44% | 43% | 18% | 23% | 23% | 19% | 14% | 26% |
| Polystyrene over 20cm | 3% | 2% | 7% | 0% | 1% | 0% | 1% | 0% | 1% |
| PPCP bottle | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

| Waste types | Hai Duong, Thach Khoi 1, site 1 | Hai Duong, Thach Khoi 1, site 2 | Hai Phong, Chanh Duong 01, Site 1 | Hai Phong, Chanh Duong 01, Site 2 | Hai Phong, Chanh Duong 01, Site 3 | Hai Phong, Chanh Duong 02, site 1 | Hai Phong, Chanh Duong 02, site 2 | Suoi Cat 01_1 | Suoi Cat 01_2 |
|---|---|---|---|---|---|---|---|---|---|
| PPCP medical waste | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PPCP other | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Fishing gear | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% |
| Cup lids, caps and small plastics | 15% | 27% | 4% | 20% | 0% | 2% | 0% | 16% | 22% |
| Other plastics over 20cm | 8% | 0% | 5% | 4% | 2% | 7% | 1% | 7% | 4% |
| Rubber | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% |
| Metal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Glass | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Other non-plastics | 14% | 9% | 11% | 33% | 13% | 33% | 14% | 19% | 19% |

## ANNEX 2.2.D:

# FLOW VELOCITY RESULTS FROM NET SAMPLING

Table 26:
**FLOW VELOCITY RESULTS FROM NET SAMPLING**

| Time | Flow velocity (m/s) | | | | | |
|---|---|---|---|---|---|---|
| | Pos. 1 (GOPRO2) | | Pos. 2 (GOPRO1) | | Pos. 3 (GOPRO3) | |
| | Upper net | Lower net | Upper net | Lower net | Upper net | Lower net |
| 8:30 AM | | | 0.26 | 0.18 | | |
| 9:40 AM | 0.35 | 0.24 | | | | |
| 10:20 AM | 0.41 | 0.27 | | | | |
| 11:30 AM | | | 0.43 | 0.3 | | |
| 1:20 PM | | | | | 0.58 | 0.36 |
| 2:25 PM | | | | | 0.63 | 0.41 |

## ANNEX 2.3.A:

# LIST OF COMPANY REPRESENTATIVES WHO PROVIDED INFORMATION FOR THE PLASTIC ALTERNATIVES ASSESSMENT

| No. | Name | Company |
|---|---|---|
| 1 | Nguyen Van Son | An Phat Xanh Plastic Joint Stock Company |
| 2 | Nguyen Thi Thao | Vina Straws Joint Stock Company |
| 3 | Le Trung Nguyen | Duy Tan Plastic Joint Stock Company |
| 4 | Nguyen Minh Anh | SDC Vietnam Investment Joint Stock Company |
| 5 | Ms. An | Hien Long Vietnam Company Limited |
| 6 | Mr. Van | Han My Plastic Company, Tien Du, Bac Ninh |
| 7 | Mai Phuong | Mai Phuong Company Limited, Tien Son Industrial Park, Bac Ninh |
| 8 | Le Anh Cuong | Fishing villages of Luoi, Tran Phu, Minh Cuong, Thuong Tin, Hanoi |
| 9 | Nguyen thi thuong | Fishing villages of Luoi, Tran Phu, Minh Cuong, Thuong Tin, Hanoi |
| 10 | Mr. Sang | Plastic Craft Village - Nhu Quynh, Van Lam Hung Yen |
| 11 | Duong Van Khoa | Plastic Craft Village - Nhu Quynh, Van Lam Hung Yen |
| 12 | Ms. Ngoc | Plastic shop owner - Nhu Quynh, Van Lam, Hung Yen |
| 13 | Nguyen Tat Thanh | Owner Supermarket Duc Thanh, Ha Dong, Hanoi |
| 14 | Nhu Dinh Tu | Tiffood 24h Food Joint Stock Company |
| 15 | Duong To Phuong | Food Shop 105 Xuan La |
| 16 | Nguyen Thi Phuong | Food store 215 Cau Giay |
| 17 | Nguyen Hong Nhung | Shop House Drinks, Xuan Phuong Cau Dien |
| 18 | Nguyen Thi Bong | Co Bong Coffee Shop, Lane 105 Xuan La, Bac Tu Liem, Hanoi |
| 19 | Nguyen Thi Thu | Hai Dang Joint Stock Company |

## ANNEX 2.3.B:

# LIST OF EXPERTS, SCIENTISTS, AND STATE MANAGERS WHO PROVIDED INFORMATION FOR THE PLASTIC ALTERNATIVES ASSESSMENT

| No. | Name | Company |
|---|---|---|
| 1 | Huynh Thi My | General Secretary of Vietnam Plastic Association |
| 2 | Nguyen Lam Tung | Amber Vietnam Company |
| 3 | Tran Thi Minh | General Statistics Office |
| 4 | Nguyen Thi Tham | Commercial Research Institute - Foreign Trade University |
| 5 | Do Van Lam | National Center for Socio-Economic Forecasting |
| 6 | Dinh Hong Embroidery | Hanoi University of Economics and Business |
| 7 | Nguyen Mai Anh | Hanoi Polytechnic University |
| 8 | Ho Dang Phuc | Vietnam Mathematical Institute |
| 9 | Tran Duy Khanh | APEC Institute for Research and Training for Entrepreneurs |
| 10 | Bui Dac Dung | Science and technology |
| 11 | Bui Van Thuyet | University of Natural Resources and Environment |
| 12 | Nguyen Van Chien | Owner of plastic shop, fishing net- District 7, Ho Chi Minh city |
| 13 | Nguyen Thi Hang | Ho Chi Minh City Department of Planning and Investment |
| 14 | Nguyen Van Hoang | Hanoi Department of Natural Resources and Environment |
| 15 | Nguyen Thi Mai | Hanoi Department of Science and Technology |
| 16 | Nguyen Lan Phuong | Vietnam Association of Cities |
| 17 | Nguyen Thanh Minh | General Secretary of Hanoi Advertising Association |
| 18 | Nguyen Hoang Cuong | Lecturer, Institute of Policy and Development, Ministry of Planning and Investment |
| 19 | Nguyen Thi Thu | Lecturer, Institute of Policy and Development, Ministry of Planning and Investment |

## ANNEX 2.3.C:

# PRODUCERS, IMPORTERS, WHOLESALERS OF PLASTIC PRODUCTS AND PLASTIC PROD-UCT ALTERNATIVES IN VIETNAM

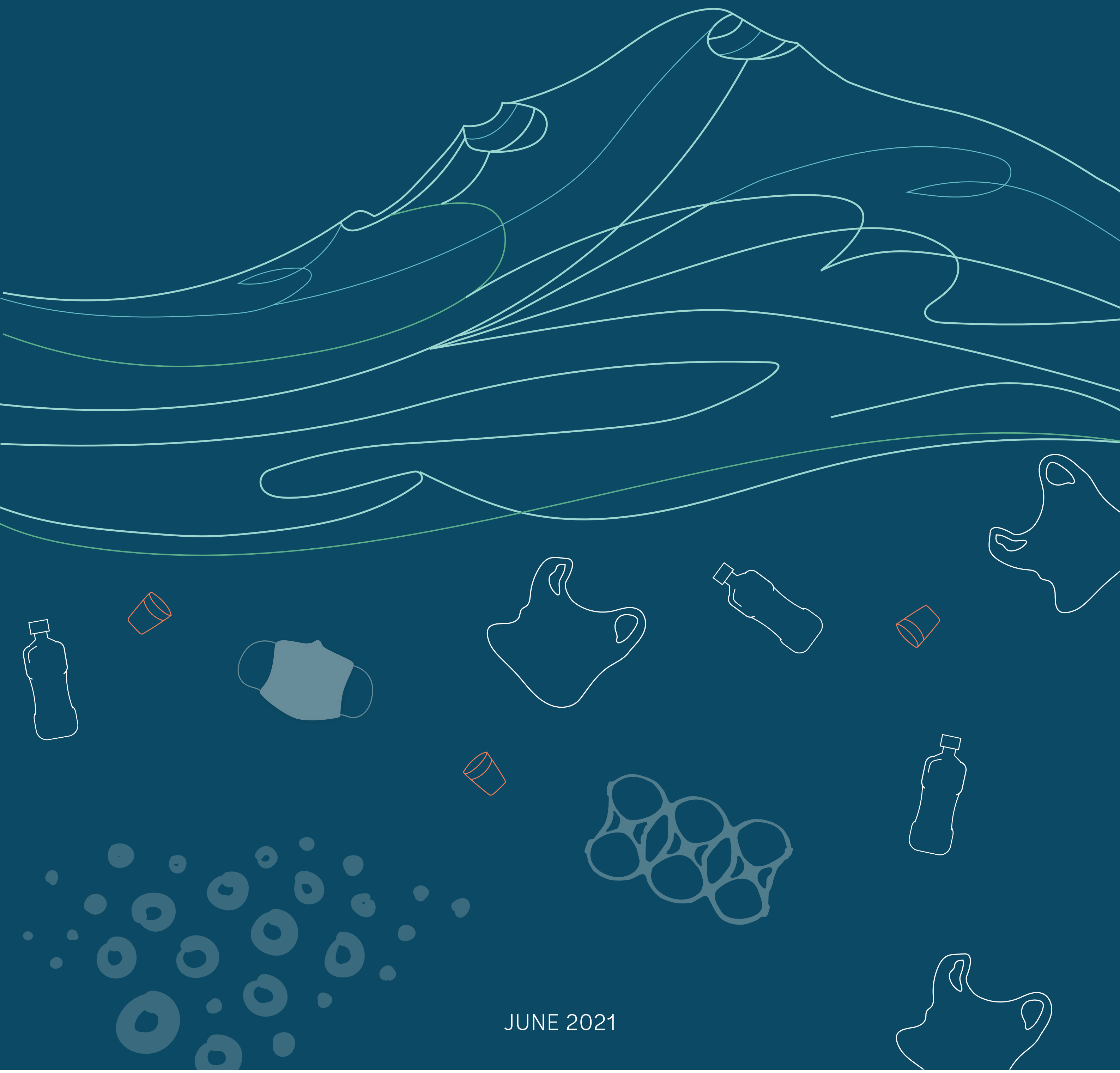
| # | Name | Website | Product | Producers/ Importers/ Wholesalers | Alternatives product |
|---|---|---|---|---|---|
| F1 | KKP Foam Trays – KKP Co.,Ltd | www.khayxopthucpham.com | Food containers | Producer | |
| F2 | Dong Sai Gon plasic Co.Ltd | https://dongsaigonplas.com | Food containers | Producer | |
| F3 | The gioi tui xop (Store) | http://thegioituixop.com | Food containers | Wholesalers | |
| F4 | Vinam Pack Co.Ltd | http://baobivinam.com/ | Food containers | Producer | |
| F5 | Hunufa Vietnam Co., ltd | https://hunufamart.com | Food containers | Importer | |
| F6 | Doanh Thuong Phat Co.,Ltd | https://doanhthuongphat.vn | Food containers | Producer | |
| F7 | Song Minh Packaging Trading | https://baobisongminh.com/ | Food containers | Producer | |
| F8 | Daily Care Import & Export Trading Co.,Ltd | http://www.dailycare.vn/ | Food containers | Wholesalers | Alternative Product:<br>- Bagasse |
| F9 | QueenPack Co.Ltd | https://queenpack.com.vn | Food containers | Importer | Alternative Product:<br>- Bagasse |
| F10 | Hapobe Packaging Co.,Ltd | https://hapobe.com | Food containers | Producer | Alternative Product:<br>- Bagasse |
| F11 | Joy Food one member limited company | https://joyfood.com.vn/ | Food containers | Wholesalers | Alternative Product:<br>- Bagasse |
| P1 | An Phat Holdings (with Aneco brands) | https://aneco.com.vn/thong-tin-san-pham/ong-hut-bao-ve-moi-truong.html | Plastic bag | Producer | Compostable plastic bags |

| # | Name | Website | Product | Producers/ Importers/ Wholesalers | Alternatives product |
|---|---|---|---|---|---|
| P2 | Binh Minh Packaging Production Trading Service Co., Ltd | https://www.baobibinhminh.com/ | Plastic bag | Producer | |
| P3 | Giang Thanh Industry Co., Ltd | http://giangthanh.bizz.vn/ | Plastic bag | Producer | |
| P4 | Hoang Thinh Packaging Company Limited | http://baobihoangthinh.com/ | Plastic bag | Producer | |
| P5 | Khang Loi Packaging company | https://baobikhangloi.com.vn/ | Plastic bag | Producer | |
| P6 | Nam Khanh Packaging Co., Ltd | http://www.namkhan-hphongco.com/ | Plastic bag | Producer | |
| P7 | Nhat Thai Trading And Manufacturing Co., Ltd | http://baobinhatthai.com/?lang=en | Plastic bag | Wholesalers | |
| P8 | Nhat Viet Paper & Plastic Packaging One Member Co., Ltd | http://baobinhatviet.com/ | Plastic bag | Producer | |
| P9 | Quoc Thai Service Trading Production Company Limited ... | http://www.baobiquocthai.com.vn/ | Plastic bag | Producer | |
| P10 | Thanh Cong Vina Trading Investment And Production JSC | http://baobithanhcong.bizz.vn | Plastic bag | Producer | |
| E1 | Bac Viet Eps Plastic Trading Production Co ., Ltd; | http://epsbacviet.com.vn | EPS | Producer | |
| E2 | Eps Vietnam Packaging Investment JSC; | www.epsvietnam.bizz.vn | EPS | Producer | |
| E3 | Hoang Phong Development and Investment Co., Ltd; | http://thungphuyhoang-phong.com/ | EPS | Wholesalers | Drum float |

| # | Name | Website | Product | Producers/ Importers/ Wholesalers | Alternatives product |
|---|---|---|---|---|---|
| E4 | Minh Phu Plastics Co.,Ltd; | www.epsminhphu.com | EPS | Producer | |
| E5 | Tan Huy Hoang Co.,Ltd; | www.tanhuyhoang.com | EPS | Producer | |
| E6 | Tin Thanh Eps Foam Co., Ltd | www.tinthanheps.vn | EPS | Producer | |
| N1 | An Phat Holdings JSC | https://anphatholdings.com/en/ | Fishing net | Importer | Compostable plastic fishing net |
| N2 | Forever Industries Co., Ltd. | https://www.forevernetco.com | Fishing net | Producer | |
| N3 | Han-A Vina Co., Ltd; | http://hanavina.com/ | Fishing net | Producer | |
| N4 | Hiep Hung Manufacturing & Trading Co., Ltd. | https://nhuahiephung.com/ | Fishing net | Wholesalers | |
| N5 | Le Ha Vina Co. Ltd | https://www.lehagroup.com/ | Fishing net | Producer | |
| N6 | Penro Industries (Vietnam) Co.,Ltd | http://penroindustries.com/ | Fishing net | Producer | |
| N7 | S.N.Y VINA Co.Ltd | www.snyvina.net.co | Fishing net | Producer | |
| N8 | Saigon Fishing Net Joint Stock Company | http://www.sfn.vn/index.php?vnTRUST =mod:product\|act:detail\|pID:8 | Fishing net | Producer | |
| N9 | Siam Brothers Vietnam JSC | https://www.siambrothersvn.com.html | Fishing net | Producer | |
| N10 | Thai Viet Co.Ltd | www.luoithaiviet.com.vn | Fishing net | Producer | |
| N11 | Thanh Loi | www.luoithanhloi.com | Fishing net | Importer | |
| N12 | Thien Phuoc Manufacturing and Trading Co., Ltd | https://luoithienphuoc.com.vn/ | Fishing net | Producer | |
| N13 | Thuan Loi Phat Production Trading And Service Company Limited | www.luoinhua.com | Fishing net | Importer | |

| # | Name | Website | Product | Producers/ Importers/ Wholesalers | Alternatives product |
|---|---|---|---|---|---|
| FP1 | Pham Gia Packaging Co., Ltd. | http://baobiphamgia.com | Food Packaging | Producer | |
| FP2 | Binh Minh Packaging Joint Stock Company | https://baobibinhminh.net/bao-bi-thuc-pham-dong-goi/ | Food Packaging | Producer | Kraft paper bag |
| FP3 | Duc Kien Packaging Co., Ltd | http://dongkinhprinting.com/in-bao-bi-giay-7.htm | Food Packaging | Wholesalers | Paper bag |
| FP4 | Gia Huy Package Printing Production Company Limited | https://www.baobigiahuy.com/ | Food Packaging | Wholesalers | |
| FP5 | Global Packing Technology Co.,Ltd | http://globalpack.com.vn/ | Food Packaging | Importer | |
| FP6 | Hanoi Packaging Production And Import- Export Company Limited | http://hanopaco.com.vn/danh-muc/san-pham-dich-vu.html | Food Packaging | Producer | |
| FP7 | Hoai Anh Plastic | http://nhuahoaianh.com/ | Food Packaging | Producer | |
| FP8 | Hop Phat Metal Packaging Joint Stock Company | http://hopphatmetal.vn/san-pham | Food Packaging | Producer | Tin box packaging |
| FP9 | Nhat Thai Packaging | http://baobinhatthai.com | Food Packaging | Wholesalers | |
| FP10 | Phat Thanh Plastic Packaging Co.Ltd | http://www.baobiphatthanh.com/bao-bi-thuc-pham-dong-goi/ | Food Packaging | Producer | |
| FP11 | Royal Packing Solution Joint Stock Company | https://hoanggiaps.com/ | Food Packaging | Producer | |
| FP12 | Tan Gia Phu Paper Packaging Production Trading Private Enterprise | http://baobigiaygiaphu.ticc.vn/ | Food Packaging | Producer | |

| # | Name | Website | Product | Producers/ Importers/ Wholesalers | Alternatives product |
|---|---|---|---|---|---|
| FP13 | Tan Hiep Loi Packaging Production Trading Joint Stock Company | http://www.tanhieploi.com.vn/san-pham/ | Food Packaging | Producer | |
| FP14 | Vinapackink Co., Ltd. | http://vinapackink.com.vn/ | Food Packaging | Producer | |
| S1 | An Phat Holdings (with Aneco brands) | https://aneco.com.vn/thong-tin-san-pham/ong-hut-bao-ve-moi-truong.html | Straw | Producer | Compostable plastic straw |
| S2 | Hoa Viet Uc Co.Ltd | www.hoavietuc.com | Straw | Producer | |
| S3 | Minh Quang glass straw | http://onghutthuytinh.com | Straw | Wholesalers | Glass straw |
| S4 | Nature Straw JSC | https://onghutthiennhien.vn | Straw | Wholesalers | Grass straw |
| S5 | Ningbo Changya Plastic Vietnam Co.Ltd | www.cnnbcy.com | Straw | Producer | |
| S6 | Ongtre Vietnam Co.Ltd | https://ongtre.vn/ong-hut-tre/ | Straw | Producer | Bamboo straw |
| S7 | Post And Telecommuni-cations Printing JSC (PTP with EcoStraw brands) | https://ecostrawsgreen.com/san-pham/ong-hut-giay-8mm-chat-luong-cao-gia-re-1.html | Straw | Wholesalers | Paper straw |
| S8 | Sao Khue Production & Commercial Co. Ltd... | https://saokhueco.vn/thuong-hieu-ong-hut-gao/ | Straw | Producer | Rice straw |
| S9 | STD JSC plastic food | www.stdvina.com.vn | Straw | Producer | |
| S10 | Tan Hung Phat Co.Ltd | www.tahufa.com | Straw | Importer | |
| S11 | Thien Minh Production and Trading Technology | www.thienminhgp.vn | Straw | Producer | |
| S12 | Viet Dung Plastic Packaging Co.Ltd | www.lynhua.net | Straw | Wholesalers | |



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