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Marine Litter Baseline in Lebanon

2021

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Abbreviations

ABS	Acrylonitrile butadiene styrene
AP	Action Plan
ANOVA	One Way Analysis of Variance
CDR	Council for Development and Reconstruction
Covid-19	Coronavirus Disease - 2019
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Digital Elevation Model
EPR	Extended Producer Responsibility
EPS	Expanded Polystyrene
GDP	Gross Domestic Product
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPS	Global Positioning System
HDPE	High Density Polyethylene
IoE	Institute of the Environment
ISWA	International Solid Waste Association
LDPE	Low Density Polyethylene
MCR	Marine and Coastal Resources
ML	Marine Litter
MPA	MPA: Marine Protected Areas
MoE	Ministry of Environment
MORES	Management of Resources and Environmental Solutions
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NGO	Non-governmental organisation
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
RWA	Resources and Waste Advisory Group
SIWI	Stockholm International Water Institute
SMLC	Société Moderne Libanaise pour le Commerce
SST	Sustainable Seas Trust
SUP	Single-Use-Plastic
SWM	Solid Waste Management
UN	United Nations
UNDP	United Nations Development Programme
UN-Habitat	United Nations-Habitat
UoB	University of Balamand
WaCT	Waste Wise Cities Tool
WB	World Bank
WFD	Waste Flow Diagram
WIOMSA	Western Indian Ocean Marine Science Association

Executive Summary

Key Findings

- Hard plastics, soft plastics and foam make up 77.7% of all marine litter found on the Lebanese beaches.
- Beddaoui (Tripoli) and Jadra (Chouf) were the main hotspots of plastic marine litter found both in April and October 2021.
- Uncollected waste, direct littering by beach goers and uncontrolled disposal sites are the main sources of marine litter.
- 70% in May 2021 and 88% in October 2021 of all marine litter collected is likely to have been dumped on land, rather than from a sea-based source.
- Plastic leakage from SWM systems averaged 3.1kgs/person/year to the environment and 1.1 kgs/ person/year to water systems in the seven cities studied. Leakages mostly occur whilst the waste is waiting to be collected.
- 73 potential new uncontrolled disposal sites were identified along 14 rivers leading to the Mediterranean Sea.
- During both the spring and fall standing-stock surveys, single-use-plastics (SUPs) items originating from Lebanon were the most found items on the Lebanese beaches.
- The most items on the seafloor, in surface waters and in sediments were found in Byblos, which is aligned with the accumulation survey results of the spring 2021, showing that Byblos has the largest marine litter load on its beaches compared to Tyre.
- Over 95%of identifiable marine litter items collected during the accumulation surveys were sold in Lebanon.

Marine Litter in Lebanon

The burden of solid waste management (SWM) in Lebanon has been growing since the 1990s. The increases in population (in particular since the Syrian conflict), urbanization, and population density; the lack of enforcement of the legislative framework for SWM; and the tendency towards consumerist social habits have escalated the scale and complexity of the SWM problem (Abbas 2017; World Bank 2011).

However, the environmental impacts of waste on Lebanon's marine and coastal environment have, until now, not received much research attention. Little to no robust or rigorously conducted marine litter sampling has been undertaken, and the dynamics of litter in the marine environment—including understanding the most prevalent items and materials, their main sources, and their pathways to the sea—have not been previously documented. The data and information gaps inhibit both sound evidence-based action by Lebanon's decision-makers and the formulation of targeted measures to prevent and reduce the flow of marine litter into the coastal environment and the Mediterranean Sea.

Objectives and Scope of the Report

In order to establish scientific evidence of marine litter sources and hotspots in Lebanon, the Ministry of Environment requested the support of the World Bank through funding from PROBLUE, a World Bank multi-donor trust fund, to implement a Technical Assistance with the following objective: (i) establish a baseline for marine litter in Lebanon and (ii) improve the capacity of Lebanese communities to prevent and reduce marine litter.

The purpose of the baseline is to inform decision-makers on the status of marine litter in Lebanon and enable the development of an action plan to prevent and mitigate the leakage of waste into Lebanon's marine and coastal environment. This report covers the baseline assessment and its results and provides a comprehensive and rigorously derived national baseline of the sources, pathways, and hotspots of marine litter.

Methodology Adopted for the Baseline Survey

Primary data on the nature and extent of marine litter in the environment, with a focus on sources, pathways, and hotspots, were collected using a set of four internationally recognized methodologies to profile and characterize the baseline situation. These included the following: (a) the UN-Habitat Waste Wise Cities Tool (WaCT)[1], (b) the GIZ/University of Leeds Waste Flow Diagram (WFD)[2], (c) the Commonwealth Scientific and Industrial Research Organisation[3] (CSIRO) Standing-Stock survey, and (d) the Sustainable Seas Trust (SST)[4] Accumulation survey.

A round of terrestrial, beach, and marine surveys was carried out in spring 2021 followed by another round in autumn 2021. This was done to provide an understanding of the fluctuations in marine litter quantity and composition throughout an entire year.

The WaCT and WFD composed the set of terrestrial surveys. The methodologies focused on characterizing the main sources and leakage points of waste, and especially plastics, into the marine environment. The WaCT is the global standard methodology developed by UN-Habitat to assess

[1] https://unhabitat.org/wwc-tool
[2] https://plasticpollution.leeds.ac.uk/toolkits/wfd/
[3] https://research.csiro.au/marinedebris/resources/
[4] https://sst.org.za/wp-content/uploads/2020/07/Barnardo-Ribbink-2020_African-Marine litter-Monitoring-Manual.pdf

baseline municipal solid waste management (MSWM) performance systems in cities. The consultant team collaborated with selected municipalities and relevant local stakeholders to understand waste flows within the city and where in the waste-service chain's municipal solid waste (MSW) leakages are most likely to occur (that is, pre- or post-collection). The WFD is a complementary observational assessment tool used to identify leakages and fates for plastics and other MSW and provides more depth on the post-collection leakages analysis. The WFD accepts (and relies on) data input from the WaCT and further extends the analysis to leakages and fates.

The two terrestrial surveys complement each other neatly, with the WaCT focusing on collected MSW while the WFD analyzes the fate of uncollected waste in the post-collection regime. The WaCT was conducted in Tyre and Byblos, and the WFD was applied in Beddaoui, Byblos, Ghazir, Beirut, Ghobeiry, Aadoussiyeh, and Tyre.

The beach surveys comprised the CSIRO and SST methodologies. The combination of the CSIRO and SST surveys gives a complete picture of the spatial and temporal distribution of marine litter on the Lebanese coastline. The CSIRO survey consists in identifying marine litter hotspots by collecting, sorting, categorizing, and weighing sampled marine litter from 24 sites along the Lebanese coastline to determine the density of litter present at a single point in time. The SST accumulation survey assesses the amount, accumulation rate, and potential sources of macro-litter at sea by visiting daily, for 8 days, the same sites. The accumulation survey was applied on two beaches in Byblos (Titanic Beach and Chekka Beach) and on two beaches in Tyre (Litani River Mouth Beach and Sour Beach).

The indicative marine surveys investigate marine litter on the seafloor, in surface waters, and in sediments to strengthen the findings from the terrestrial and beach surveys and to allow an understanding of the sources and pathways of marine litter. For marine litter on the seafloor, underwater transects were used to estimate marine litter density between depths of 0 and 20 meters due to its proximity to the leakage points on shore. The study of marine litter in sediments was carried out at the same transect belts as for marine litter assessment on the seafloor by scuba divers (50 to 100 meter transect belts), and 3 kilograms from three sampling points per transect belt were collected.

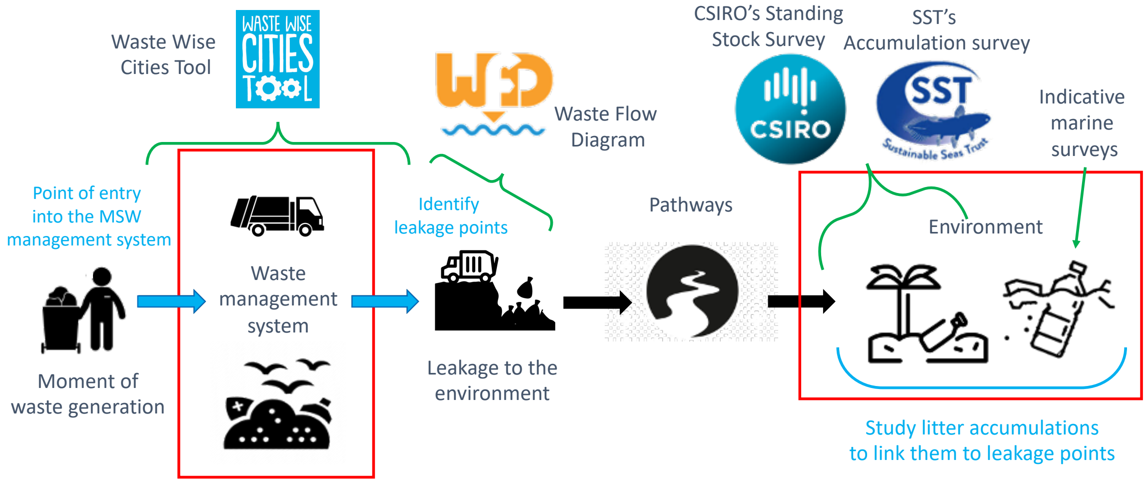
Finally, the indicative assessment of marine litter in surface waters was undertaken at the same sites as those for marine litter assessment on the seafloor by applying the visual-survey method. A boat sailed at an average speed of 2 knots for a minimum of 1 hour on a preset transect parallel to the shore with a field of vision of 5 meters on each side with observers counting floating litter within the set field of vision.

The implementation of the terrestrial, beach, and marine surveys allowed the capture of data on the waste-management systems in urban areas most at risk of waste leakage to the environment, and of data on litter-accumulation hotspots on beaches and in river mouths along the coast of Lebanon.

Structure of the Report

The report is structured to show the results for the hotspots, sources, and pathways by combining the findings of all surveys as indicated in Figure ES.0.1 below.

Figure ES.0.1: Surveys Implemented across the Source-to-Sea Spectrum



Source: World Bank.

Each chapter of this report is introduced by the following summary of that chapter's main issues, methodologies, and analytical tools (see Figure ES.0.2 below).

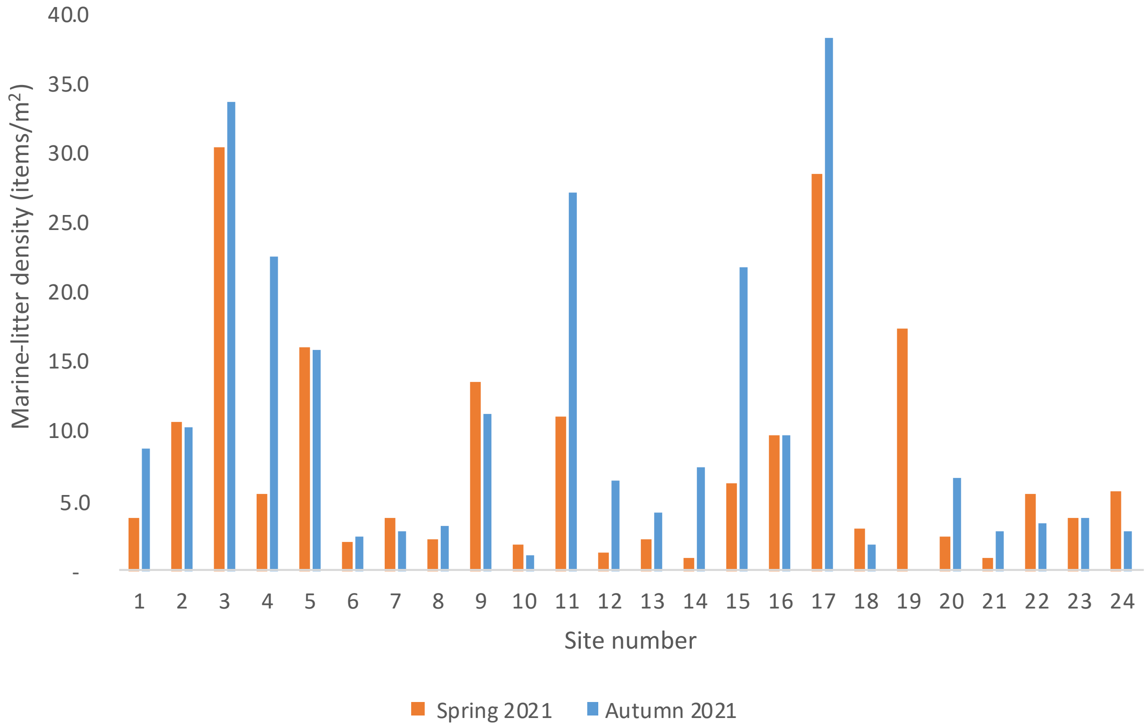
Figure ES. 0.2: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools Regarding Lebanon's Marine Litter (ML)

Source: World Bank.

Chapter 2 of this report discusses hotspots of marine litter throughout Lebanon:

Overall, marine litter was omnipresent on the Lebanese beaches. From the total 51,514 items collected in the spring and autumn standing-stock surveys, 76.0 percent were hard, soft, or foam plastics. Similar hotspots were found in both surveys, especially around urban areas (Tripoli, Saida). Of the 23 sites studied in the autumn, 14 sites had higher marine litter-densities compared to the spring survey, due to a) the lack of beach cleanup after the summer months, and b) new settlements close to the beaches studied, specifically for the two emerging hotspots of Saint-Simon in Beirut and Dbayeh. See Figure ES.0.3.

Figure ES. 0.3: Marine litter Density on Lebanese Beaches



Source: World Bank.

Chapter 3 discusses main sources of marine litter in Lebanon:

Over 82 percent of the marine litter collected during the accumulation surveys was found in the supratidal zone of the beach. The most-frequently found items along Lebanon's coastline were items commonly brought by beach visitors, specifically single-use plastics (bottle caps, beverage bottles, cigarette butts, cups, and straws). Furthermore, the WaCT showed that uncollected waste represents an important source of marine litter, and that 73 potential new dumpsites may have opened since 2017 on the banks of Lebanese rivers, which act as pathways for marine litter. Therefore, it is clear that plastic leakages into the environment come from three main sources:

- Direct littering by beach visitors. Touristic activities close to the Mediterranean Sea are amongst the most predominant land-based sources of plastic leakages and therefore of marine litter into the sea.
- Uncollected waste within cities. The collection coverages of Tyre and Byblos (78 percent and 82 percent, respectively) are lower than in other upper-middle-income countries, which usually have collection coverages close to 100 percent. The uncollected waste ends up in the environment, on land or in water systems, in drainage systems, or is burned.
- Uncontrolled disposal sites along riverbanks. A detailed review of the UNDP's map of disposal sites in 2017 and additional satellite imagery revealed around 73 potential new disposal sites located on the riverbanks of Lebanese rivers, leading to the Mediterranean Sea. See Table ES.0.1.

Table ES.0.1: Main Sources of Marine Litter in Lebanon

Marine litter items	Quantities (number of items)	Geographical hotspots (site name, nearest city)
Hard plastic fragments	4,003–5,829	Tripoli Mina, Maamelten (Jounieh), Ramlet el Baida (Beirut)
Polystyrene fragments	3,967–4,499	Qalamoun (Tripoli), Titanic Beach (Byblos), Maamelten (Jounieh), Jadra (Saida)
Soft plastic fragments	2,409–3,020	Mazraat Aartousi (Tripoli), Maamelten (Jounieh), Dbayeh, Jadra (Saida)
Bottle caps/lids	1,525–2,061	Tripoli Mina, Mazraat Aartousi (Tripoli), Ramlet el Baida (Beirut)
Plastic beverage bottles	621–1,569	Qalmoun (Tripoli), Koubba (Batroun)
Soft plastic cups/lids	904–2,055	Tripoli Mina, Maamelten (Jounieh), Damour (Beirut)
Cigarette butts	691–2,755	Tripoli Mina, Saint-Simon (Beirut), Khalde (Beirut), Saida Beach
Food wrappers/labels	589–602	Mazraat Aartousi (Tripoli)
Glass fragments	583–1,019	Tripoli Mina, Titanic Beach (Byblos), Naqoura
Straws	566–614	Mazraat Aartousi Tripoli), Maamelten (Jounieh), Ramlet el Baida (Beirut)
Multilayer food-packaging	392–1,195	Qalamoun (Tripoli), Maamelten (Jounieh), Dbayeh

Source: World Bank.

Chapter 4 presents the results of the WFD assessments and marine surveys.

The WFD investigated the post-collection regimes of seven cities and the fate of uncollected waste. The marine surveys indicated the quantity and composition of waste on the seafloor, in surface water, and in sediments; the marine surveys also indicated the potential pathway that litter may have taken to reach the marine environment.

On average, 3.1 kg/person/year of plastic waste escaped from SWM systems of the seven cities studied, and ended up in the environment. This includes 1.1 kilograms/person/year reaching water systems.

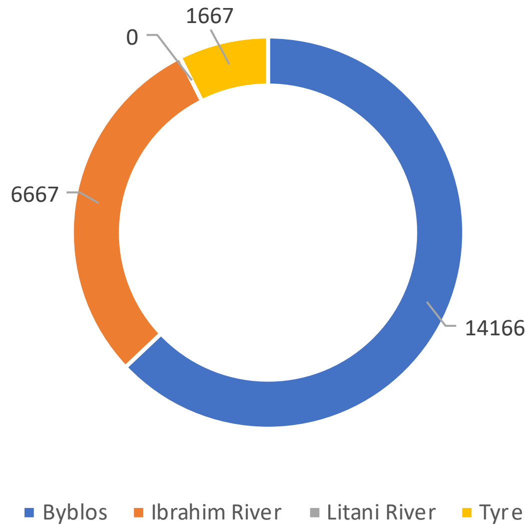
The greatest leakages from SWM systems to water systems were found in Byblos (5.9 kg/person/year), followed by Tyre (1.1 kg/person/year), (Beddaoui (0.9 kg/person/year), Ghazir (0.9 kg/person/year), Beirut (0.9 kg/person/year), Ghobeiry (0.6 kg/person/year), and Aadoussiyeh (0.4 kg/person/year). Open collection containers are the main influencers of plastic leakages. Furthermore, litter density on the seafloor was also the highest in Byblos, with plastics dominating the materials found in the marine environment.

Chapters 5 and 6 discuss the distribution of marine litter on the Lebanese coastline.

The results are disaggregated into the most-frequently found materials, items, polymers, and brands. A key finding is that the top 10 items found during the spatial and temporal changes in marine litter quantified the large presence of SUPs (single-use plastics) and other types of plastic items, pointing at beachgoers as the main source of these items and direct littering as the main pathway.

The findings demonstrate that marine litter mainly originates from land-based sources. From the potential land-based sources, the SWM systems were investigated with the WaCT and WFD surveys to understand the overall performance of the pre- and post-collection regimes of SWM systems. Uncollected waste was found to be the primary factor influencing leakages, and there is no major evidence of leakages from within SWM systems from collection to the recovery/disposal sites. GIS analysis has further shown that there has been an increasing number of uncontrolled disposal sites located within 500 meters of river shores (73 potential new sites since 2017), which could be potential sources of marine litter, with rivers being the main pathways to the sea. The marine-survey data showed that the nature of the uncollected waste on surface water, on the seafloor, and in sediments gives confidence that the dominant issue of marine litter in Lebanon is residents' and tourists' poor behavior, and that coastal tourism through direct littering is the main source of marine litter in Lebanon. See Figure ES.0.4.

Figure ES. 0.4: Litter Density on the Seafloor per Site (in Items per Square Kilometer)



Source: World Bank.

Chapter 7 presents recommendations for future monitoring, research, and strategic actions:

Based on the findings of the baseline assessment, the report's main recommendations for future research and action are the following:

- Enhancing the data set that these baseline surveys created. More work is needed to understand the role of rivers as pathways for marine litter, the contribution of uncontrolled disposal sites along riverbanks to marine litter, and the environmental and health impact of microplastics.

- A national benchmark for emission of plastic pollution. Further resources are needed to profile a representative number of municipal waste management systems, representing different geographical and socioeconomic situations, and different municipal solid waste operator models. The numbers of the systems, situations, and models should be sufficient to achieve the level of representativeness needed to guide decision-making, policy making, and resource allocation.

- The monitoring and evaluation of future data. The post-collection regimes along the Lebanese coastline showed that future surveys should be implemented to obtain data that can be benchmarked against the baseline of an average of 3.1 kg/person/year of plastic released into Lebanon's water systems.

- The draft Action Plan provides suggestions for the necessary shifts in national policies, regulations, finance, and institutional framework for marine litter prevention, including needed stakeholders' engagement.

- The draft Action Plan presents short-, medium-, and long-term actions including (a) awareness-raising activities; (b) applying and enforcing extended producer responsibility; (c) bans on unnecessary and damaging products or activities; (d) economic incentives targeting consumption; and (e) improving legislation, transparency, and product labelling. Other recommended actions call for waste-management measures in conjunction with research into product design to facilitate reuse, repair, and recycling while improving the implementation of existing legislation.

Notes

[1] https://unhabitat.org/wwc-tool
[2] https://plasticpollution.leeds.ac.uk/toolkits/wfd/
[3] https://research.csiro.au/marinedebris/resources/
[4] https://sst.org.za/wp-content/uploads/2020/07/Barnardo-Ribbink-2020_African-Marine litter-Monitoring-Manual.pdf

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Abbas, I. 2017. "Solid Waste Management in Lebanon: Challenges and Recommendations." *Journal of Environment and Waste Management* 4 (2): 53–63.

World Bank. 2011. *Republic of Lebanon Country Environmental Analysis.* Report No. 62266-LB. Washington, DC: World Bank.

1 Introduction

Figure 1.1: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools

Source: World Bank.

1.1 Marine Litter in Lebanon

Municipal solid waste management (MSWM) systems can include waste collection (both formal and informal), transfer/transport, recycling, recovery, and disposal. At any stage during or before these processes, waste may leak into the environment. Once it has leaked to the environment, waste takes one of many pathways (major pathways include waterways and wind) and ends up accumulating in the environment, where it continues to have negative impacts for months to years depending on the materials.

The burden of solid waste management (SWM) in Lebanon has been growing since the 1990s. The increase in population (in particular since the Syrian conflict), in urbanization, and in population density; the lack of enforcement of the legislative framework for SWM; and the tendency towards consumerist social habits have escalated the scale and complexity of the SWM problem (Abbas 2017; World Bank 2011).

Environmental protection, and in particular SWM, in Lebanon is regulated by a complex legislative system/framework and governed by several public administrations whose roles are complementary and, in some cases, overlapping. Solid waste has contributed to polluting the Lebanese marine environment: In 2005, water pollution was estimated to be Lebanon's costliest environmental pollution problem, reaching 1.08 percent of GDP (US$80 million) (World Bank 2011).

In 2011, around 90 percent of the Lebanese population lived in urban areas (World Bank 2011) mostly situated along the coast where the economic sector thrives, and for which marine litter can pose environmental, health, and economic threats. A United Nations Development Programme (UNDP) study on Lebanon—State of the Environment and Future Outlook—published in 2020 shows that economic, environmental, and social problems arise as municipalities struggle with the recovery and disposal of their municipal waste; 2,700,000 tonnes of such waste were generated in Lebanon in 2018 (SOER 2020). Fifty-one percent of such waste ends up in one of the 341 operational municipal solid waste (MSW) disposal facilities currently operating in Lebanon, mainly located at riverbanks, rainwater streams, and coastal areas, which become pathways for the waste towards the seashores (UNDP 2017). Recently, in light of the economic crisis that began in October 2019, the number of uncontrolled disposal facilities in Lebanon seems to have increased, aggravating environmental pollution.

The environmental impacts of waste on Lebanon's marine and coastal environment have, until now, not received much research attention. Little to no robust or rigorously conducted marine litter sampling has been undertaken, and the dynamics of litter in the marine environment—including understanding the most prevalent items and materials, main sources, and pathways they take to reach the sea—have not been previously documented. The data and information gaps inhibit sound evidence-based action by Lebanon's decision-makers and inhibit the formulation of targeted measures to prevent and reduce the flow of marine litter into the coastal environment and the Mediterranean Sea.

1.2 Objectives and Scope

To establish scientific evidence regarding marine litter sources and hotspots in Lebanon, the Ministry of Environment requested the support of the World Bank through funding from PROBLUE, a World Bank multi-donor trust fund, to implement a Technical Assistance with the objective of establishing a baseline for marine litter in Lebanon and improving the capacity of Lebanese communities to prevent and reduce pollution in marine environments.

The baseline can inform relevant decision-makers on the status of marine litter in Lebanon and enable the development of an action plan to prevent and mitigate the leakage of waste into Lebanon's marine and coastal environment. This report covers the baseline assessment and its results and provides a comprehensive and rigorously derived national baseline of the sources, pathways, and hotspots of marine litter.

Sources, pathways, and hotspots were defined as follows:

Source: Activity, industry, or sector contributing to the release and accumulation of marine litter in the environment. A source can be either land-based (dumpsites, public littering, agricultural activities, improper disposal of litter, and so forth) or sea-based (fishing boats, cargo ships, recreational boats, harbors, and so forth).

Pathway: The means through which litter is transported from its source to the marine environment. Usual pathways include rivers, wind, tides, direct dumping, and so forth.

Hotspot: Sites where large amounts of litter accumulate. They are identified by comparing the quantity of litter in various places. Uncontrolled/illegal dumpsites and touristic areas are usually the main hotspots.

The baseline assessment builds on existing knowledge and employs established methodologies to collect new information on the following:

- Weaknesses in Lebanon's SWM system and quantities and sources of waste leaking into the marine environment;
- Main pathways by which these waste leakages are transported; and
- Hotspots where waste accumulates in Lebanon's marine and coastal environment to describe the most prevalent types of litter found there and help trace them back to their sources.

The assessment of marine litter leakage from SWM systems and the identification of sources, hotspots, and pathways of marine litter was achieved by focusing on two fundamental stages in the source-to-sea spectrum, as discussed in the following section.

1.3 Methodological Approach

The approach underlying this report focuses on two stages of the source-to-sea spectrum (SIWI 2019) where data are most concentrated, because waste is most concentrated where it is handled by the SWM system and in the natural accumulation zones. This approach thereby maximizes the amount of useful data and actionable information that can be generated from the resources available.

Data have been collected on:

- Waste management systems in urban areas most at risk of waste leakage to the environment; and
- Litter-accumulation hotspots on beaches and in river mouths along Lebanon's coast.

These two stages in the lifecycle of marine litter share one crucial similarity. They are natural accumulation points where large amounts of waste are deposited, either by anthropic means or natural wave action for beach litter. In both cases, the high density of waste that can be found at these two points in the marine litter lifecycle make the most fertile ground for detailed, rigorously conducted, quantitative research methods.

The waste management systems in urban areas were investigated by implementing the Waste Wise Cities Tool (WaCT)[1] and the Waste Flow Diagram (WFD) "terrestrial" methodologies[2]. The litter-accumulation hotspots on beaches and river mouths followed the Commonwealth Scientific and Industrial Research Organisation[3] (CSIRO) "Standing-Stock" and Sustainable Seas Trust (SST)[4] "Accumulation" methodologies that composed the set of "beach" surveys. The terrestrial and beach surveys were complemented by indicative marine survey methodologies.

The WaCT is the global standard methodology developed by UN-Habitat to assess baseline MSWM performance systems in cities. The consultant team collaborated with selected municipalities and relevant local stakeholders to understand waste flows within the city and where in the waste service chain MSW leakages are most likely to occur (that is, pre- or post-collection).

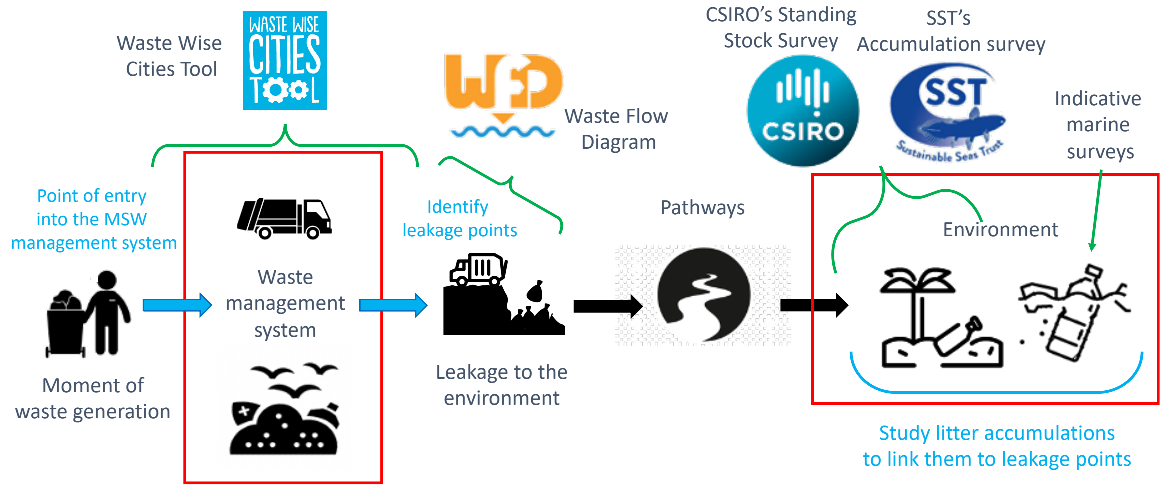
The WFD is a complementary observational assessment tool used to identify leakages and fates for plastics and other municipal solid wastes and provides more depth on the post-collection leakages analysis. The WFD accepts and relies on data input from the WaCT and further extends the analysis to leakages and fates. The two terrestrial surveys complement each other neatly, with the WaCT focusing on collected MSW while the WFD analyzes the fate of uncollected waste in the post-collection regime.

The combination of the CSIRO and SST surveys gives a complete picture of the spatial and temporal distribution of marine litter on the Lebanese coastline. The CSIRO survey consists of collecting, sorting, categorizing, and weighing sampled marine litter from 24 sites along the Lebanese coastline to determine the density of litter present at a single point in time. The CSIRO method is helpful in identifying marine litter hotspots but does not take into account temporal changes. This survey was therefore complemented with the accumulation survey (that is, the SST survey), which aims to assess the amount, accumulation rate, and potential sources of macro-litter at sea, therefore giving a temporal distribution of marine litter on the Lebanese shoreline.

The indicative marine surveys investigate marine litter on the seafloor, in surface waters, and in sediments to strengthen the findings from the terrestrial and beach surveys and enable an understanding of the sources and pathways of marine litter. For marine litter on the seafloor, underwater transects were used to estimate marine litter density between depths of 0 and 20 meters due to its proximity to the leakage points on shore. The study of marine litter in sediments was carried out at the same transect belts as for marine litter assessment on the seafloor by scuba divers (50 to 100 meter transect belts), and 3 kilograms from three sampling points per transect belt were collected. Finally, the indicative assessment of marine litter in surface waters was undertaken at the same sites as those for marine litter assessment on the seafloor by applying the visual survey method. This requires a boat to sail at an average speed of 2 knots for a minimum of 1 hour on a preset transect parallel to the shore with a field of vision of 5 meters on each side with observers counting floating litter within the set field of vision.

The implementation of the surveys across the source-to-sea spectrum is shown in Figure 1.2, and indicators measured by the project are shown in Table 1.1.

Figure 1.2: Surveys Implemented across the Source-to-Sea Spectrum



Source: World Bank.

Table 1.1: Summary Table of all Indicators Measured by this Project's Primary Data Collection Surveys

Survey	Indicator	Disaggregation
Waste Wise Cities Tool (WaCT)	Household waste generation per capita (kg/person/day) Waste generation rate (t/day) Waste collection rate (t/day) Waste recovery rate (t/day) Waste managed in controlled facilities (t/day)	12 waste categories in the WaCT Plastic polymers Low/medium/high income
Waste Flow Diagram (WFD)	Plastic leakage to the environment (kg/day)	Per major source Per major pathway
Standing Stock Beach Litter Survey	Density of litter per linear meter of shoreline (items/m)	Item type Material type Plastic polymers Location
Beach Litter Accumulation Survey	Density of litter per linear meter of shoreline (items/m) Accumulation rate of litter per linear meter of shoreline (items/m/day)	Item type Material type Plastic polymers Location Wet vs. dry side of beach
Remote Sensing Analysis of Disposal Sites along Rivers	Number of disposal sites within 500 m (sites/river) Density of disposal sites per linear kilometer (sites/km/river) Change in number of disposal sites since 2016 (sites/river) Change in area of disposal sites since 2016 (Δm^2/site)	Per river Municipal/construction waste (if possible) Active/closed site (if possible)
Indicative Marine Surveys	Density of litter per m^2 of sea floor surveyed (items/m^2) Density of litter per sample of sediment (items/sample) Density of litter per m^2 of sea surface surveyed (items/m^2)	Item type Material type Location

Source: World Bank.

1.4 Stakeholder Involvement

The terrestrial, beach, and marine surveys were implemented in close consultation with stakeholders. The project was launched during an inception meeting held in February 2021. Key stakeholders from the Ministry of Environment, the municipalities of Tyre and Byblos, various nongovernmental organizations (NGOs), and other concerned national and international institutions were invited to attend the meeting. The meeting presented the project, its intended activities and expected outcomes, and gathered feedback and other relevant information. Additional meetings were conducted with the municipalities of Tyre and Byblos to ensure close collaboration during the implementation of the surveys. Once all the surveys were completed, a January 2022 validation meeting was organized to present the results of the baseline assessment to key stakeholders. All stakeholders that had participated in the implementation of the project were invited, along with stakeholders that had taken part in the inception phase. Feedback from the validation workshop was taken into account for the final version of this Baseline Report on Marine Litter in Lebanon, which was submitted to the World Bank in February 2022.

1.5 Temporal Coverage of the Surveys

The terrestrial and beach surveys were first implemented in the spring of 2021 (April–May) and were reproduced in the fall of 2021 (October–November) to obtain a yearly dataset of marine litter loads and their distribution in Lebanon. The results of the terrestrial, beach, and marine surveys are presented in this report and represent the baseline for marine litter in Lebanon. While the initial purpose of selecting April–May and October–November as the study months was to reflect the differences between the dry (spring) and wet (autumn) seasons, in fact summer climate extended until November with high temperatures and dry weather. This prevented the team from collecting data in autumn, representative of the wet season. However, this allowed the team to shift the focus from seasonal variations to the pre- and post-touristic seasons.

The repeated collection of marine litter data throughout the year 2021 makes the data that are presented below the baseline for marine litter monitoring against which future data collected should be benchmarked.

1.6 Geographical Coverage of the Surveys and Site Selection

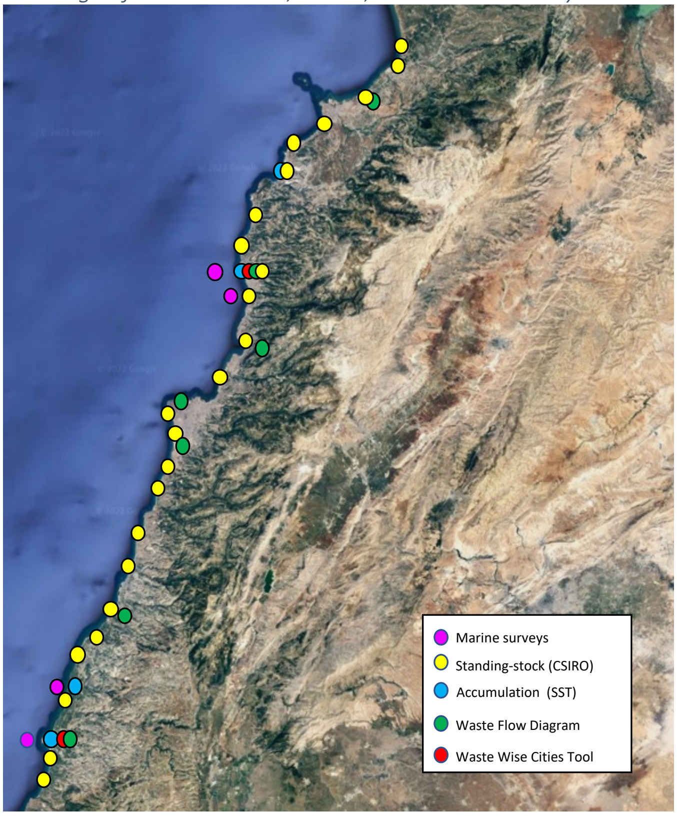
The sites studied for the surveys were selected to reflect Lebanon's diverse coastal environment. The WaCT and WFD were implemented in the touristic cities of Byblos and Tyre. A further five villages and cities were selected for the application of the WFD based on their strategic geographic location, MSWM-operator model, and proximity to marine litter hotspots. The five villages and cities selected were Beddaoui, Ghazir, Beirut, Ghobeiry, and Aadoussiyeh.

For the CSIRO survey, 24 sites evenly distributed and covering the entire Lebanese coastline from Aakar to Naqoura were visited. As advised in the CSIRO methodology, the sites were randomly selected to reflect the diversity of site types (varying population densities, proximity to roads and waterways, land use types, and so forth), with even distance between each site (around 10 kilometers).

The SST and marine surveys took place in Tyre and Byblos to supplement the datasets acquired during the WaCT and WFD. For the SST survey, the beaches were selected following the selection criteria of the SST's "Accumulation survey" methodology. These criteria included consideration of natural ecosystems (for example, avoidance of beaches with endangered species present); beach substrate (sand, gravel, or other substrate where litter can accumulate); slope gradient (which should be low to moderate); the site's dimension (minimum 500-meter length); ability to access the site; and so forth. The beaches chosen in Tyre and Byblos were selected since they were the only ones fulfilling the length criteria in the areas, in addition to fulfilling the rest of the criteria mentioned above.

The location of all the sites studied as part of this project are shown in Figure 1.3. Further details on each site surveyed during this project are presented hereafter in the corresponding sections.

Figure 1.3: Geographical Coverage of the Terrestrial, Beach, and Marine Surveys in Lebanon



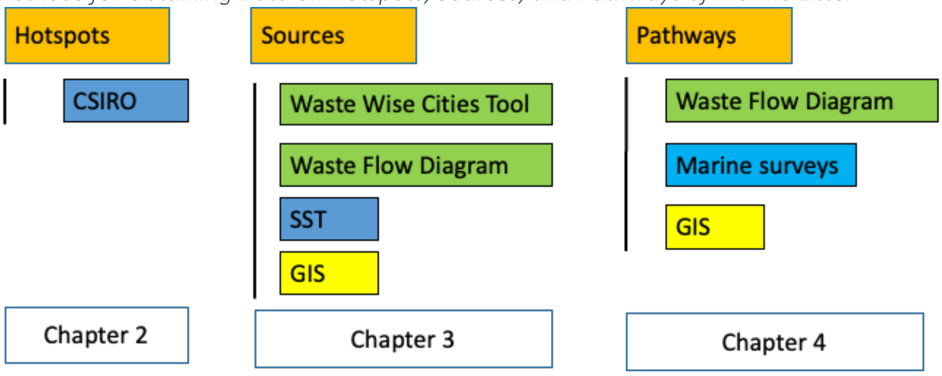
Source: World Bank.

1.7 Report Structure

This report describes the different methodologies followed in the marine litter baseline assessment in Lebanon and summarizes the main findings. Chapter 1 introduces the overall project, its objectives, and the approach implemented to establish the baseline. Chapters 2, 3, and 4 present the results for the hotspots, sources, and pathways of marine litter, respectively, which were determined from the combination of the terrestrial, beach, and marine surveys. The breakdown of the surveys and the findings they yield is depicted in Figure 1.4 below

Chapter 5 details the finding of the CSIRO survey to capture the spatial distribution of marine litter, and Chapter 6 addresses the temporal accumulation of marine litter, showing detailed results of the SST (Accumulation) survey. Chapter 7 proposes recommendations for future action including research that will strengthen the baseline. Appendices at the end of the document detail the methodologies implemented during the baseline assessment, the sites visited during the CSIRO surveys, and the litter categories used for the marine surveys.

Figure 1.4: Methods for Obtaining Data on Hotspots, Sources, and Pathways of Marine Litter



Source: World Bank.
Note: The blocks in green represent terrestrial surveys, the blocks in dark blue the beach surveys, the blocks in yellow the GIS and the block in turquoise the marine surveys.

Each chapter of the report is introduced by the following summary of that chapter's main issues and the methodological tools adopted for conducting the analysis (see Figure 1.5).

Figure 1.5: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools

Source: World Bank.

Notes

[1] https://unhabitat.org/wwc-toolhttps://plasticpollution.leeds.ac.uk/toolkits/wfd/https://research.csiro.au/marinedebris/resources/
The WaCT was developed as a collaboration between UN-Habitat and RWA-Wasteaware, Eawag, and the University of Leeds. https://unhabitat.org/sites/default/files/2021-02/Waste%20wise%20cities%20tool%20-%20EN%207%20%281%29.pdf

[2] The WFD was developed through a collaboration between GIZ, the University of Leeds, EAWAG, and RWA-Wasteaware. https://plasticpollution.leeds.ac.uk/toolkits/wfd/

[3] https://www.csiro.au. The "standing-stock" methodology ("Survey Methodology Handbook v1.4") can be found at https://research.csiro.au/marinedebris/resources/

[4] https://sst.org.za. The "accumulation" survey methodology can be found at https://sst.org.za/wp-content/uploads/2020/07/Barnardo-Ribbink-2020_African-Marine-Litter-Monitoring-Manual.pdf

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2 Hotspots

Figure 2.1: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools

Source: World Bank.

2.1 Key Findings

Key Findings

Key Finding: Beddaoui (Tripoli) and Jadra (Chouf) were the main hotspots of plastic marine litter found both in April and October 2021.

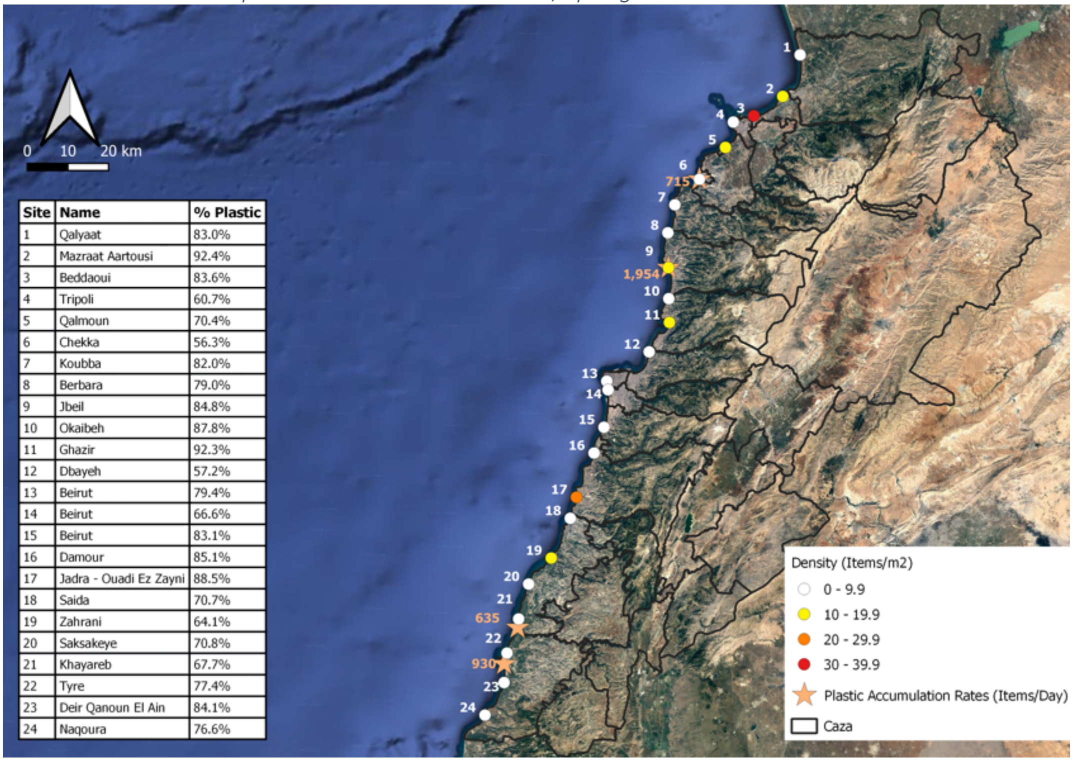
Importance: Coastal urbanization, lack of collection services and touristic activities are thought to be the main drivers of marine litter deposition on the Lebanon coastline.

Implication: Beaches located close to large urban settlements, that are easily accessible to the public and don't have regular cleanup activities are more likely to be hotspots of plastic marine litter.

2.2 Detailed Findings

Hotspots of marine litter are found where waste accumulates in Lebanon's marine and coastal environment. One round of beach surveys was conducted in April–May 2021, and a second round was conducted in October-–November 2021 to create a complete yearly dataset for marine litter in Lebanon. Marine litter hotspots were found by investigating marine litter density on 24 beaches from Aakar to Naqoura, using the "standing-stock" survey methodology of the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The marine litter load and composition data collected were disaggregated by most-common items found, item-specific accumulation rates, brands, polymer types, geographic trends in litter types, and an assessment of most-likely pathways and sources in each survey location and for each major type of litter. These results are presented in Section 5. A detailed list of all the sites visited is presented in Appendix B CSIRO Sites and Figure 2.3 show the marine litter hotspots for each site surveyed in spring and autumn 2021.

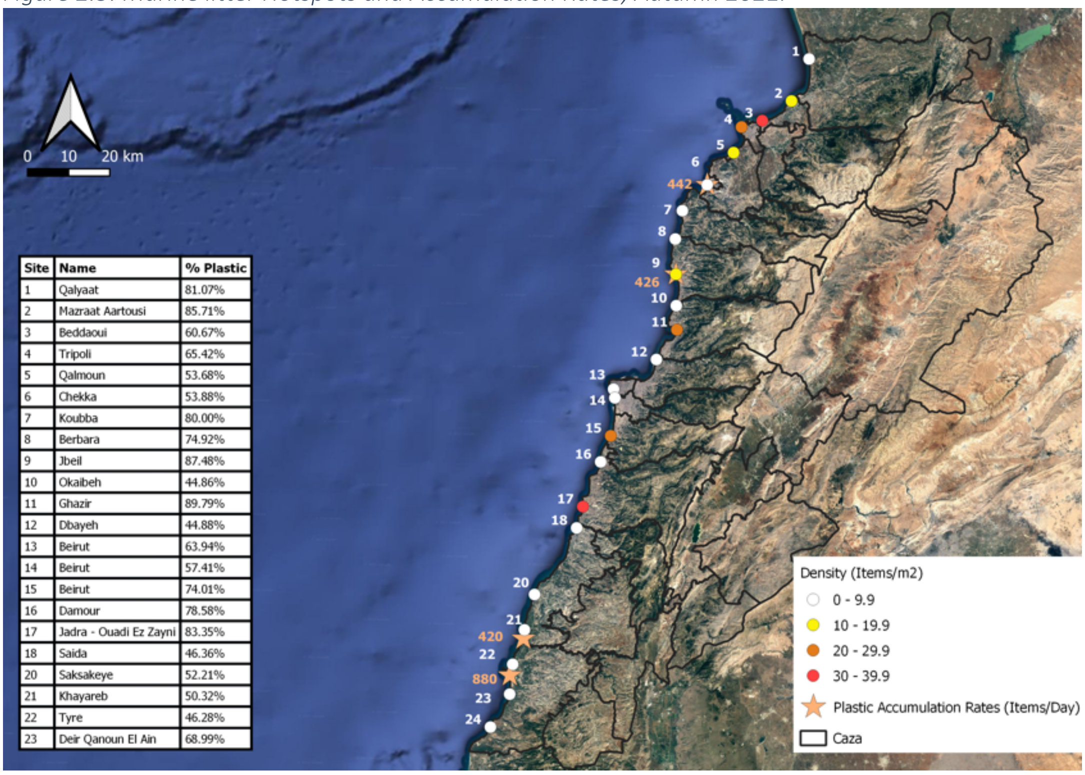
Figure 2.2: Marine litter Hotspots and Accumulation Rates, Spring 2021



Site	Name	% Plastic
1	Qalyaat	83.0%
2	Mazraat Aartousi	92.4%
3	Beddaoui	83.6%
4	Tripoli	60.7%
5	Qalmoun	70.4%
6	Chekka	56.3%
7	Koubba	82.0%
8	Berbara	79.0%
9	Jbeil	84.8%
10	Okaibeh	87.8%
11	Ghazir	92.3%
12	Dbayeh	57.2%
13	Beirut	79.4%
14	Beirut	66.6%
15	Beirut	83.1%
16	Damour	85.1%
17	Jadra - Ouadi Ez Zayni	88.5%
18	Saida	70.7%
19	Zahrani	64.1%
20	Saksakeye	70.8%
21	Khayareb	67.7%
22	Tyre	77.4%
23	Deir Qanoun El Ain	84.1%
24	Naqoura	76.6%

Source: World Bank.

Figure 2.3: Marine litter Hotspots and Accumulation Rates, Autumn 2021.



Site	Name	% Plastic
1	Qalyaat	81.07%
2	Mazraat Aartousi	85.71%
3	Beddaoui	60.67%
4	Tripoli	65.42%
5	Qalmoun	53.68%
6	Chekka	53.88%
7	Koubba	80.00%
8	Berbara	74.92%
9	Jbeil	87.48%
10	Okaibeh	44.86%
11	Ghazir	89.79%
12	Dbayeh	44.88%
13	Beirut	63.94%
14	Beirut	57.41%
15	Beirut	74.01%
16	Damour	78.58%
17	Jadra - Ouadi Ez Zayni	83.35%
18	Saida	46.36%
20	Saksakeye	52.21%
21	Khayareb	50.32%
22	Tyre	46.28%
23	Deir Qanoun El Ain	68.99%

Source: World Bank.

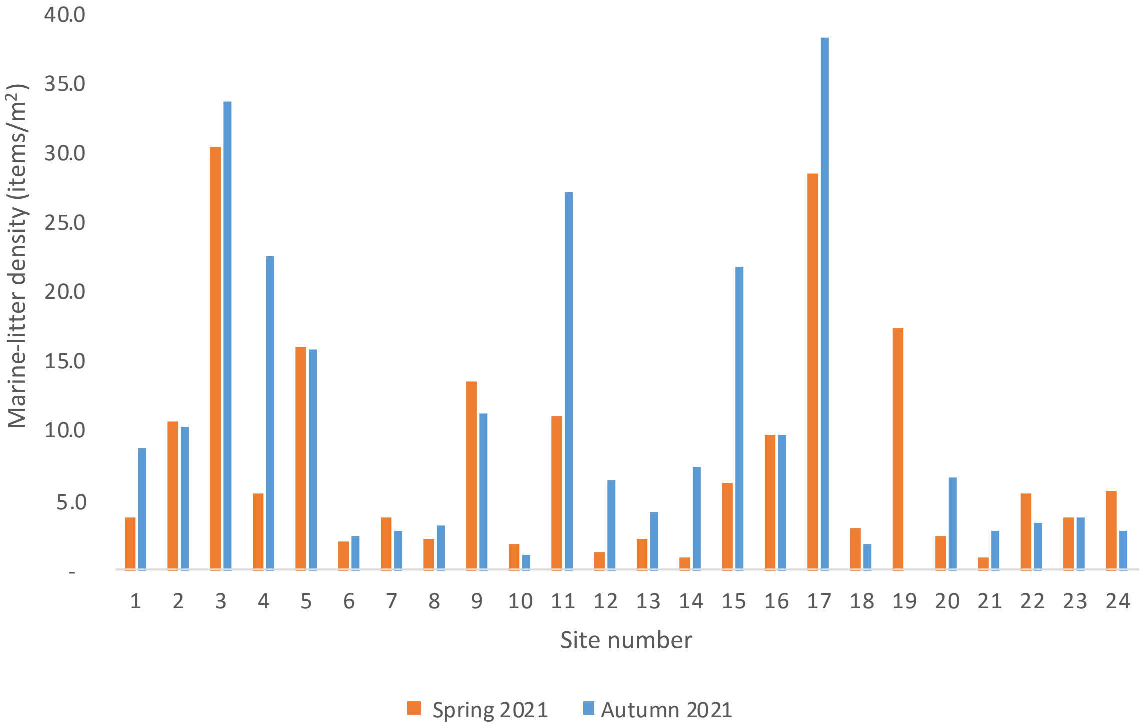
From the figures above, it can be observed, on one hand, that the South of Lebanon (from site 18 to site 24), and the sections between sites 6 and 8 (between Chekka and Batroun), and sites 12 and 14 (around Beirut) consistently have a lower marine litter density throughout the year, ranging between 0 and 19.9 items/m^2. On the other hand, sites 3 next to Tripoli and site 17 in the North of Sidon stand out in Spring and Autumn as the sites with the highest marine litter density (above 20 items/m^2), making them recuring, established hotspots.

The main hotspots of plastic marine litter in Lebanon are Beddaoui (Tripoli) and Jadra (Chouf).

Table 2.1 and Figure 2.4 shows the variation in marine litter density between the two rounds of surveys. Figure 2.5 depicts scenes from the survey activities. Further observations can be drawn:

- 14 sites have higher marine litter density, and nine sites have lower marine litter densities during the second round of surveys. One site (Zahrani) could not be visited during the second survey for safety reasons.
- Site 3 (Beddaoui, Tripoli) and site 17 (Jadra, Chouf) were the hotspots with the highest marine litter density, both in April and October 2021. Site 5 (Qalamoun, Tripoli) also remains a hotspot.
- New hotspots have emerged, such as site 4 (Tripoli Mina), site 11 (Ghazir, Keserwan) and site 15 (Beirut).
- The greatest increase in marine litter density was at Saint-Simon in Beirut (site 14), with a marine litter density rocketing from 0.89 items/m^2 to 7.47 items/m^2. In Dbayeh (site 12), the density ballooned by 415 percent, jumping from 1.24 to 6.40 items/m^2.
- The most noticeable improvement was in Naqoura (site 24), with a decrease of 49 percent in marine litter density.
- The sites that have a river input, Koubba and Nahr Ibrahim (sites 7 and 10), both show a lower litter density in the second round of surveys compared to the first one (-28 percent and -38 percent, respectively). The lack of rain prior to the start of the survey upstream of the rivers likely prevented solid waste from being washed down by the rivers and accumulating on the beaches.
- The marine litter density at site 4 (Tripoli Mina) increased by 303 percent, with a majority of the litter being hard plastic fragments, plastic caps, glass fragments, and cigarette butts.

Figure 2.4: Marine litter Density on Lebanese Beaches.



Source: World Bank.

Table 2.1: Variation in Maritime-Litter Density: First vs. Second Rounds of Surveys, by Site.

Site #	Site name	Caza	Density spring (items/m^2	Density autumn (items/m^2	Variation between first and second survey (percent)
1	Qalyaat	Aakar	3.8	8.7	+132
2	Mazraat Aartousi	Minniyeh-Danniyeh	10.7	10.4	-3
3	Beddaoui	Tripoli	30.5	33.7	+10
4	Tripoli	Tripoli	5.6	22.5	+303
5	Qalmoun	Tripoli	16.0	15.9	-1
6	Chekka	Batroun	2.1	2.5	+22
7	Koubba	Batroun	3.8	2.7	-28
8	Berbara	Byblos	2.3	3.2	+37
9	Jbeil	Byblos	13.5	11.4	-16
10	Okaibeh	Keserwan	1.9	1.2	-38
11	Ghazir	Keserwan	11.2	27.1	+143
12	Dbayeh	Matn	1.2	6.4	+415
13	Ramlet Al Baida	Beirut	2.3	4.1	+80
14	Saint-Simon	Beirut	0.9	7.5	+743
15	Khalde	Beirut	6.2	21.8	+251
16	Damour	Chouf	9.8	9.8	+1
17	Jadra	Chouf	28.6	38.3	+34
18	Saida	Saida	3.1	2.0	-36
19	Zahrani	Saida	17.4	–	–
20	Saksakeye	Saida	2.5	6.6	+169
21	Khayareb	Saida	1.0	2.8	+188
22	Tyre	Tyre	5.6	3.4	-39

Site #	Site name	Caza	Density spring (items/m^2	Density autumn (items/m^2	Variation between first and second survey (percent)
23	Deir Qanoun El Ain	Tyre	3.8	3.7	-2
24	Naqoura	Tyre	5.6	2.8	-49
Median density (item/ m^2)			4.7	6.6	

Source: World Bank.
Note: For site 19, "–" means that the data is not available. An explanation for this is provided in Section 5.

Looking at the marine litter density in the spring from Table 2.1, Beddaoui (site 3), Jadra (site 17) and Zahrani (site 19) have the highest rates across Lebanon. The high marine litter densities found at sites 3 and 17 are explained by the dumping of waste and the wastewater outlets emerging directly on the beaches. In Beddaoui, the beach is located behind an agricultural field, and large amounts of fragments of plastic baskets and equipment used to carry the vegetables were collected during the survey. In addition to the wastewater which also carries litter onto the beach, the site is located 200 meters north of an uncontrolled disposal site, managed by a private company – increasing the chances of waste leaking from the site and being transported to the site studied. In Jadra, textiles and clothes were found in piles across the beach, indicating that they were directly openly dumped on the beach. Zahrani's situation is similar to Beddaoui's beach as it is tucked away behind a petrochemical plant, and therefore hardly accessible to the public (although there is a public access). As the most found items on the beach (hard plastic fragments, shoes and plastic bottle caps and bottles) are diverse and showed different stages of degradation, the heavy littering at that site is harder to explain. The plastic fragments may indicate that the beach was once used more often by visitors and is now less visited.

The sites in Dbayeh, Kharayeb and Saint-Simon (sites 12, 21 and 14 respectively) showed the lowest marine litter densities across Lebanon during the spring 2021. This is particularly interesting as Dbayeh and Saint-Simon are amongst the sites with the highest marine litter density in the fall. The three beaches have more differences than common points, making it hard to hypothesize on their low results in marine litter density. Dbayeh beach is a small beach close to the highway, between the urban settlements of Beirut and Jounieh, Kharayeb beach is hidden behind agricultural fields in the South of Lebanon, away from larger cities, and Saint-Simon beach is at the heart of a large informal settlement in the south of Beirut. While the beaches in Kharayeb and Dbayeh have less visitors due to their harder access for the public, the residents indicated that the beach is regularly cleaned; the field team may have sampled the beach shortly after a cleanup activity took place.

The results of the survey in the fall show that Jadra and Beddaoui are still amongst the three beaches with the highest marine litter density. The beach in Ghazir (site 11) comes as the third most littered beach. When visited in the spring, the beach was privatised and cleaned regularly by the restaurant close to the shore. However, when the team visited the beach for the survey during the fall, the beach had been split in two: a part belonging to the restaurant (who is responsible for the cleanliness of that section of the beach) and a part freely accessible to the public, which was heavily littered. On the latter part of the beach, hard plastic fragments were found in abundance, specifically on the most recent strandline and the storm strandline, indicating that marine debris might have been washed from ashore, or that larger items deposited by the restaurant or visitors broke down due to wave exposure and sunlight.

The lowest marine litter densities in the fall were found in Chekka (site 6), Saida (site 18), and Okaibeh (site 10). The beaches sampled in Saida and Okaibeh were cleaned shortly before the team visited them, probably explaining the low amount of marine litter found. In Chekka, whilst the beach is not regularly cleaned, two main parameters may explain its low marine litter density. Firstly, little human activity takes place and the beach does not attract many visitors. Secondly, the cliffs standing west of it may divert waste travelling northward with the currents, keeping it clean from litter potentially coming from sea-based sources, or being washed ashore.

When looking at the highest and lowest variations in marine litter density for each individual sites, it is noticeable that the three largest variations in marine litter density (sites 14 with +743 percent, 12 with +415 percent and 4 with +303 percent) are larger by hundreds of times the magnitude of the three smallest variations (sites 23 with -2 percent, 5 with -1 percent and 16 with +1 percent). Sites 12 and 14 share the common characteristic of being situated in the middle of informal settlements; in Dbayeh, an informal settlement had set up on the beach between the two surveys, and in October 2021, it was clear that the families living on the beach were discarding their waste directly onto the sand and water, drastically increasing the marine litter density present at the site. In Saint-Simon, the marine litter density results rely on the residents' ability to remove their waste from the beach, as there are no formal collection services serving the area. From these results, it would seem that coastal urbanization combined with lacking collection services are important contributors to marine litter.

Additionally, sites 5, 16 and 23 are beaches that are not popular amongst locals and tourists, regardless of the season, hence the little variations observed. Sites 16 and 23 are hard to access for the public (site 23 is behind agricultural fields and site 16 is hidden behind a restaurant on a highway), and site 5, while being easily accessible by car, has not been adapted to receive visitors (it does not have a clear path between the road and the beach, there are no restaurants or supermarkets nearby, and is located behind a small harbor, making it potential dangerous for children).

Urbanization and the lack of collection services were common factors to the most littered beach studied.

Figure 2.5: Scenes from Baseline Survey Activities

Source: World Bank.

3 Sources

Figure 3.1: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools

Source: World Bank.

The solid waste management systems of the urban areas of Tyre and Byblos were selected to assess potential sources of marine litter in Lebanon. Their proximity to the Mediterranean Sea and intense touristic activities, especially during the summer months, put those systems at particular risk of waste leakage to the marine environment.

3.1 Key Findings

Key Findings

Key Finding: 70 percent in May 2021 and 88 percent in October 2021 of all marine litter collected is likely to have been dumped on land, rather than from a sea-based source. 73 potential new uncontrolled disposal sites were identified along 14 rivers leading to the Mediterranean Sea.

Importance: National mismanagement of solid waste through uncontrolled disposal and uncollected waste seems to be amongst the major sources of marine litter in Lebanon.

Implication: Reducing marine litter loads on the Lebanese coastline can be achieved by transitioning from uncontrolled disposal to controlled disposal, expanding waste collection systems and tackling misbehavior from beach visitors.

3.2 Marine Litter Washed from Ashore versus Marine Litter Dumped on Land

Accumulation beach surveys allow for determining quantities of marine litter, changes in those quantities, and potential sources of marine litter found on beaches. The specificity of accumulation surveys—compared to standing-stock surveys—allows differentiation between litter accumulated on the supratidal area (the "dry" side of the beach, above the high-water mark), on the one hand, and litter accumulated on the intertidal area (the “wet” side of the beach, below the high-water mark), on the other hand. This specificity enables surveyors to differentiate between marine litter washed up from the ocean (if collected on the wet side) and marine litter resulting from dumping by beachgoers (if collected on the dry side). This chapter examines the amount of litter found on either side of the high-tide mark in Byblos and Tyre and links these findings to data on items and brands (see Chapter 6), to gain understanding of the origin of marine litter from land-based and sea-based activities.

The accumulation survey methodology used in Lebanon was developed by the Sustainable Seas Trust (SST). This methodology is described in detail in Section 3.5 of the Marine Litter Monitoring Manual, which was published by the SST in September 2019 through its African Marine Waste Network project in association with the Western Indian Ocean Marine Science Association (WIOMSA). The association is partnering with the SST to apply the same methodology in seven countries in the western Indian Ocean region as part of a 3-year project on marine litter monitoring[1].

On the four sites selected in Tyre and Byblos (see Chapter 6, Section 6.1), a 600-meter stretch of beach was demarcated—a 500-meter transect with two 50-meter buffer zones on each side. On Day Zero of the survey, the entire 600-meter stretch was cleaned of all visible litter from the water’s edge to the dominant vegetation at the top of the beach. Each day from Day 1 to Day 7, the survey team revisited both sites at the same time and collected all the new litter that appeared.

Table 3.1 shows the percentages of the total count (and weight in grams) of items (for example, plastic bottles, cigarette butts, bottle caps, plastic bags, and so forth) found on the dry and wet sides of the beach, during the spring assessment. For both cities, around 70 percent of the litter by count was dumped on the beach (that is, its immediate source was land-based), and 30 percent was washed ashore by the sea. It is commonly acknowledged that 80 percent of plastic waste reaches the sea from land-based sources, and about 90 percent of plastic waste flows down waterways to the seas.

As mentioned above, it is assumed that an item found on the dry side of the beach most likely originated from land-based activities, and an item collected on the wet side is more likely to have been washed ashore (but could have originated from either land-based or sea-based sources). However, this study’s methodology did not exclude the possibility that items found on the dry beach might have been brought from the sea and been pushed inland by strong winds, or that an item discarded by a visitor on the dry beach reaches the wet part. This source of potential error in the tallies is mitigated during the sorting process in the following way: if, for instance, a chocolate-bar wrapper is found on the wet side of the beach but shows no damage caused by long journeys at sea, then it is counted in the dry part.

Table 3.1: Dry and Wet Fractions of the Marine Litter Found in Tyre and Byblos, Spring 2021

Tyre									
Total		Dry				Wet			
Count	Weight	Count	Weight (g)	Percent of count	Percent of weight	Count	Weight (g)	Percent of count	Percent of weight
20,883	234,411	14,752	114,190	70.6	48.7	6,131	120,221	29.4	51.3

Byblos									
Total		Dry				Wet			
Count	Weight	Count	Weight (g)	Percent of total count	Percent of total weight	Count	Weight (g)	Percent of total count	Percent of total weight
27,862	228,405	19,469	166,624	69.9	73.0	8,393	61,781	30.1	27.0

Source: World Bank.

Table 3.2 below shows that 60.0 percent of the total waste at the Litani River Mouth Beach was discovered on the dry side of the beach, and therefore 40.0 percent was found on the wet sand. By contrast, 96.8 percent of the litter at Chekka Beach originated from inland sources. This difference may result from the different geographical conditions at the two beaches: Chekka Beach is hidden behind a cliff that breaks the currents coming from the south and prevents significant waves from forming and carrying marine debris towards the shore, as shown in Figure 3.2. On a sunny day without wind, the intertidal area of Chekka Beach is the smallest (around 1 meter wide) of the four beaches studied, contributing to the low amount of litter found on this part of the beach. A satellite view of Litani River Mouth Beach is shown in Figure 3.3.

At least 70 percent of all litter collected during the May 2021 survey is likely to have been dumped on land.

Table 3.2: Dry and Wet Fractions of the Marine Litter Found at the Litani River Mouth and Chekka Beaches, Spring 2021

Litani River Mouth Beach									
Total		Dry				Wet			
Count	Weight	Count	Weight (g)	Percent of total count	Percent of total weight	Count	Weight (g)	Percent of total count	Percent of total weight
6,323	104,696	3,792	66,235	60.0	63.3	2,531	38,461	40.0	36.7
Chekka Crystal Beach									
Total		Dry				Wet			
Count	Weight	Count	Weight (g)	Percent of total count	Percent of total weight	Count	Weight (g)	Percent of total count	Percent of total weight
5,924	72,321	5,734	70,471	96.8	97.4	190	1,850	3.2	2.6

Source: World Bank.

Figure 3.2: Cliff to the West of Chekka Beach, Stopping the Currents' Momentum Coming from the South

Source: World Bank.

Figure 3.3: Litani River Mouth Beach

Source: World Bank.
Note: The intertidal area is visible from the water's edge to the limit between the wet and dry sides of the beach.

Figure 3.4: Marine Debris Close to the Shore on Sour Beach

Source: World Bank.
Note: The dark marine debris items visible in the picture were most likely found the following day on the wet sand.

The autumn 2021 accumulation survey was marked by stormy weather, with strong winds on Day 2 and Day 3 in Byblos and light rain showers on Day 2 in Tyre. Strong winds and rains made it difficult to determine the intertidal line and could have blown items coming from the sea towards the back of the beach. Survey team members used their informed judgement to determine whether litter items were washed from ashore or came from the sea.

In Tyre, 89.1 percent of the items were found on the dry side of the beach, as shown in Table 3.3, suggesting that marine litter originates mainly from land-based activities on the beaches studied. This finding is consistent with the type of items found—mainly single-use plastics (SUPs)—which are usually products discarded by beach visitors. Despite the daily cleanups during the high summer season until mid-October, the prolongation of the beautiful days attracted visitors until November, at the time the survey was conducted. The high frequency of beachgoer visits, the ending of daily cleanups, and the lack of infrastructure for solid waste disposal (such as bins) does not encourage people to dispose of their waste responsibly, driving poor behavior from visitors as a main cause for beach litter. Soft plastic fragments, bottle caps, and cigarette butts were the main items found on the wet side of the beach.

In Byblos, 87.0 percent of the items in the autumn survey were found on the dry side of the beach (see Table 3.3), for similar reasons as for Tyre. The main items found on the wet side of the beach were soft, hard, and polystyrene plastic fragments, showing high levels of wear due to the marine environment.

Table 3.3: Dry and Wet Fractions of the Marine Litter Found in Tyre and in Byblos, Autumn 2021

Tyre									
Total		Dry				Wet			
Count	Weight (g)	Count	Weight (g)	Percent of total count	Percent of total weight	Count	Weight (g)	Percent of total count	Percent of total weight
34,609	141,188	30,830	97,123	89.1	68.8	3,779	44,065	10.9	31.2
Byblos									
Total		Dry				Wet			
Count	Weight (g)	Count	Weight (g)	Percent of total count	Percent of total weight	Count	Weight (g)	Percent of total count	Percent of total weight
10,942	118,011	9,523	97,725	87.0	82.8	1,419	20,286	13.0	17.2

Source: World Bank.

Section 3.4 provides comparisons between the accumulation rates on the wet (intertidal) and dry (supratidal) areas of each beach to approximate the input of litter from beach-going visitors and the daily deposition from the sea.

Figure 3.5: Day Zero on Byblos Titanic Beach during the Autumn Survey

Source: World Bank.
Note: The survey team was supported by the Scouts of Tripoli.

At least 88 percent of all litter collected during the fall 2021 survey is likely to have been dumped on land.

3.3 Solid Waste Management Systems

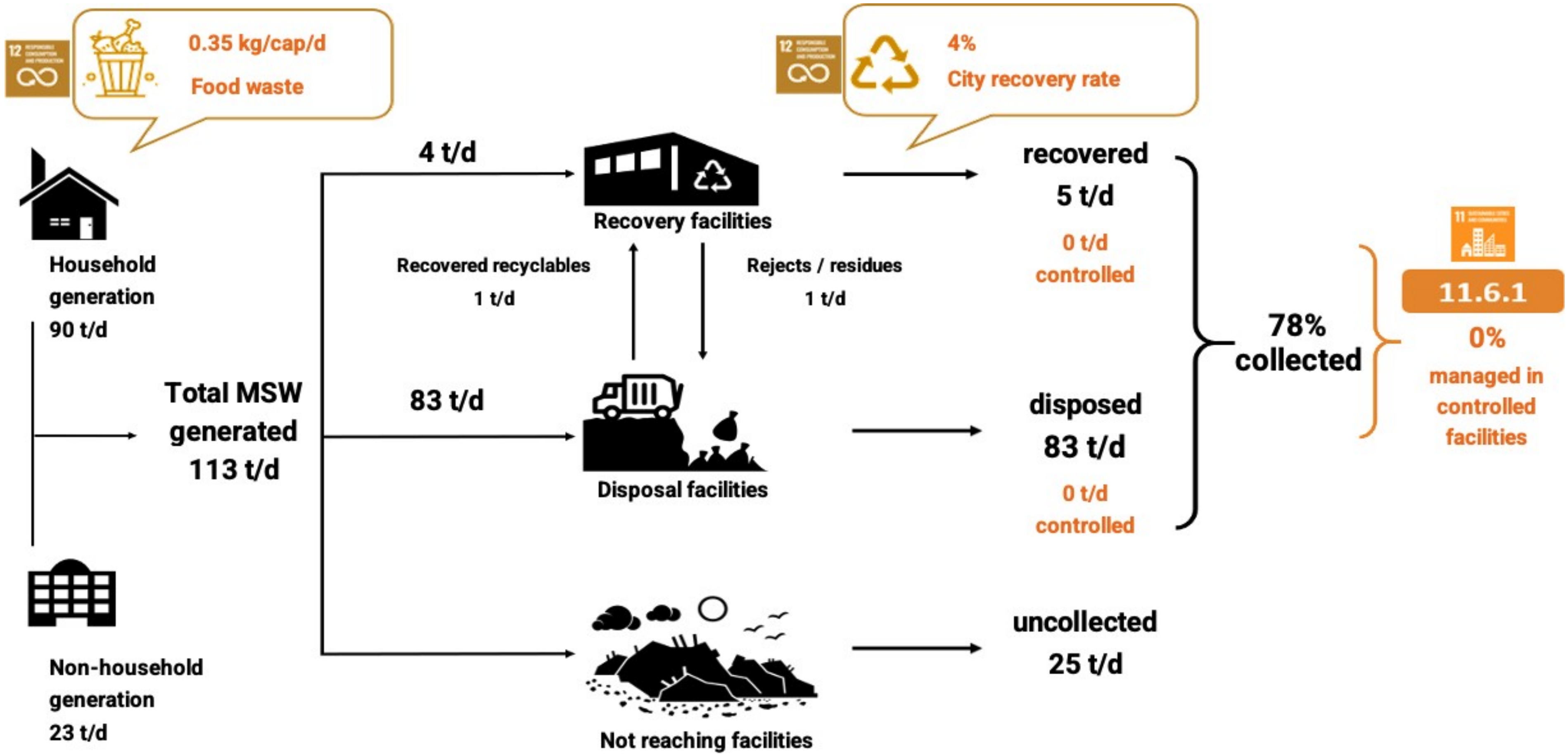
In Tyre and Byblos, uncollected waste and uncontrolled disposal are the main source of solid-waste leakages to the environment.

In April 2021, the implementation of UN-Habitat's Waste Wise Cities Tool in Tyre and Byblos helped in mapping the flows of collected MSW and characterizing the main sources of solid waste from municipal waste management systems. The results of the city assessments are illustrated in Figure 3.6.

Tyre's SWM landscape is constantly evolving, due to the ongoing economic crisis and Covid-19 pandemic. Figure 3.6 highlights the fate of collected MSW in Tyre. Based on a representative sample of household-waste surveys, it is estimated that 113 tonnes of solid waste are generated per day in Tyre. Of this quantity, an estimated 78 percent is collected, while around 22 percent remains uncollected. The collected waste is separated into two categories based on the form of management it undergoes: Around 83 tonnes per day are estimated to be landfilled in either of Tyre's or Bourj el Chemali's disposal sites, neither of which meets UN-Habitat's definition of a "controlled" management facility[2]. Meanwhile, around 5 tonnes per day (4 percent of the total solid waste generated) were found to be managed by informal apex traders, since the formal recovery value chain in Tyre is inexistent. Materials recovered by apex traders in Tyre are sent to specialized end-of-chain recyclers throughout Lebanon, since there is little recycling capacity within Tyre. Plastic PET and 3D Plastics are sent to Nabatiyeh to be reprocessed into pellets. Cardboard and nylon are redirected to Saida, and metals are sent to Ghazzieh to be shipped outside of Lebanon. Despite a reliable waste-collection service (78 percent), poor practices at the disposal facilities and a low recovery rate render the SWM system unable to prevent the release of (plastic) waste into the environment.

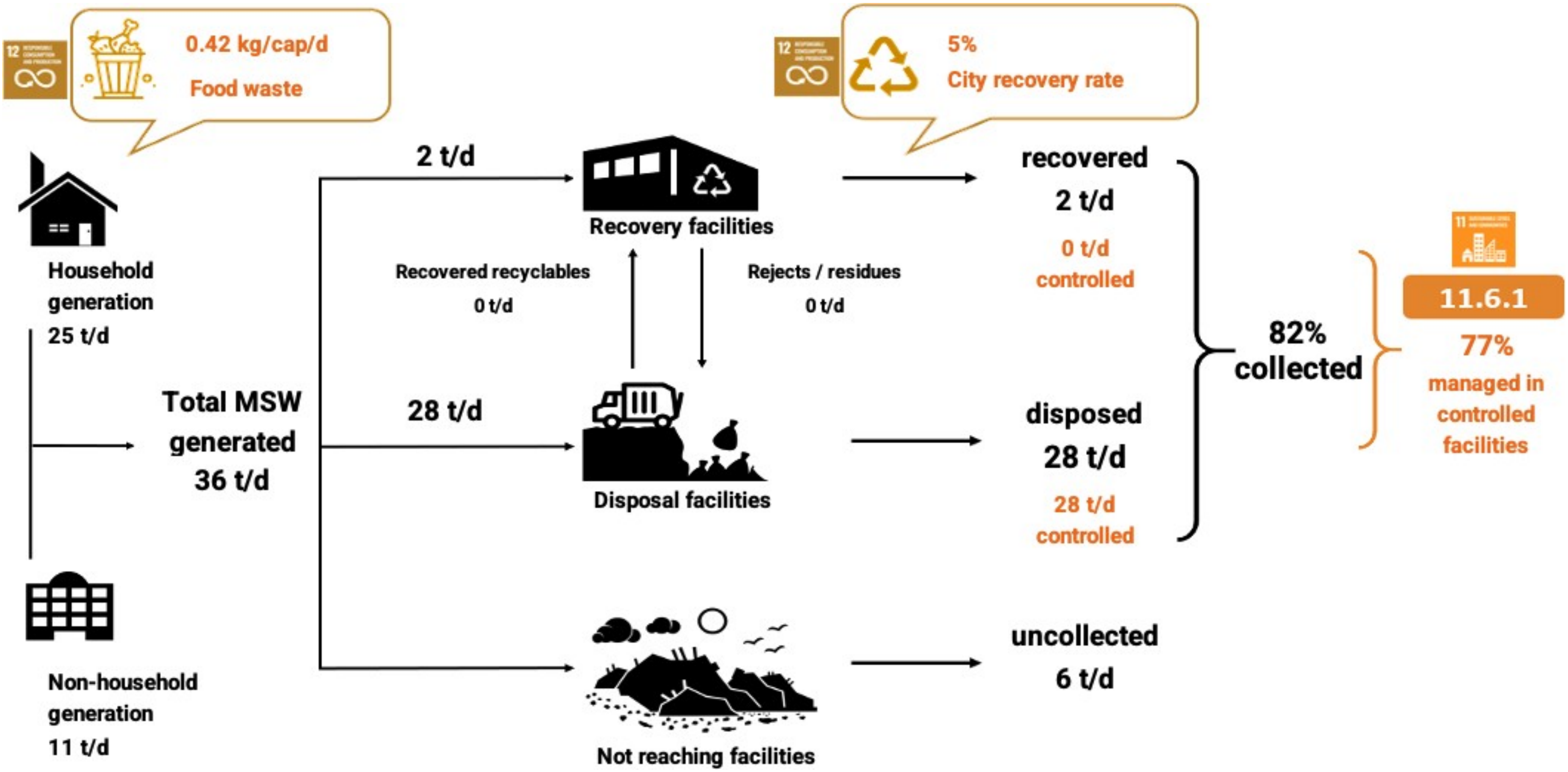
Byblos's SWM system has historically been the object of discontent amongst the local population. However, improvements took place despite the degrading economic situation, and the disposal site can now be classified as a "controlled" facility, based on UN-Habitat's definition. Figure 3.7 depicts the results from the WaCT assessment in Byblos. Byblos has a collection service coverage of 82 percent; of the 36 tonnes of solid waste produced daily, 28 tonnes are taken to the Hbaline disposal site (77 percent), and 2 tonnes are recovered (5 percent). Every day, 6 tonnes of waste remained uncollected and leaked into the environment. The fate of this uncollected waste is evaluated in the WFD assessment. Byblos has a weak recovery value chain, with one formal facility receiving 2 tonnes daily from the formal collection services. Local initiatives, mainly by NGOs, have tried to contribute to improving Byblos's recovery rate. Door-to-door collection for plastic waste is an example of such initiatives, which are usually short-lived.

Figure 3.6: MSW Flows in Tyre.



Source: World Bank.
Note: 11.6.1 refers to the Sustainable Development Goal's target of the same number.

Figure 3.7: MSW Flows in Byblos. Note: 11.6.1 refers to the Sustainable Development Goal's target of the same number.



Source: World Bank.

Note: 11.6.1 refers to the Sustainable Development Goal's target of the same number.

3.4 Uncontrolled Disposal Sites

Using GIS analysis, 73 potential new uncontrolled disposal sites were identified along 14 rivers leading to the Mediterranean Sea.

MSW disposal sites in river valleys are main sources of solid waste that contribute to litter in coastal zones. Existing MSW disposal sites were located through remote sensing and techniques of satellite-imagery analysis that meet the following criteria:

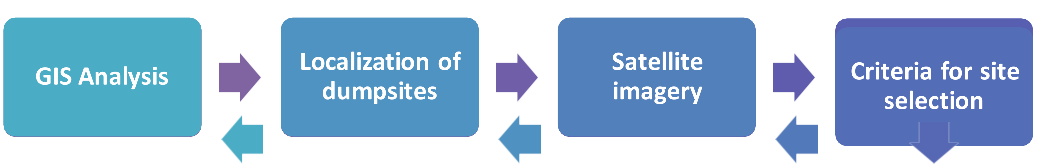
- Minimum site size of 10 x 10 meters;
- Visible through satellite imagery; and
- 500-meter belt on each side of riverbanks or contours of the highest peaks, whichever is reached first.

All coastal perennial rivers were considered for analysis. Al Kabir River was excluded for security reasons since it represents the northern border between Lebanon and Syria. Al Assi River was excluded since it flows through Syria and Turkey and discharges onto the Turkish coast. A map developed by UNDP (UNDP 2017) in 2017 locating MSW dumpsites throughout all of Lebanon was provided to the project team by the Ministry of Environment (MoE). The newly identified MSW dumpsites meeting the above-listed criteria were added to that UNDP map. Production and analysis were carried out by the use of the ESRI ArcGIS Pro 2.7.1. and an updated "Basemap" was produced for river valleys. Production of the Basemap required the use of several databases and layers (see Appendix B) to show all identified MSW dumpsites in the target area in addition to other information of interest.

Mapping and analysis of MSW sources into coastal areas was conducted as follows (Figure 3.8): slopes were extracted from the Digital Elevation Model (DEM) and overlaid with the hydrological and administrative layers. Satellite imagery was then used to identify new MSW disposal sites within the study area according to the selection criteria and added to the layer of MSW disposal sites produced by UNDP. All layers were combined into the "Basemap" for the identification and localization of disposal sites for further GIS analysis.

The list of data and layers for use in the production of the "Base map" is shown in Table 3.4. Mapping and analysis of MSW sources into coastal areas was conducted by extracting the slopes from the DEM and overlying them with the hydrological and administrative layers. Satellite imagery was then used to identify new MSW disposal sites within the study area according to the criteria of selection and added to the layer of MSW disposal sites produced by UNDP. All layers were combined into the "Base map" for the identification and localization of disposal sites for further GIS analysis.

Figure 3.8: Production of the "Base map" Methodology.



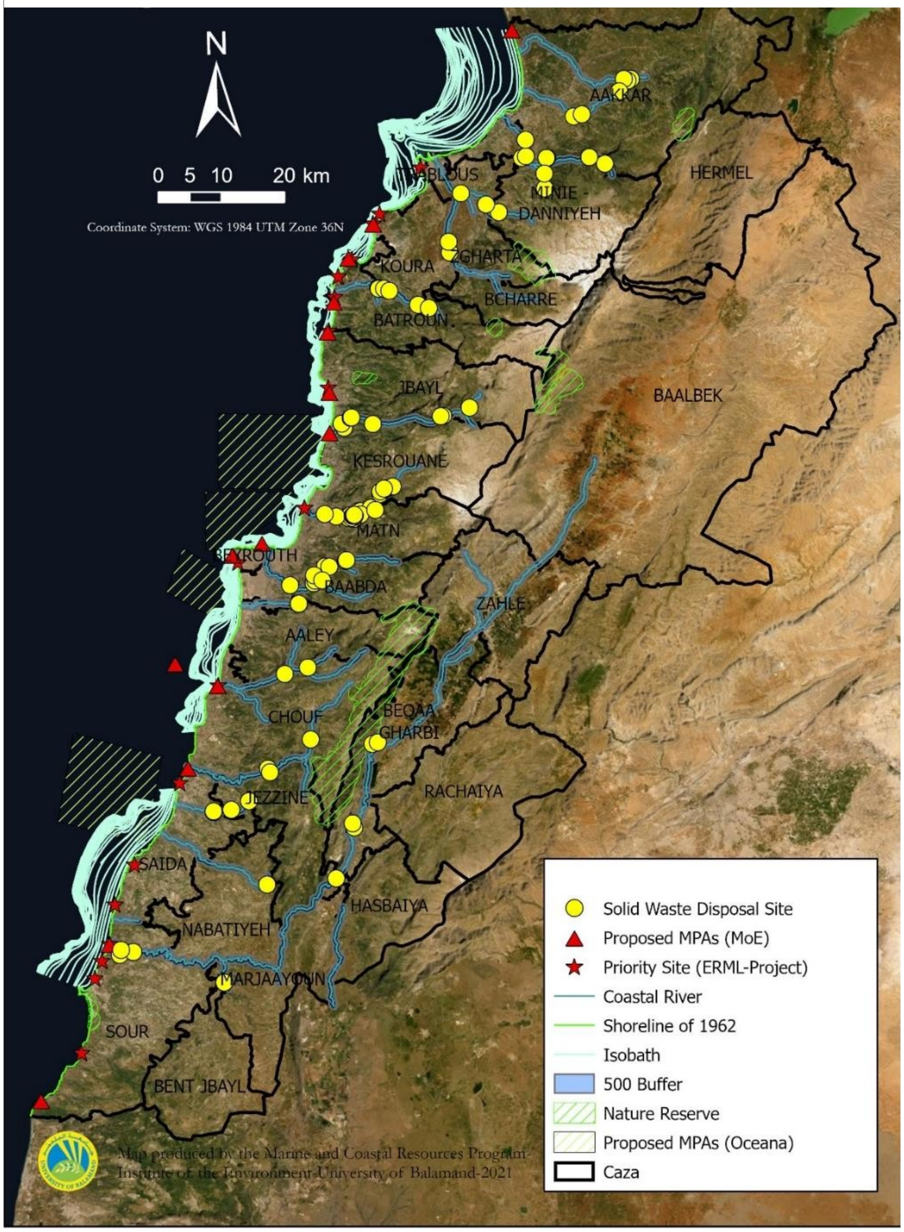
The “Basemap” showed a total of 110 MSW sites along rivers (Figure 3.9), with 37 extracted from the UNDP data and 73 potential new sites identified through satellite imagery. Only 32 of the sites were identified in forested areas. It is expected that a larger number of such sites exist in river valleys, but they could not be located through remote sensing or satellite imagery analysis due to thick vegetation cover.

Table 3.4: List of Data and Layers for U use in the Production of the “Basemap”. Source: MCR-IoE-UOB.

Data category	Description	Use
Dumpsite	Location of dumpsites in the study area (UNDP 2017)	Base for MSW dumpsites
Coastal zone	Bathymetry, shoreline of 1962, satellite images from the University of Balamand (UoB)[3]	Geographical description of the coastal zone
Administrative		
Urban settlements	Landcover/land use map of 2017 for the study area (1/50,000)	Mapping settlements in the study area
Mohafaza (Governorate) and Caza (Districts) limits	Cadastral limits within each Caza and Mohafaza	Locating dumpsites within administrative management units
Topography (Digital Elevation Model – DEM)		
Slope	10 m resolution	Site-selection criteria
Natural resources		
Protected areas	Including protected valleys, natural reserves, and other protected marine and terrestrial areas (RAMSAR, MPA, and so forth; MoE)	Location dumpsites relative to identified protected areas
Sensitive sites	Ecological and cultural sites (ERML, UNDP 2013); Sites included in “Lebanon’s Marine Protected Area Strategy” (MoE, IUCN 2012)	Location dumpsites relative to identified sensitive areas
Hydrology	Landcover/land use map of 2017 including rivers and water bodies (hydrological map) for the study area (1/50,000)	Mapping of rivers and main water bodies in the study area
Risks		
Evolution	Shoreline evolution (comparative study 1962 vs. 2010; IoE-UoB)	Changes in shoreline length/erosion/accretion/sea-filling

Source: World Bank.
Note: DEM = Digital Elevation Modelling.

Figure 3.9: Solid Waste-Disposal Sites along Lebanon's Coastal Rivers

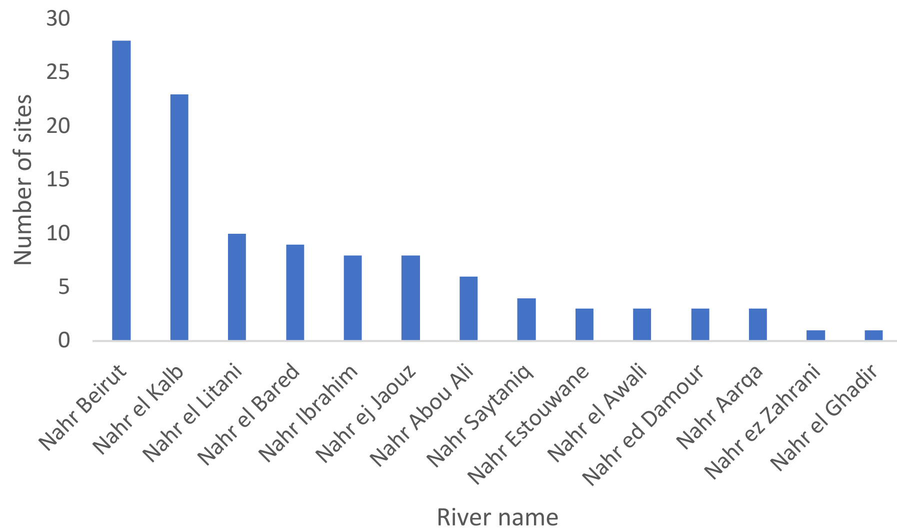


Source: World Bank.

Note: MPA: Marine Protected Areas. Priority Sites: highest priority dumpsites for closure and rehabilitation plans due to their potential impacts on their environment.

The Beirut and El Kaleb rivers exhibited the highest numbers of MSW sites (28 and 23 sites, respectively), while the El Zahrani and El Ghadir rivers recorded the lowest numbers with one site each (see Figure 3.10). Identified sites require further field validation to fully confirm the type of localized MSW sites.

Figure 3.10: Number of Municipal Solid Waste Sites per or along Each River



Source: World Bank.

While most potential new dumpsites were found on Nahr Beirut (the Beirut River), most priority sites were identified in the south of Lebanon, between Saida and Tyre.

3.5 Beachgoers

The most predominant items on the Lebanese beaches originate from coastal tourism and public littering (SUPs, cigarette butts, food wrappers, multilayer food packaging, and so forth).

The most predominant items on Lebanese beaches originate from coastal tourism and public littering. Direct entry is the dominant pathway in particular for soft plastic fragments (usually from SUP bags), bottle caps, plastic beverage bottles, SUP cups, cigarette butts, food wrappers, glass fragments, straws, and multilayer food packaging (crisps, snack bars). Typically, these items are brought and used by beach visitors and released to the environment by direct dumping. The top 10 items found during the CSIRO and Accumulation surveys are discussed in Section 5.3 of Chapter 5 and Section 6.4 of Chapter 6, respectively. The accumulation rates for the top 10 items (Section 6.4) are particularly interesting since they demonstrate the higher accumulation rates on the dry part of the beach compared to the wet part of the beach, especially for SUP items, and therefore point to beachgoers as a main source of plastic pollution.

The general lack of infrastructure (bins, frequent collection service), combined with a lack of awareness about the impact of (plastic) marine litter, does not encourage proper disposal of SUPs and recreational items. As a result, such items are likely directly discarded onto beaches, where they slowly degrade. Heavier items (like glass or metal fragments) will tend to sink into the sand. They could also be transported by tides towards the supratidal area, towards the water where they will sink to the seabed or be carried by the current to the open sea.

On a sandy beach, waste will tend to sink into the sand, where it becomes a threat to the beach fauna. If not discarded directly, waste may have been transported from inland sources via rivers. Of the 24 beaches studied in the CSIRO survey, only Koubba (site 9) and Nahr Ibrahim (site 10) have a river input. However, items reaching the Mediterranean Sea via rivers can be brought back to shore by currents; therefore, one cannot exclude the role that rivers may have as a major pathway for marine litter. Lighter items can be transported more easily by wind: soft plastic fragments, cups, multilayer food packaging, and so forth could have been discarded near the beach and then be blown towards the coast to end up on the beach. If items are directly littered on the beach, strong winds coming from the open sea generally push them to the back of the beach, where they get trapped in vegetation or end up littering inland areas.

Notes

[1] For more information on the WIOMSA Marine Litter Monitoring Project, see the Sustainable Seas Trust website at https://sst.org.za/projects/african-marine-waste-network/wiomsa-marine litter-monitoring-project/

[2] The "Level of Control" of disposal and recovery facilities is determined by assessing operational-health and safety-regulation compliance, environmental regulation compliance, operational setups, and so forth.

For details on how the level of control is determined, please refer to annex 7 of the WaCT's methodology.
[3] The satellite imagery was obtained from the University's databases.

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4 Pathways

Figure 4.1: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools

Source: World Bank.

4.1 Key Findings

Key Findings

Key Finding: Plastic leakage from SWM systems averaged 3.1 kilograms/person/year to the environment and 1.1 kilograms/person/year to water systems in the seven cities studied. Leakages mostly occur whilst the waste is waiting to be collected.

The most items on the seafloor, in surface waters and in sediments were found in Byblos, which is aligned with the accumulation survey results of the spring 2021, showing that Byblos has the largest marine litter load on its beaches compared to Tyre.

Importance: There is a correlation between the amount of waste found on the beaches, in surface water, on the seafloor and in sediments.

Implication: Direct littering on land and/or at sea may be the most important pathway for marine litter, but more research is needed to verify this assumption.

4.2 Solid Waste Management Systems

The following section shows the results of the Waste Flow Diagram (WFD)[1] assessments in seven coastal villages and cities. The WFD assessment quantifies the amount of plastic that escapes the SWM service chain and ends up in the environment and allows to understand which stage of the service chain could be better managed to prevent the loss of plastic waste to the environment. The WFD also assesses where plastic waste ends up after it reaches the environment. Four fates are possible: in water systems, on land, burnt, or in drains.

For the seven cities in which the WFD was applied, a data collection exercise on the baseline situation of the SWM system was complemented by an observational assessment. The observational assessment was carried out at each stage of the SWM system (i.e., collection, transportation, recovery, and disposal). Observations were also conducted on solid waste prior to the moment it is collected, i.e., when it is waiting to be collected. Observations targeted specific aspects (called "leakage influencers") that would cause plastic leakage at each stage of the SWM system. By rating each leakage influencer, the surveyor gets an accurate understanding of the weaknesses of each SWM stage.

As this project focuses on understanding how SWM systems may be land-based sources of marine plastic pollution, for each city, the plastic leakage rate is given as a) the total plastic leakage per person per year, and b) the plastic leakage to water systems per person per year.

The results are presented starting from the northernmost city studied. Key definitions for this chapter are provided below.

Municipal Solid Waste (or simply "waste" in the sections below):	Waste generated from households, commerce, businesses, and institutions. It also includes bulky waste, waste collected by municipal services and from street cleaning services.
Waste generated:	Municipal solid waste produced by a source.
Plastic waste:	Plastic fraction from the overall waste generated.
Waste leakage:	Waste escaping the SWM system and entering the environment.
Plastic-waste leakage (or plastic leakage):	Plastic fraction from the total waste generated that escapes the SWM system and enters the environment.
Fate of plastic leakage	Where the leaked plastic waste ends up in the environment: either on land, in water systems, burnt or in drains.
Plastic-leakage rate	Quantity of plastic released into the environment from the SWM system, per year, for each resident of the city considered.
Leakage influencer	Aspect of the SWM system that may cause plastic leakage.
Mismanaged plastic waste	Plastic waste that has either not been collected, or that has been collected but has leaked from the SWM system and ended up in the environment.

4.2.1 Beddaoui

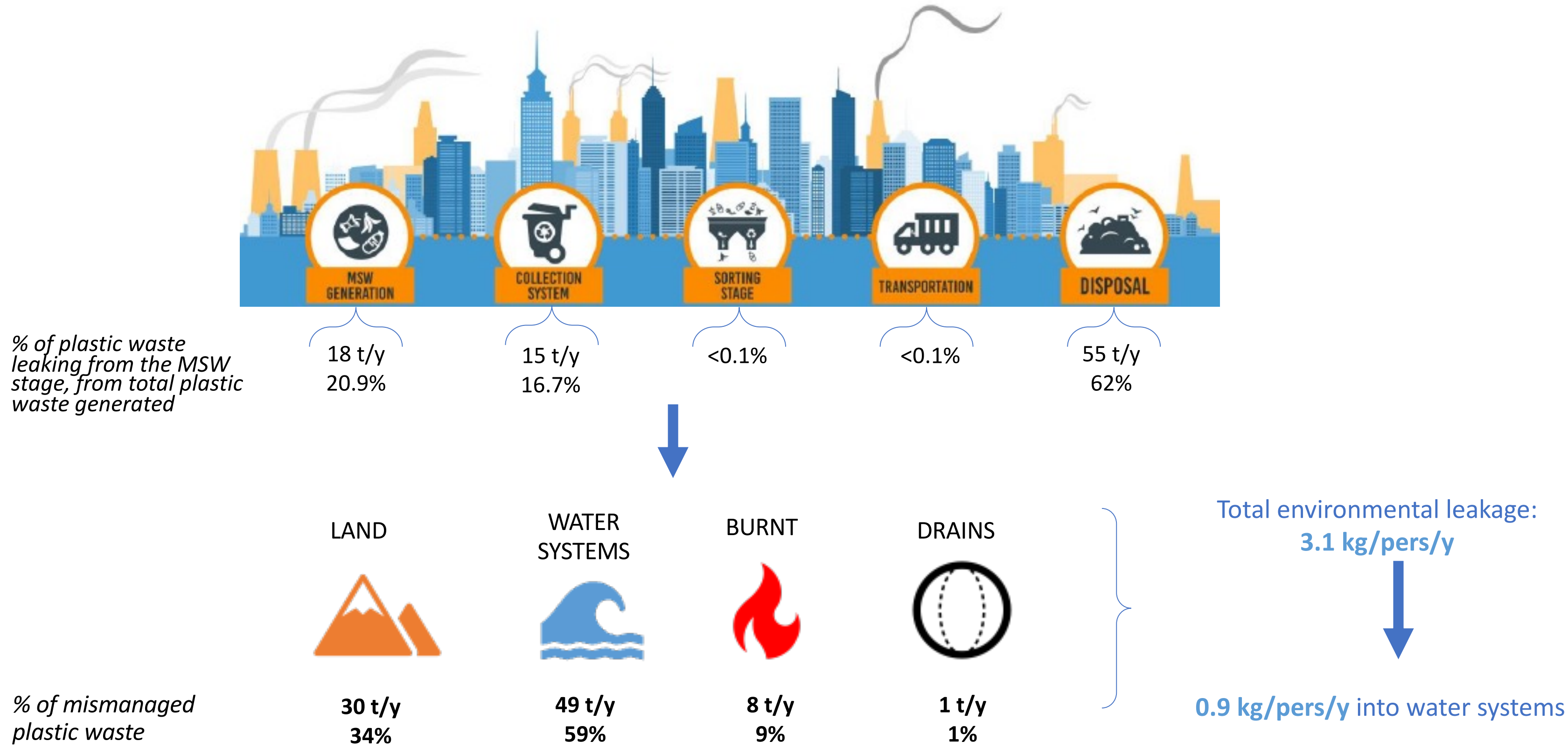
In Beddaoui, 3.1 kilograms/person/year of plastic leaks into the environment, including 0.9 kilogram/person/year into water systems. Plastic generation in Beddaoui is estimated to be 64.8 kilograms/person/year. Figure 4.2 presents the detailed results.

Despite the high collection coverage in Beddaoui (95 percent), 88 tonnes of plastic remain uncollected each year and leak into the environment (14 percent of the total plastic waste generated). The main leakages occur at the disposal facility in Tripoli (62 percent of the total leakages), due to poor practices and the site's close proximity to the Mediterranean Sea. The facility's poor practices include the following:

- Lack of daily cover and compaction of the waste: Waste is piled above ground with full exposure to wind, rain, and surface runoff, which can cause light plastic items to easily escape the facility;
- Collection containers' high level of damage;
- Their openness to the environment, which increases the plastic leakages from the collection system;
- Informal sector's recyclables-extraction method; and
- "Loose" disposal of waste directly into collection containers rather than first being contained in bags.

Water systems are the most common fate of plastic leakages in Beddaoui: 59 percent of the total plastic waste leaking into the environment ends up mostly in the Mediterranean Sea (49 tonnes/year) (see Figure 4.2). Land is the second-most-common fate, with 34 percent of the total mismanaged plastic waste finding its way to it. There was some evidence of burning of waste, but this is not believed to be a widespread practice.

Figure 4.2: Fate of Uncollected Plastic Waste in Beddaoui



Source: World Bank.

Figure 4.3: Single-Use Plastic Bag Blown by Wind in Tripoli's Disposal Site

Source: World Bank.

4.2.2 Byblos

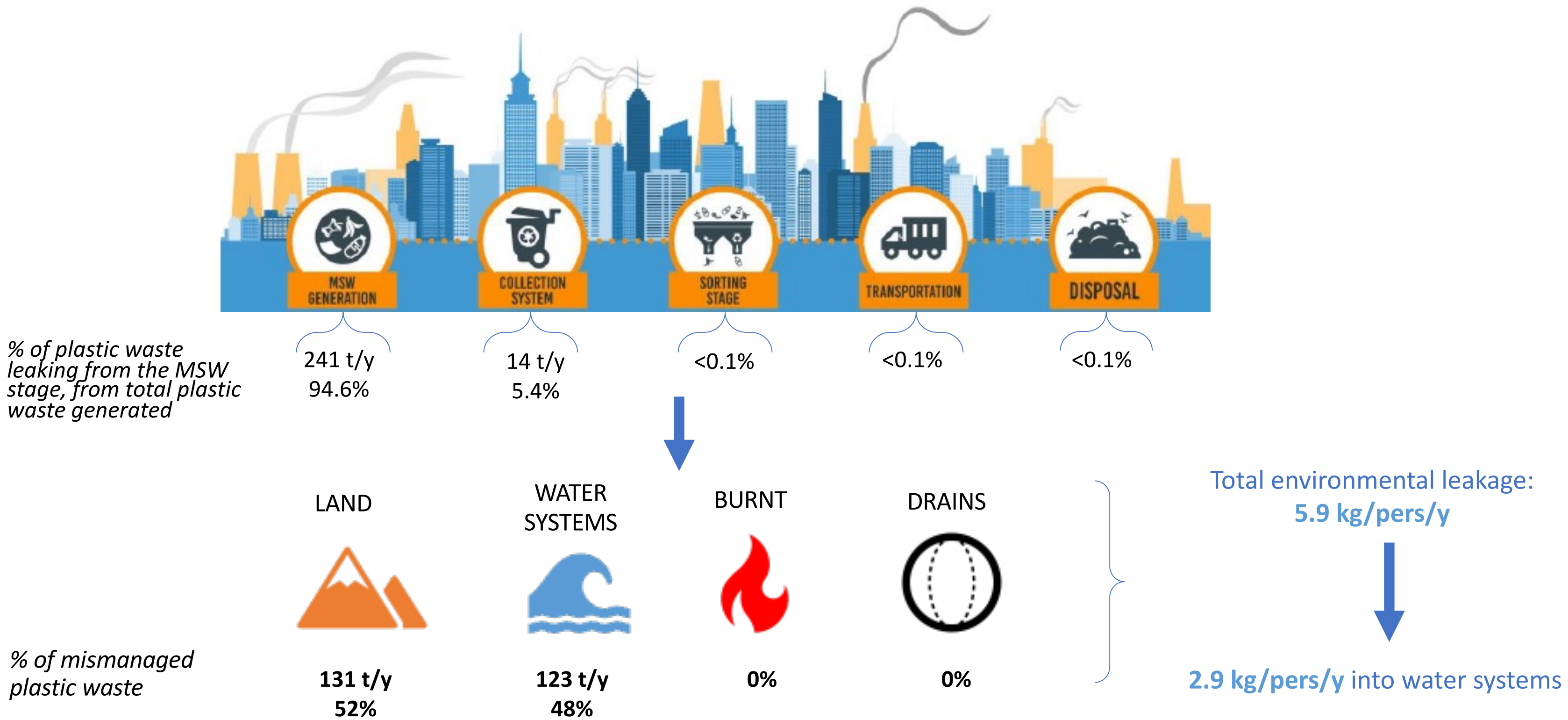
Based on the WaCT data presented in Chapter 3, Section 3.2, and observations carried out in the field in Byblos, plastic waste generation is estimated to be 2,517 tonnes per year (58.9 kilograms/person/year) and plastic leakage is anticipated to be 5.9 kilograms/person/year, including 2.9 kilograms/person/year into water systems (5 percent of plastic-waste generation). Figure 4.4 presents a model of the fate of uncollected waste in Byblos. All the numbers refer to only the plastic fraction of MSW, in metric tonnes per year.

It is estimated that approximately 254 tonnes per year (700 kilograms/day) of plastics are released from Byblos's SWM system into the natural environment, which corresponds to 10 percent of the total plastics generated by the city. From this fraction, 131 tonnes end up on land (52 percent of mismanaged plastic waste) and 123 in water systems (48 percent of mismanaged plastic waste). Clearly, the proximity of Byblos to the Mediterranean Sea means that the plastics emissions directly contribute to the plastic pollution of the oceans.

Uncollected waste is the main source of plastic leakages from the SWM system. Annually, 241 tonnes of solid waste (94.6 percent of the total leakages) fail to be collected by formal or informal collection services. Leakages also originate while waste is being stored waiting for collection services. Each year, 14 tonnes of plastic leak from the collection phase with the main leakage influencers being collection containers. The containers are available in all districts but are typically open to the environment and show some level of damage.

Poor behaviour is another cause of high plastic leakages in Byblos. The city receives a high influx of tourists all year round and specifically during the high summer season. The findings from the beach surveys indicate that single-use plastics (SUPs) are the most frequently found items on Byblos's Titanic Beach, which confirms that direct littering by beach visitors and residents is another major cause of plastic leakage.

Figure 4.4: Fate of Uncollected Plastic Waste in Byblos



Source: World Bank.

4.2.3 Ghazir

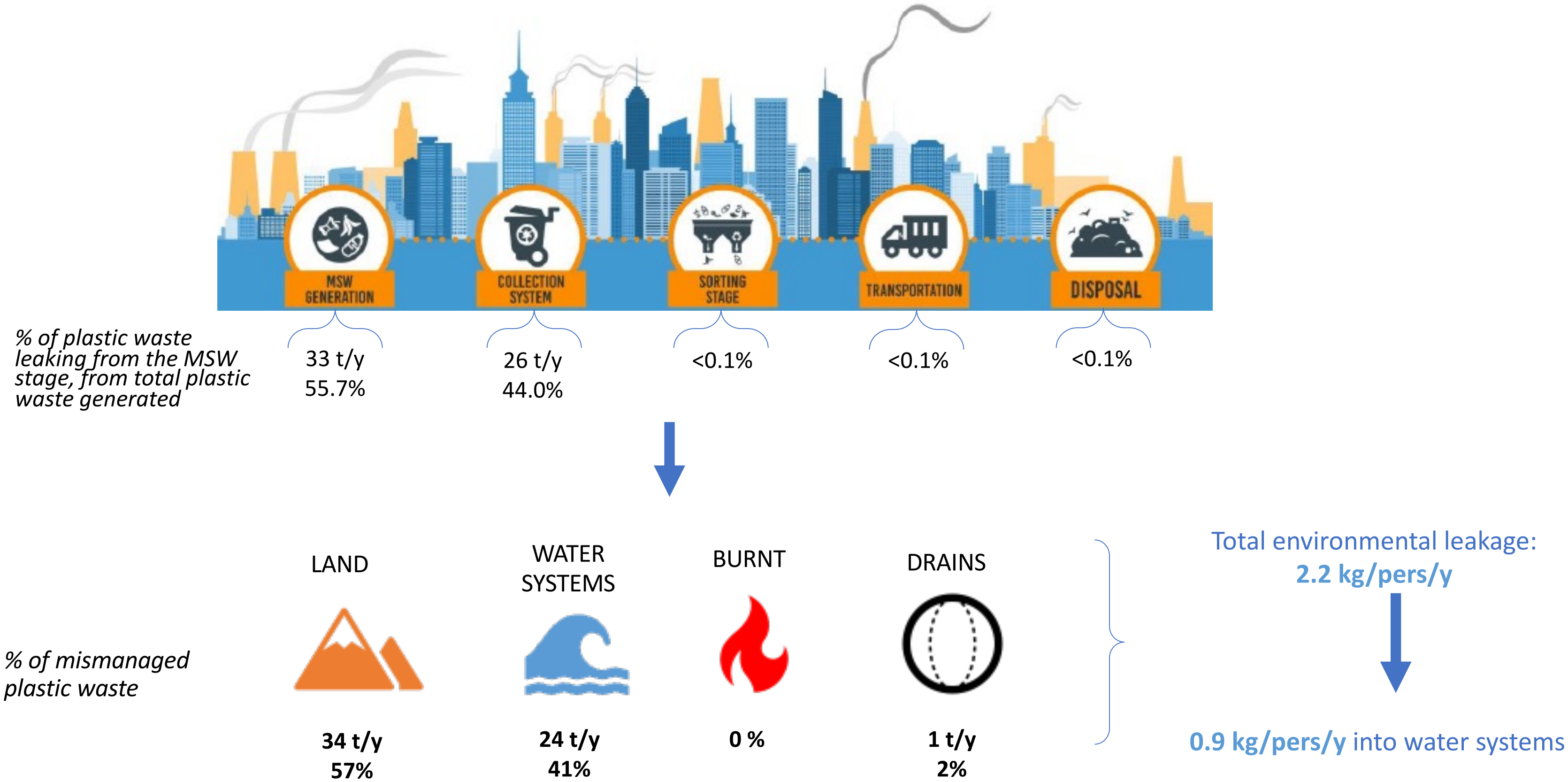
In the village of Ghazir, 1,108 tonnes of plastic waste are generated yearly (42.0 kilograms/person/year), of which 2.2 kilograms/person/year leak into the environment, including 0.9 kilogram/person/year into water systems (2 percent of plastic waste generated), as shown in Figure 4.5.

Usually, there is a correlation between collection coverage and plastic leakages; in Ghazir, the high collection coverage (95 percent) minimizes plastic leakages between the generation and collection stages. Furthermore, the daily covering and compaction of waste at disposal facilities prevent high plastic leakages in the sorting, transportation, and disposal stages of the SWM system.

The total plastic leakages are evenly spread between uncollected waste (55.7 percent) and the collection stage (44.0 percent). During the collection stage, collection containers represent the highest leakage potential, since they are open to the environment. Despite a regular collection service, waste accumulates rapidly and overflows around the bins, where it can be blown away by wind (if the waste is light and uncontained in a bin bag), taken by animals, or simply remain uncollected.

Most of the plastic leakages end up on land (3 percent of the total plastic generated), followed by water systems (2 percent) and drains (<1 percent).

Figure 4.5: Fate of Uncollected Plastic Waste in Ghazir



Source: World Bank.

4.2.4 Beirut

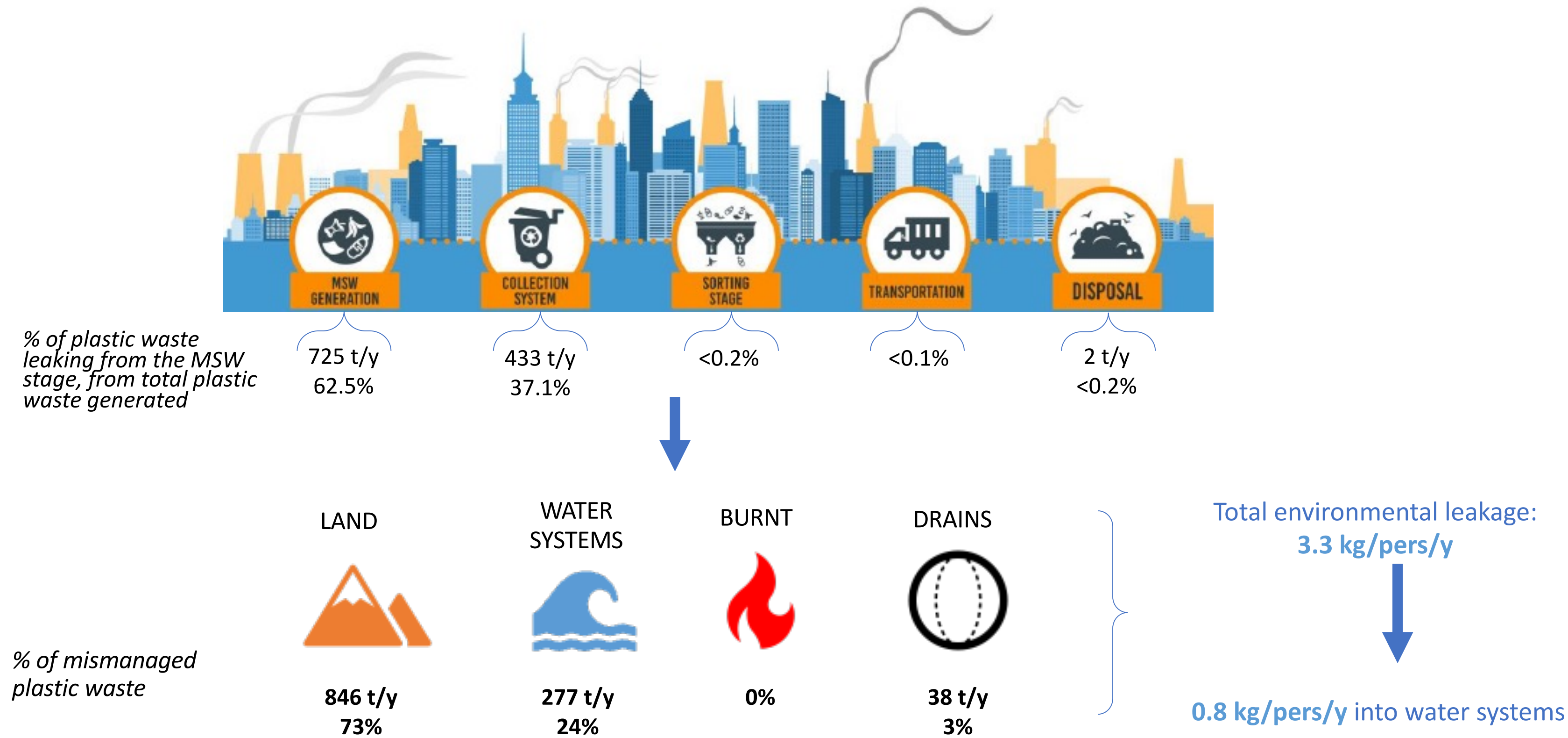
In Lebanon's capital, 18,889 tonnes of waste are generated each year (52.4 kilograms/person/year). Each year, 3.3 kilograms/person escape the SWM system and end up in the environment. Of this, 0.8 kilogram/person/year ends up in water systems, representing 2 percent of the total plastic waste generated. Figure 4.6 presents the results of the WFD for Lebanon's capital.

The results presented in the figure above were found by observing and assessing the metropolitan municipal area and not the entire governorate. In the city, most leakages (65.5 percent) are due to uncollected waste, with 725 tonnes each year leaking into the environment. During the collection stage, 37.1 percent of the waste usually escapes from the SWM system (433 tonnes/year) due to the collection containers being open to the environment. Mainly due to the proximity of the sites to the Mediterranean Sea, some minor leakages occur at the Bourj Hammoud and Costa Brava disposal sites (0.2 percent, 2 tonnes/year), where Beirut's waste is sent for disposal.

Because they are built on Beirut's shoreline of the Mediterranean Sea, the disposal facilities are subject to strong wind and surface runoff during the winter months. The daily compaction and covering of the waste, the fencing of the site, and the 80-meter-long stone breakwaters significantly reduce the potential for leakage from the facilities.

Most of the leaked plastic waste ends up on land (5 percent of the total plastic waste generated). The dumping on land of uncollected waste remains the most important leakage into the environment, while leakages from disposal sites and during collection are also present. Water systems are not spared (2 percent of total plastic waste generated), due to Beirut's location on the Mediterranean Sea and the river Nahr Beirut flowing through it. Moreover, the two disposal sites serving the city (Costa Brava and Bourj Hammoud) are located on the shoreline, increasing the chances of waste directly entering to the sea.

Figure 4.6: Fate of Uncollected Plastic Waste in Beirut



Source: World Bank.

4.2.5 Ghobeiry

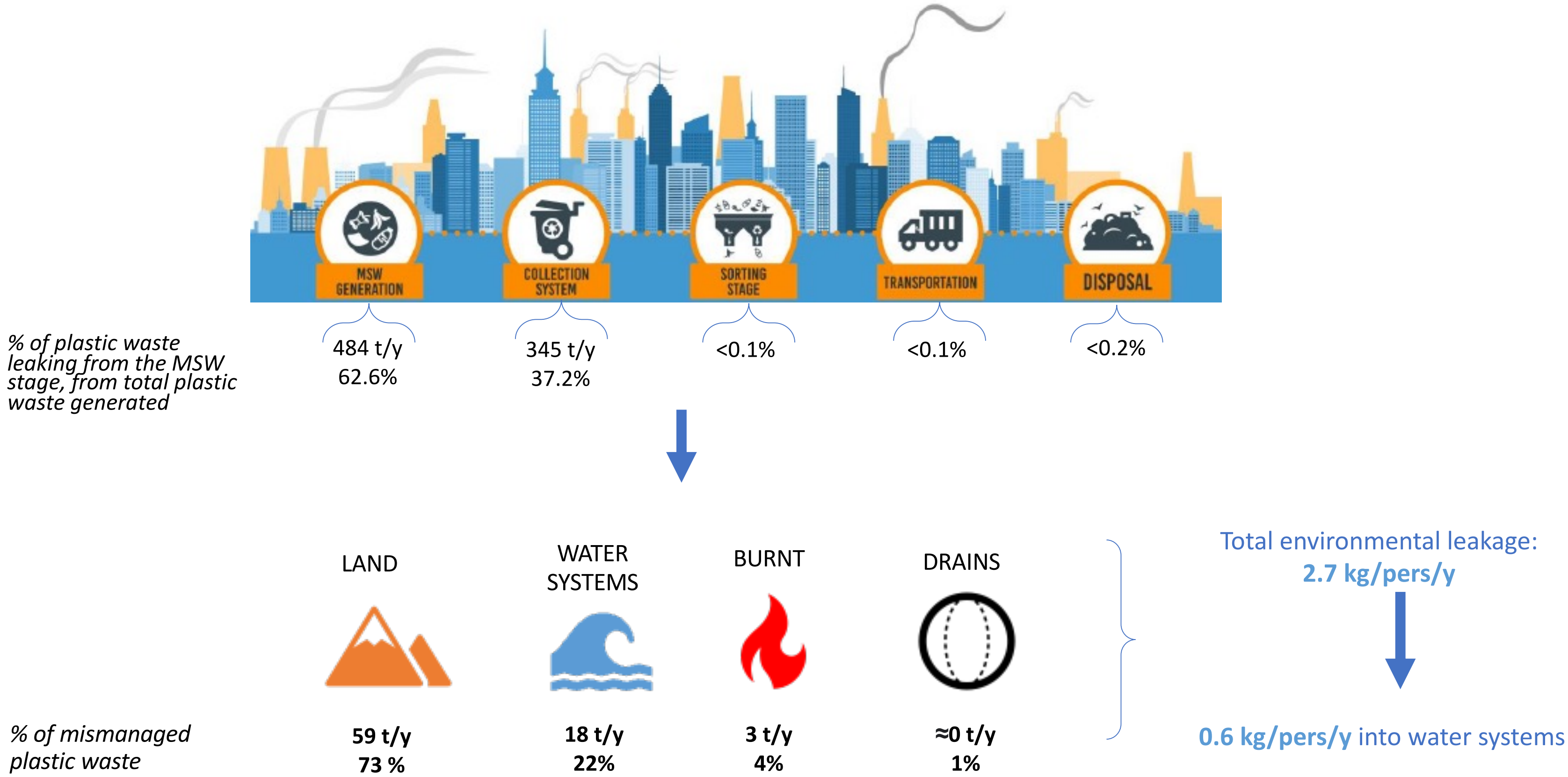
Figure 4.7 shows the results of the WFD assessment in the Beirut suburb of Ghobeiry. The city generates 1,260 tonnes of plastics waste each year, of which 80 tonnes leak into the environment (6 percent of plastic waste generated). Plastic leakage to water systems is estimated to be 0.6 kilogram/person/year (1 percent of total plastic-waste generation).

Figure 4.7 shows the following:

1. 73 percent of all unmanaged plastic waste (i.e., the plastic that has leaked into the environment) ends up on land, and 22 percent in water systems.
2. Uncollected waste is the main source of plastic leakages into the environment, since 62.6 percent of the total plastic leakages occur prior to when waste is taken by collection services.
3. Collection containers are open to the environment and in poor condition. They offer easy access to animals looking for food and allow the accumulation of waste in their surroundings, causing leakages into the environment.

While open and damaged containers are the main source of plastic waste leaking onto land during the collection stage, Ghobeiry's proximity to the Mediterranean Sea (<1 kilometer) promotes diffuse leakage to water systems during collection rounds. Land remains the main fate of leaked plastic waste (6 percent of total plastic waste generated), followed by water systems (1 percent), since 172 tonnes each year reach the Mediterranean Sea and other streams leading to it.

Figure 4.7: Fate of Uncollected Plastic Waste in Ghobeiry



Source: World Bank.

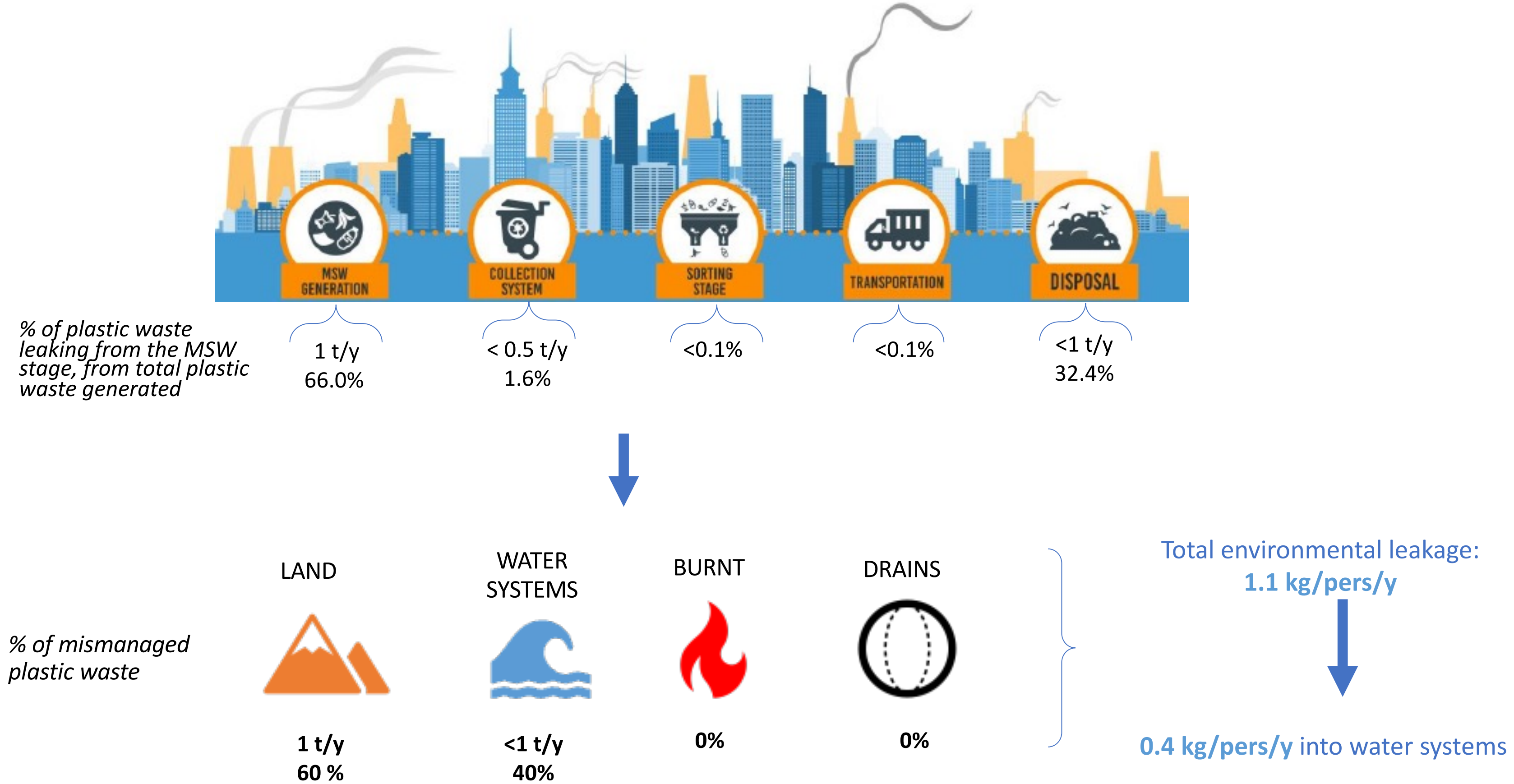
4.2.6 Aadoussiyeh

Figure 4.8 depicts the fate of uncollected plastic waste in Aadoussiyeh. Each resident in Aadoussiyeh annually generates on average 15 kilograms of plastics waste (27 tonnes generated for the village in total), of which 1.1 kilograms leaks into the environment, including 0.4 kilogram to water systems (3 percent of total plastic-waste generation).

As seen in the above figure, uncollected plastic accounts for 66.0 percent of the total plastic leakages. With a high collection coverage (around 95 percent), it is expected that uncollected waste would be the predominant source of plastic leakages in Aadoussiyeh. Poor practices at the disposal site contribute to 32.4 percent of the total plastic leakages. More specifically, the poor practices at the disposal site include piling waste above ground with no cover nor compaction and discharging waste in undesignated zones. Finally, the site is located on the coast in Saida, where heavy and persistent winter winds can easily blow away lighter items.

However, land is the most common fate of leaked plastic: 60 percent (over 1 tonne) of the total leakages end up on land each year, before water systems (40 percent, 1 tonne/year). The burning of waste and direct dumping in drains is not believed to be a common practice in the recovery and disposal facilities.

Figure 4.8: Fate of Uncollected Plastic Waste in Aadoussiyeh



Source: World Bank.

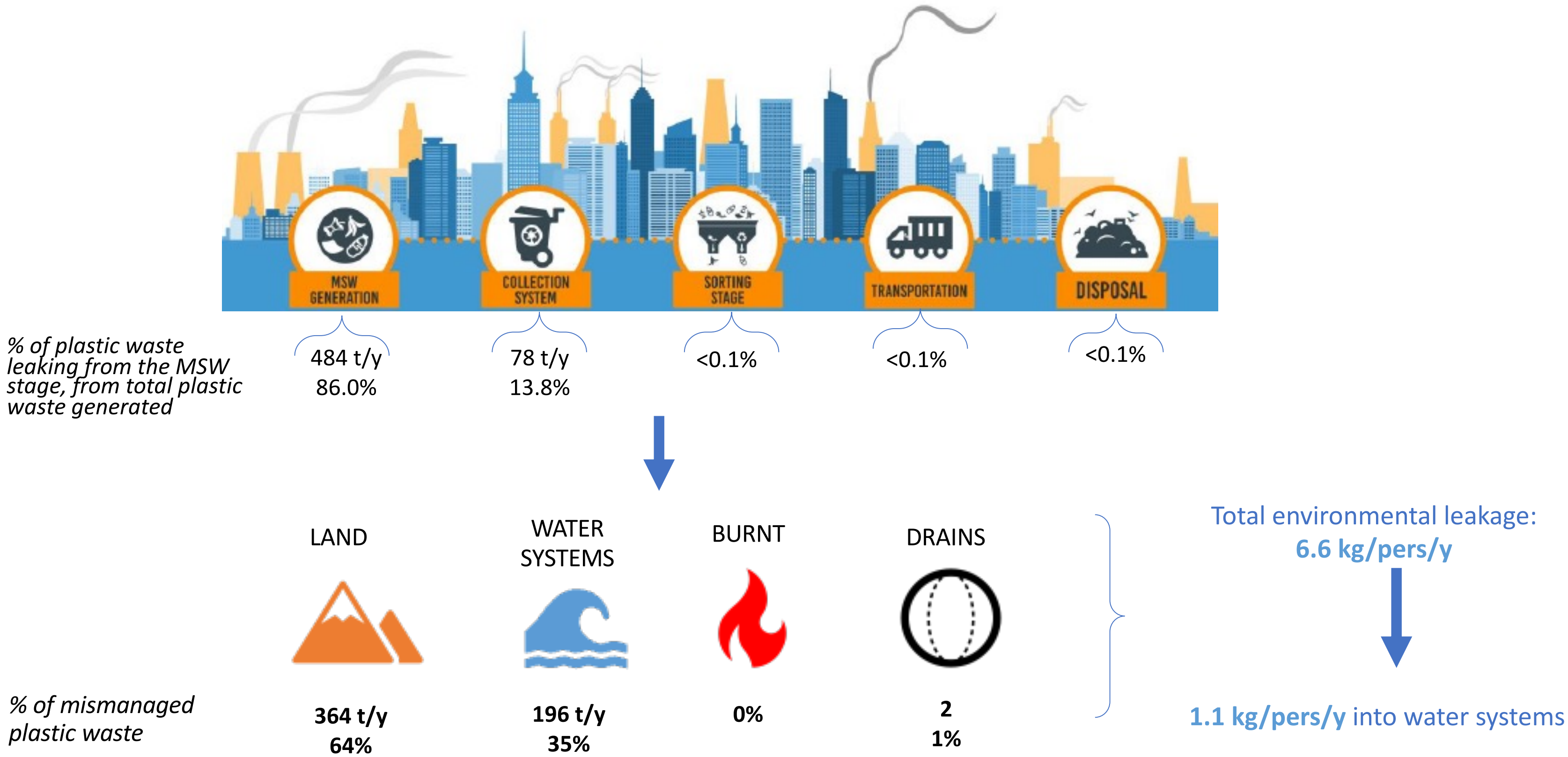
4.2.7 Tyre

Figure 4.9 presents the results of the WFD assessment in Tyre. Annually, 5,818 tonnes of plastic waste are generated in Tyre (32.7 kilograms/person/year), of which 3.2 kilograms/person/year of plastic leak into the environment, including 1.1 kilograms/person/year to water systems (3 percent of total plastic waste generated). This corresponds to 6.6 kilograms of plastic leaking into the environment per person, per year, including 1.1 kilograms to water systems. These leakages are mainly due to the following:

1. High amount of uncollected MSW (86 percent of total plastic leakages);
2. Manual loading of waste to some collection vehicles from portable containers; and
3. Lack of vehicle cover for collection trucks, especially in the areas of Tyre (that is, the areas of the old city) whose streets cannot allow access for large compactor trucks, leading light plastic items to easily escape.

Plastic waste leaking from collection services (and from uncollected sources) most often ends up on land (364 tonnes/year) or in water systems (196 tonnes/year) (see Figure 4.9). Since Tyre is bordered on three of its four sides by the Mediterranean Sea, there are multiple opportunities for plastic waste to litter the coastal areas and enter the water systems. Leakages to water systems may become worse during the summer period, when the city typically welcomes around 50,000 tourists during the high season, (equivalent to its own population, including Borj El Chemali). The SWM system must therefore be extremely flexible to provide consistent service throughout the year, despite seasonal fluctuation in its population.

Figure 4.9: Fate of Uncollected Plastic Waste in Tyre



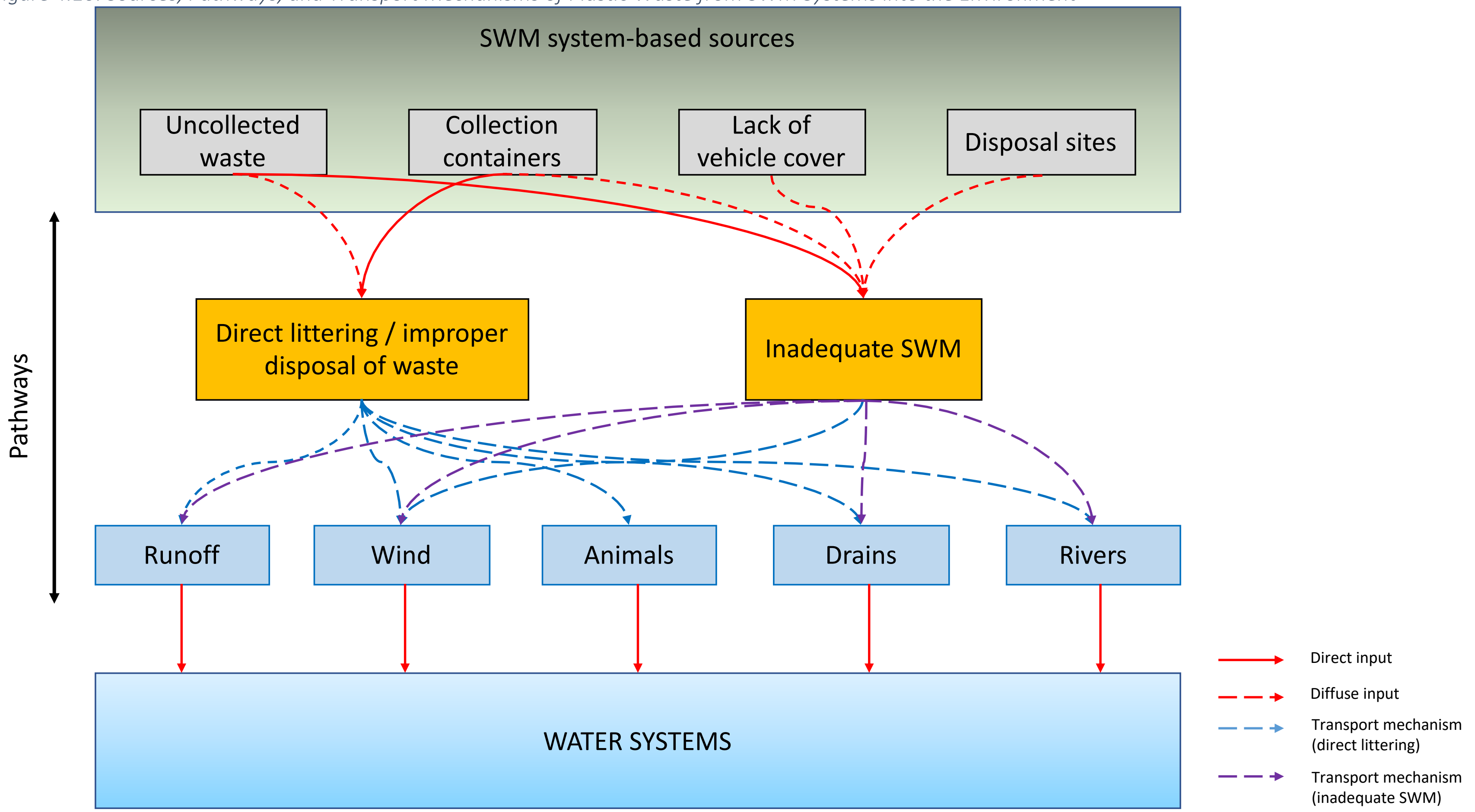
Source: World Bank.

All the cities studied as part of the WFD assessment are coastal cities with strong touristic activities, which explains the large proportion of plastic leakages ending up in water systems. The following sources of plastic leakages from the SWM system are common to all cities:

1. Uncollected waste is the most common source of plastic leakages. In Byblos, it represents nearly 95 percent of the total plastic leakages from the SWM system.
2. Collection containers being open to the environment contributes to plastic leakages in all cities studied. The easy access of containers coupled with an insufficient number of containers and/or infrequent collection services leads to an accumulation of waste that can exceed the capacity of the container and cause leakages into the environment.
3. Collection trucks' lack of covers for their loads and the manual loading of collection trucks are general practices in small cities that have narrow streets, which prevent or impede access for large compactor trucks.
4. Disposal sites also contribute to plastics being released into the environment, especially the facilities that do not meet the UN-Habitat's definition for a "controlled" facility. All facilities serving the cities studied are located on the Lebanese shoreline, which also increases the chances of direct leakages into the sea.

Figure 4.10 summarizes the main sources, pathways, and transport mechanisms from the SWM systems in Lebanon. Direct littering by residents and tourists, on the one hand, and inadequate SWM systems, on the other hand, are the two main causes of plastic waste being released into the environment from the four sources listed above.

Figure 4.10: Sources, Pathways, and Transport Mechanisms of Plastic Waste from SWM Systems into the Environment



Source: World Bank.

4.3 Marine Surveys

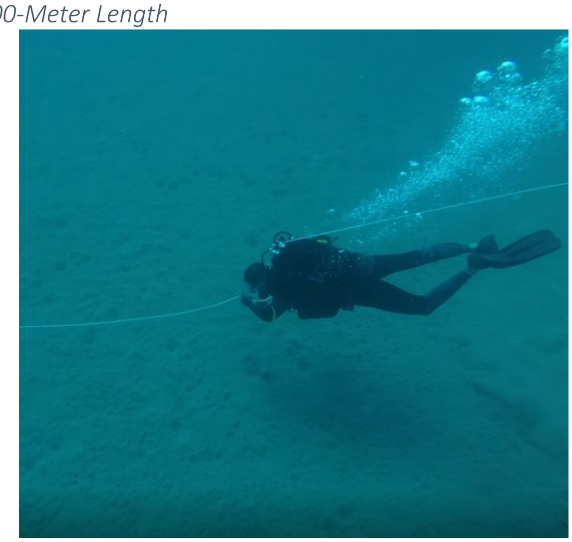
On the wet side, three main indicative marine assessments were undertaken covering marine litter on the seafloor, in surface waters, and microlitter and mesolitter in marine sediments. Microlitter are particles with sizes smaller than 5 mm, while mesolitter are particles with a size range between 5 and 25 mm (Haseler et al. 2018). The first two assessments were indicative in nature while the third was quantitative. Missions were organized to carry out all data and sample collection in one field day per site to benefit from optimum weather conditions.

4.3.1 Seafloor

The highest number of items and litter density on the seafloor was recorded in Byblos (14,166), followed by Tyre (6,667), the Ibrahim River (1,667), and then the Litani River (0).

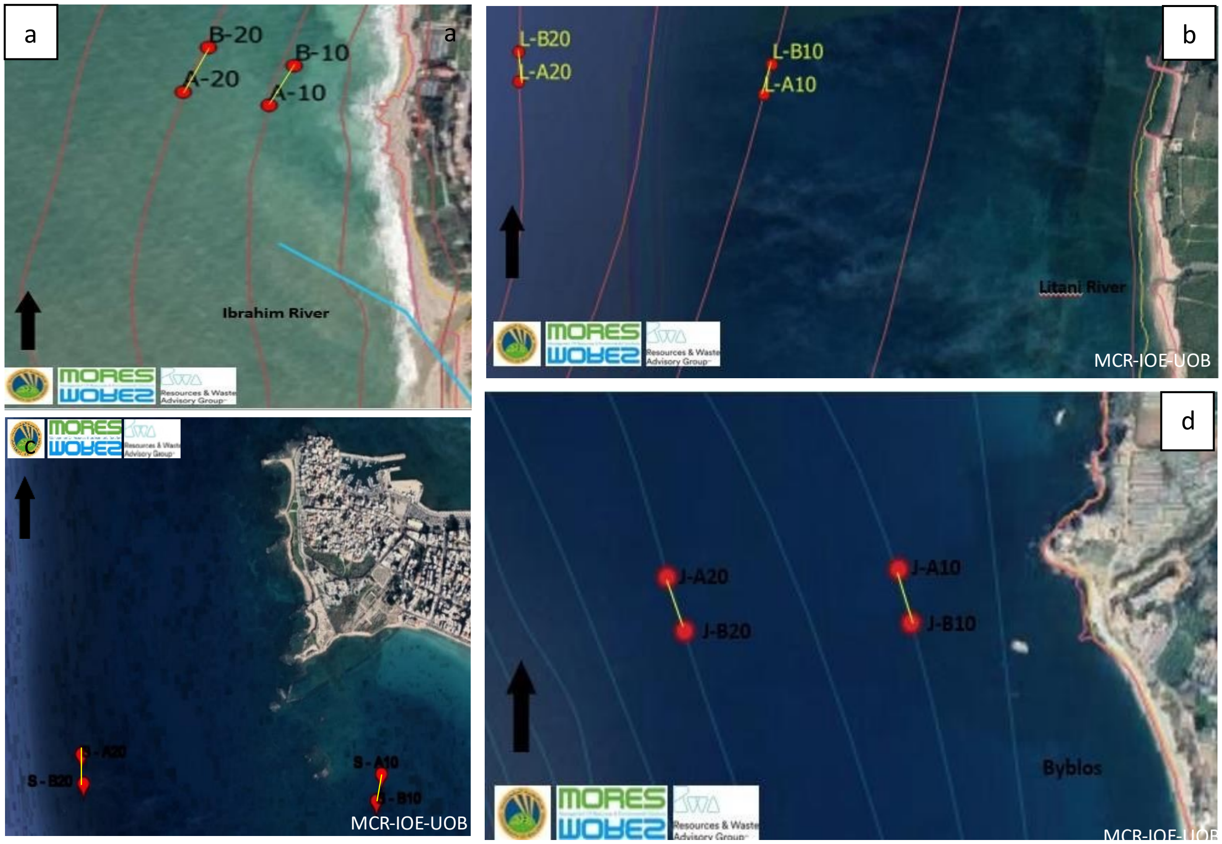
The objective was to assess marine litter on the seafloor of the selected sites through the application of the transect-belt technique, which is based in visual observations where encountered items are counted, identified, and photographed in situ. In each mission, two transect belts of 100 meters each, parallel to the shore at 10- and 20-meter depths were deployed based on the bathymetrical maps provided by the Lebanese Army (Figure 4.11). A field of vision of 3 meters on each side of the belt was assessed by trained scuba divers covering a surface area of 600 m^2 per transect belt. Each dive was video recorded to further validate the field data at the IoE Laboratories.

Figure 4.11: Transect Belt of 100-Meter Length



Source: World Bank.

Figure 4.12: Transects for Assessing Marine Litter on Sea Floor at 10- and 20-Meter Depths: (a) Ibrahim River, (b) Litani River, (c) Tyre, and (d) Byblos



Source: World Bank.

The categories and sizes of items for litter on the seafloor were adopted according to JRC (2013) for the Mediterranean and the Black Sea (Appendix C Litter Categories for the Mediterranean Sea and Black Sea).

Each site was sampled once during optimal forecasted weather conditions, and the results were expressed in litter density as items/km^2—see Angiolillo et al. (2021); Ioakeimidis et al. (2015); JRC (2013); and Miliute-Plepiene et al. (2018). For sites opposite river estuaries, transect belts were deployed 500 meters to the north given that litter usually drifts northward off the Lebanese coast in response to prevailing wind and current directions. Collected data were recorded per depth but reported as total per site. Since no bathymetrical maps were available for the site opposite to and south of the city of Tyre, a depth transducer was used to locate the appropriate depth for the deployment of both transect belts.

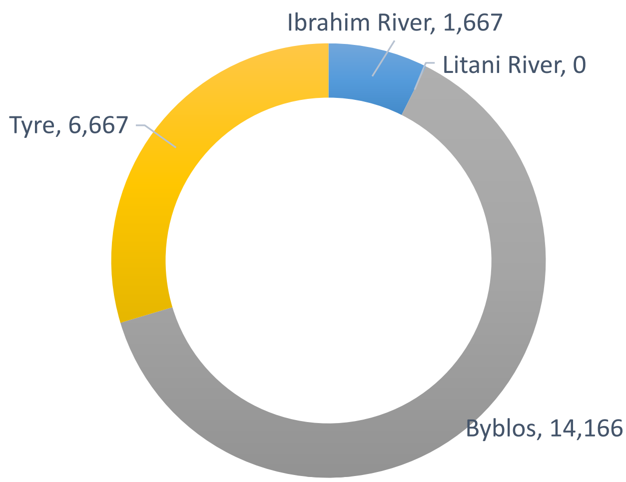
The highest number of items and litter density were recorded in Byblos, followed by Tyre, then the Ibrahim River, and then the Litani River (see Table 4.1 and Figure 4.13). The number of recorded items did not appear to reflect a large problem of seafloor pollution in the surveyed areas. This may be due to several reasons, including the period the survey was undertaken, which was two months after the last rains stopped, resulting in a time interval when no solid waste was washed into the coastal zone by rivers. In addition, seafloor litter, if present, may have been suspended into the water column during rough seas and drifted from the sampled location.

Table 4.1: Total number and density of marine litter on the seafloor

Site	Transect belt		Litter density (Items/site surface)	
	10 m	20 m	1,200 m^2	1 km^2
Byblos	6	11	17	14,166
Tyre	6	2	8	6,667
Ibrahim River	2	0	2	1,667
Litani River	0	0	0	0

Source: World Bank.

Figure 4.13: Marine Litter Density on the Seafloor/Site (Items/km²)



Source: World Bank.

Items found on the seafloor were mostly plastics of different categories (such as plastic bags), and some rubber and glass items, with different periods spent in marine waters (see Table 4.2 and Figure 4.14).

Table 4.2: Total Number of Litter-Item Types on the Seafloor

Site	Category		
	Plastic	Glass	Rubber
Byblos	16	0	1
Tyre	7	1	0
Ibrahim River	2	0	0
Litani River	0	0	0
Total	25	1	1

Source: World Bank.

Figure 4.14: Examples of litter items on the seafloor in different surveying sites

Source: World Bank.

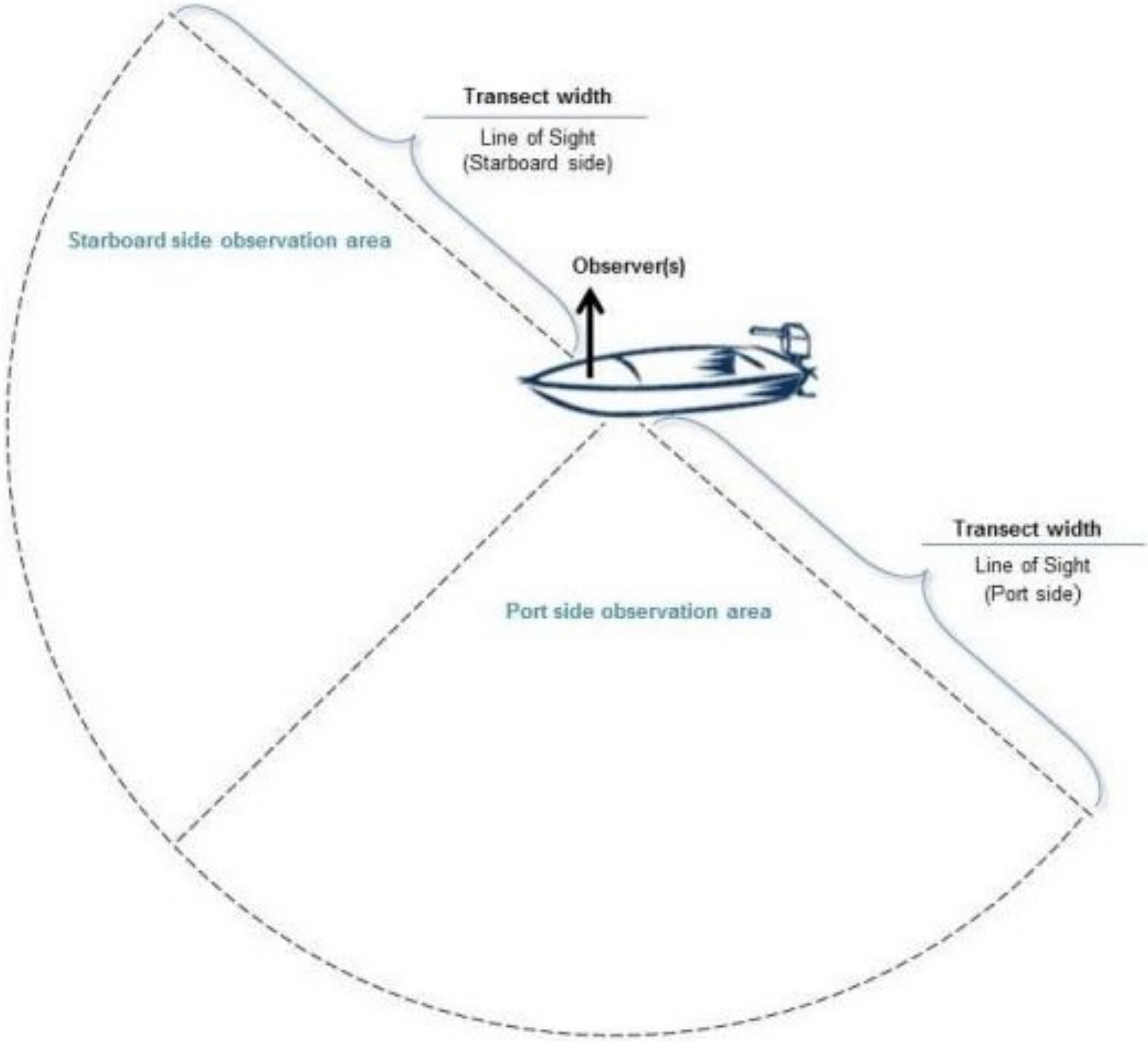
Results obtained from the underwater surveys were indicative since they were limited in time and space and most likely did not fully capture the extent of marine litter pollution on the seafloor. For a better understanding, regular surveys should be carried out on a monthly basis for at least one year. Sampling activities should be intensified before and after rainstorms to evaluate the contribution of rivers to marine litter since distribution of marine litter is affected by factors including wind, waves, currents, and weather systems such as storms. In addition, the density of material forming marine litter and time spent in marine waters determine items' ability to float on the surface, be transported, or sink.

4.3.2 Surface waters

Of the 3,672 items recorded on the surface waters in Tyre and Byblos, 1,708 were plastics (46.5 percent).

Surface marine litter for all four sites was assessed based on the visual survey method of Lippiatt, Opfer, and Arthur (2013) and JRC (2013). In brief, a boat sailed at an average speed of 2 knots for a minimum of 1 hour on a preset transect parallel to the shore with a field of vision of 5 meters on each side of the boat. The total surface area covered = 10 meters x distance travelled (Figure 4.15). Floating litter was counted, identified, and sized where possible by two dedicated boat-based observers. The categories and sizes assigned to items of floating litter were adopted according to JRC (2013) for the Mediterranean and the Black Sea (see Appendix C Litter Categories for the Mediterranean Sea and Black Sea). Litter smaller than 2.5 x 2.5 cm was recorded as "unspecified" due to difficulty in identification in the field. The path was recorded by a GPS, mapped (Figure 4.16), and the surveyed surface area calculated. Each site was sampled once, and results were expressed in litter density (items/km^2; JRC 2013).

Figure 4.15: Visual-Survey Method for Marine Surface Litter



Source: Lippiatt, Opfer, and Arthur (2013)

Figure 4.16: Observation of Surface Marine Litter at the Ibrahim River

Source: World Bank.

Byblos showed the highest concentration of surface litter and litter density while Litani and Tyre showed the lowest (Tables 4.2 and 4.3). The majority of surface litter identified in Byblos fell under the category "Unspecified" due to the small sizes (smaller than 2.5 x 2.5 cm) of those items.

Table 4.3: Number of Surface Litter per Item Type

Site	Plastic	Wood	Paper	Other	Unspecified	Total
Byblos	1,383	2	4	1	1,936	3,326
Ibrahim River	239	1	0	2	1	243
Litani River	44	3	1	0	0	48
Tyre	42	0	2	0	7	51

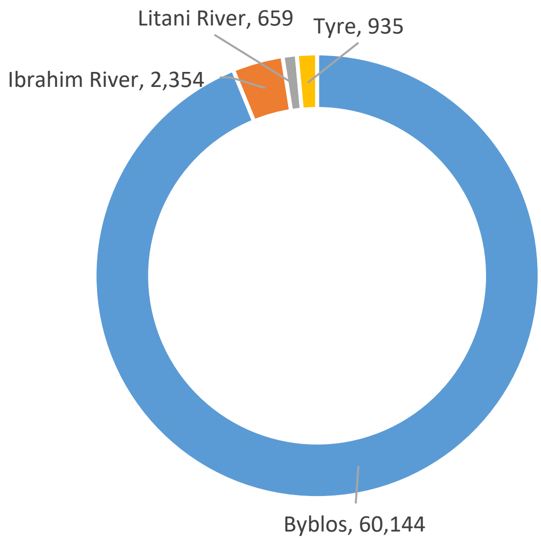
Source: World Bank.

Table 4.4: Surface Litter per km^2 of the Surveyed Sites

Site	Total items	Surface area covered (km^2)	Litter density (items/km^2)	Period (min)
Byblos	3,326	0.0553	60,144	70
Ibrahim River	243	0.1032	2,354	148
Litani River	52	0.0556	935	80
Tyre	51	0.0774	659	102

Source: World Bank.

Figure 4.17: Surface-Litter Density (Items/km²)



Source: World Bank.

The size of plastic litter at the Ibrahim River (189 items, 79 percent); near Litani (20 items, 45 percent); and near Byblos (957 items, 69 percent) was between 2.5 x 2.5 cm and 5 x 5 cm with no plastic litter recorded for this size category at Tyre, while the size of of plastic litter at Tyre (18 items) was between 5 x 5 cm and 10 x 10 cm with no plastic litter recorded for this size category at the three other sites (Table 4.4).

Table 4.5: Number and Size of the Main Plastic Item in Each Site

Site	Number of items	
	2.5 x 2.5 cm	5 x 5 cm to 10 x 10 cm
Ibrahim River	189	0
Litani River	20	0
Byblos	957	0
Tyre	0	18

Source: World Bank.

In conclusion, during the four missions, a total of 3,672 items was recorded of which 1,708 were plastics (46.5 percent), while 1,947 small floating particles (53.0 percent) were difficult to identify, and the remaining were of miscellaneous types (Figure 4.18).

Figure 4.18: Percent Surface Litter Observed per Category

Source: World Bank.

4.3.3 Sediments

The highest number of microplastic items in sediments were recorded in the Ibrahim River, followed by the Litani River, then Tyre, and then Byblos. For mesolitter, all identified marine litter in sediments were plastics, with the highest number of items recorded in Byblos, followed by the Litani River, the Ibrahim River, and then Tyre.

During the seafloor survey for both the 10-meter and 20-meter depths, sediment samples were collected by the scuba divers (Figure 4.19) at the predefined points of 0 meter, 50 meters, and 100 meters from each transect belt. At least one kilogram of sediments was taken from each point for further treatment and analysis at the IoE Laboratory according to Galgani et al. (2019), JRC (2019), and Kazour et al. (2019).

Figure 4.19: Sediment Collection along the Transect Lines

Source: World Bank.

Samples were processed for each size category (>700 µm and between 25 µm and 700 µm) at the IoE-UOB laboratory as described in Section 4.1.3 where particles were identified, recorded, and sample photographs taken.

In brief, two methods were applied to identify marine mesolitter and microlitter in sediments. Samples were sieved and analyzed for two item-size categories, one for items >700 µm and the other for items between 25 µm and 700 µm:

- Items >700 µm: One kilogram of each of the sediment samples was sieved using the Eijkelkamp automatic sieve and marine litter in the sample >700 µm identified by category and color.
- Items between 25 µm and 700 µm: 50 grams of sediments from each sample were pretreated with hydrogen peroxide (H_2O_2) to degrade organic matter, washed with ultrapure water, and then rinsed through a metal sieve. A density-separation solution of $ZnCl_2$ was added to the samples, the mixture stirred, and allowed to settle for 1 hour. The solution was then filtered through a filter paper of 20–25µm and microplastics captured. The filter paper was then observed under a microscope and identified items recorded and selected ones photographed. Results were then expressed as number of items per weight of sediment (item/kg).

For both, items were recorded according to the following categories:

- Rubber, metals, glass, textiles, wood, paper, plastics, other, and unspecified (see Appendix B).
- Plastics, mesolitter, and microlitter were further identified into the following subcategories:
  - Pellets, fragments, fiber, film, rope and filaments, microbeads, rubber, sponge/foam;
  - And according to color: transparent, blue, red, black, green, orange, yellow, and purple.

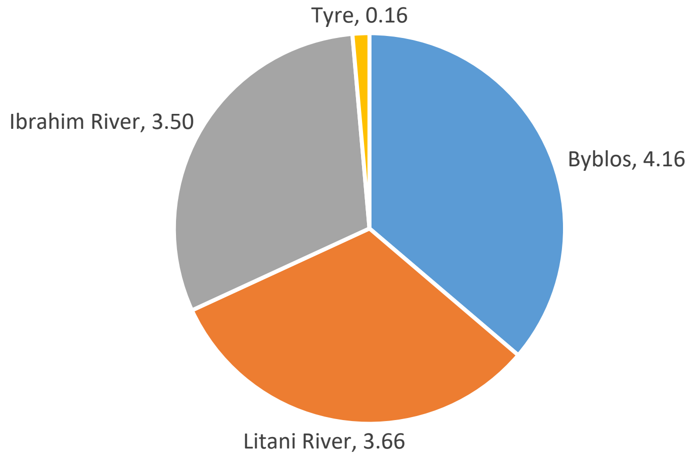
For mesolitter and microlitter >700 µm, 3 kilograms of sediments were analyzed per transect (1 kilogram per sampling point) for a total of 6 kilograms for both transect lines and results presented per site (Table 4.5, Figure 4.20). The results showed that all identified marine litter in sediments belong to the plastic category with the highest number of items >700 µm recorded in Byblos, followed by the Litani River, then the Ibrahim River and then Tyre.

Table 4.6: Marine Mesoplastic and Microplastic >700 µm in Sediments

Site	# items/transect belt/3 kg sediments		Litter density/site	
	10 m	20 m	# items/6 kg	# items/1 kg
Byblos	16	9	25	4.16
Litani River	5	17	22	3.66
Ibrahim River	14	7	21	3.50
Tyre	1	0	1	0.16

Source: World Bank.

Figure 4.20: Marine Mesoplastic and Microplastic >700 µm Density in Sediments (Items/kg)



Source: World Bank.

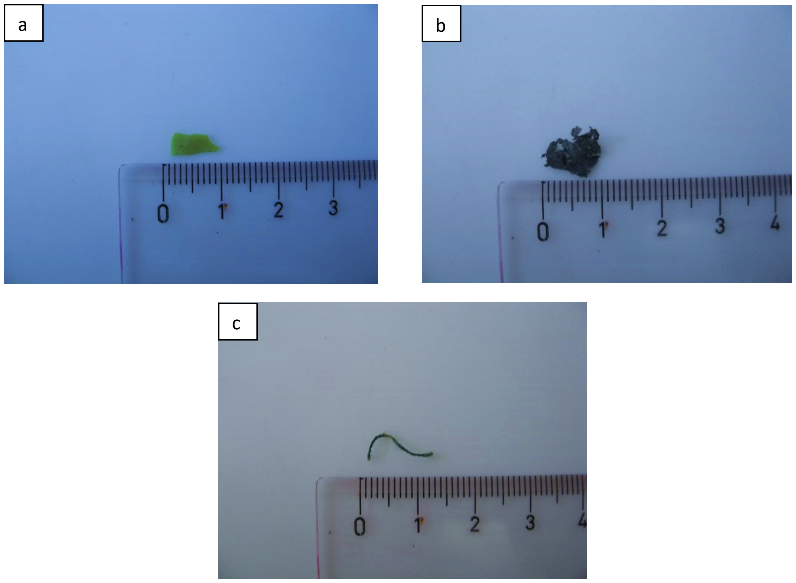
Identified items were composed of plastic, mainly in the categories of fragment, fiber, and rope and filament (Table 4.6, Figure 4.21).

Table 4.7: Item Count and Density per Category of Mesoplastic and Microplastic >700 µm in Sediments

Site	Total # items/site		Density/category					
			Fragment		Fiber		Rope and filament	
	/6 kg	/1 kg	Items/6 kg	Items/kg	Items/6 kg	Items/kg	Items/6 kg	Items/kg
Byblos	25	4	18	3	2	0	5	1
Litani River	22	4	1	0	21	4	0	0
Ibrahim River	21	4	15	3	6	1	0	0
Tyre	1	0	1	0	0	0	0	0

Source: World Bank.

Figure 4.21: Examples of Marine Mesoplastics and Microplastics >700 µm in Sediments: (a) and (b) Plastic Fragments, (c) Synthetic Filament



Source: World Bank.

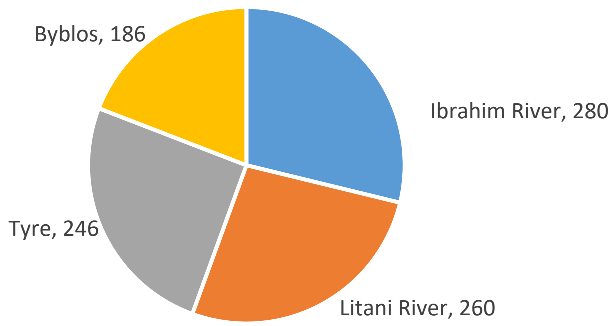
For microplastics between 25 and 700 µm, 150 grams of sediments were analyzed per transect (50 grams per sampling point) for a total of 300 grams for both transect lines and results presented per site (Table 4.7). The highest number of items were recorded in the Ibrahim River, followed by the Litani River, then Tyre, and then Byblos (Table 4.7, Figure 4.22).

Table 4.8: Item Count and Density of Marine Microplastics between 25 and 700 µm in Sediments

Site	# items/transect belt/150 g sediments		Litter density/site	
	10 m	20 m	# items/300 g	# items/1 kg
Ibrahim River	43	41	84	280
Litani River	47	31	78	260
Tyre	27	47	74	246
Byblos	41	15	56	186

Source: World Bank.

Figure 4.22: Litter Density for Marine Microplastics between 25 and 700 µm in Sediments (Items/kg)



Source: World Bank.

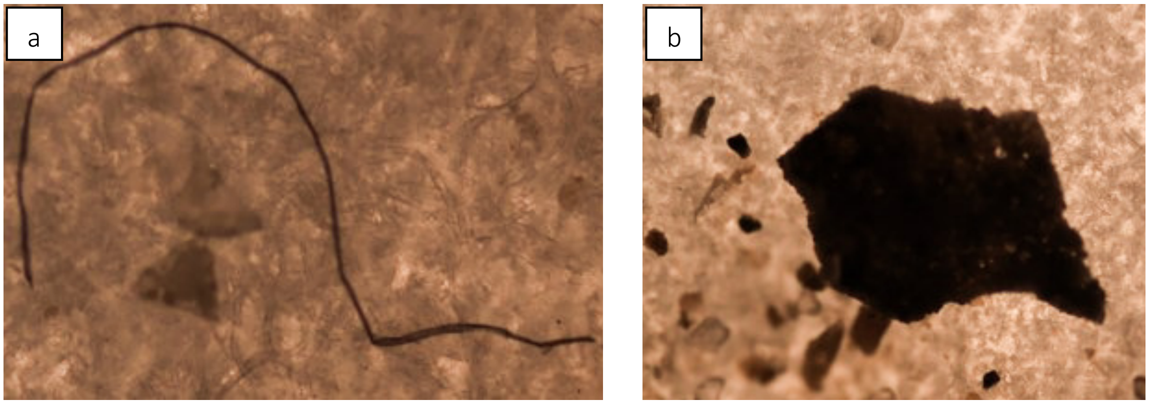
Identified items mainly were from fragment, fiber, pellet, and rope and filament categories, and of different colors (Table 4.8, Figure 4.23). There were more particles with sizes ranging between 25 and 700 µm than particles >700 µm along different sampling sites. Such results warrant further investigation regarding why such differences occur.

Table 4.9: Item Count and Density per Category of Microplastic 25–700 µm

Site	Total # items/site		Category							
			Fragment		Fiber		Pellet		Rope and filament	
	/300 g	/1 kg	Items/ 300 g	Items/kg	Items/ 300 g	Items /kg	Items/ 300 g	Items /kg	Items/ 300 g	Items/kg
Ibrahim River	84	280	37	123	44	147	3	10	0	0
Litani River	78	260	28	93	43	143	7	23	0	0
Tyre	74	247	12	40	49	163	0	0	13	43
Byblos	56	187	12	40	41	136	0	0	3	10

Source: World Bank.

Figure 4.23: *Examples of Marine Microplastics between 25 and 700 µm in Sediments: (a) Synthetic Filaments, (b) Plastic Fragment*



Source: World Bank.

The results obtained were statistically analyzed as part of a Master of Science Degree in Environmental Science carried-out by Ms. Catherina Daoud in 2021 at the Department of Environment Science, Faculty of Arts and Sciences, University of Balamand, and hosted by the MCR-IoE-UOB. The report was entitled "Baseline Assessment for Microplastics in the White Seabream *Diplodus Sargus* and in Marine Sediments in Lebanese Coastal Waters." A one-way analysis of variance (ANOVA) test and the independent t-test were conducted to test significance between the different depths and between the different sites. All statistical tests were done using SPSS software and the significance level was set at $p < 0.05$. No significant differences were found between results from different transect lines (10 and 20 meters) nor between different sites.

For a better understanding of mesolitter and microlitter in sediments, sampling should also be carried out before and after storm and flood events in addition to regular surveys. Sediments get disturbed in turbulent seas resuspending mesolitter and microlitter in the water column and tend to be carried by currents and waves.

Notes

For more information on the Waste Flow Diagram, and other plastic pollution toolkits, see the University of Leeds' "End Plastic Pollution" webpage. https://plasticpollution.leeds.ac.uk/toolkits/wfd/

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5 Spatial Distribution

Figure 5.1: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools

Source: World Bank.

The implementation of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) methodology enables the mapping of the spatial distribution of marine litter throughout the Lebanese coast. From the 51,514 items collected over two seasons, the methodology returned data on the following indicators:

- Density of litter per linear meter of shoreline (items per meter);
- Marine litter item types (top 10 items identified);
- Material type (top 10 materials identified—plastic, paper/cardboard, metal, and so forth);
- Plastic polymer (ranking— High-density polyethylene (HDPE), Low-density polyethylene (LDPE), Polypropylene (PP), Polyethylene Terephthalate (PET), Polystyrene (PS) and so forth); and
- Brands (top 10 brands identified).

The detailed results for each indicator are presented below.

5.1 Key Findings

Key Findings

Key Finding: During both the spring and fall surveys, single-use-plastics (SUPs) items originating from Lebanon were the most found items on the Lebanese beaches.

Importance: This shows the large consumption of SUPs throughout Lebanon, and points towards a general misbehavior from people who discard their waste inappropriately, and a general national mismanagement of waste.

Implication: Enforcing targeted measures could be envisaged to reduce the production and consumption of SUPs items, notably involving the producers identified.

5.2 Study Sites

Twenty-four sites distributed along Lebanon's coast were selected using a standardized approach with a minimum spacing of 10 kilometers, as shown in Figure 5.2. The GPS coordinates and geographical locations of these sites are detailed in Appendix B. Three to four sites were sampled per day, starting from the northernmost sites.

Figure 5.2: CSIRO Survey's 24 Sites

Source: World Bank.

The CSIRO methodology was applied at each site. For each beach studied, three transects were randomly selected at least 50 meters apart and at least 50 meters from the access point to the beach. The length of transects was measured from the water's edge to 1 meter into the dominant vegetation; all transects were 2 meters wide. In total, 69 transects were sampled. The study's focus was on the geographic diversity of sites, and it would have been impossible to control for tidal level or time without substantially extending the survey's duration. Consequently, the time of day and level of tide at the time of sampling were not considered as factors in data collection or analysis. However, at each beach, the transects were selected to proportionally reflect the different habitats (boulders, sand, and so forth).

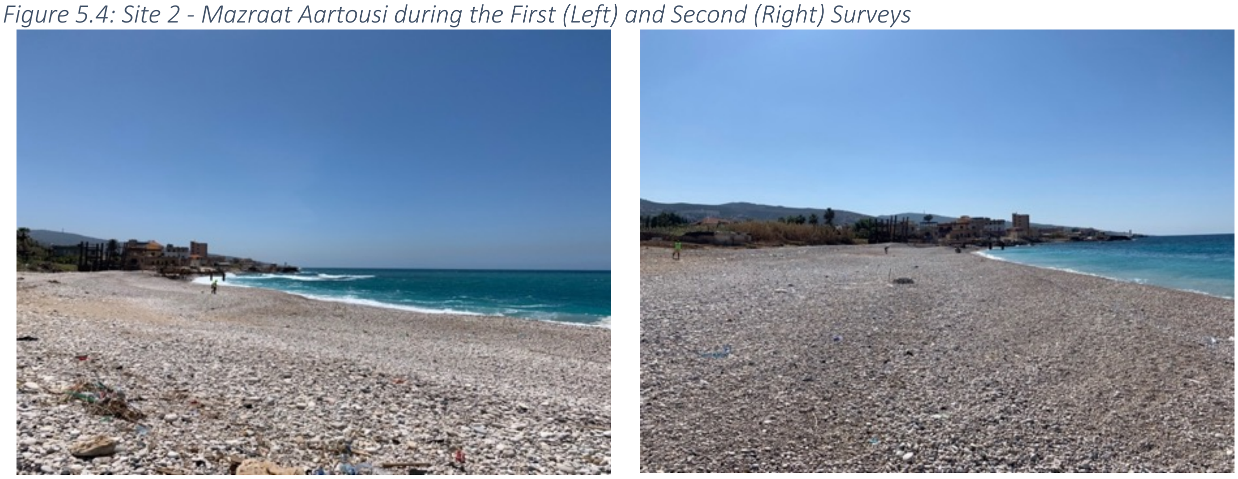
During the second round of surveys conducted in autumn 2021, 23 of the 24 sites studied in the first round were surveyed. On October 11, 2021, a fuel tank caught fire at the Zahrani power plant next to Sidon (locally known as "Saida") (Figure 5.3), so the operational decision was made to avoid this beach (site 19), so as to not endanger the team's health and safety.

A selection of pictures from six sites during the first- and second-round surveys is included below. They exhibit the varying shore shapes, backshore types, substrates, and gradients the team came across for this survey. Minimal changes in the beaches' environments were noticed compared to the first round of surveys. Photos of the team in action are also presented.

Figure 5.3: Site 19 - Oil Tank on Fire at the Zahrani Power Plant on the Day of the Beach Visit (October 11, 2021)

Source: World Bank.

Figure 5.4: Site 2 - Mazraat Aartousi during the First (Left) and Second (Right) Surveys



Source: World Bank.

Figure 5.5: Site 7 - Koubba during the First (Left) and Second (Right) Surveys

Source: World Bank.

Figure 5.6: Site 8 - Berbara during the First (Left) and Second (Right) Surveys

Source: World Bank.

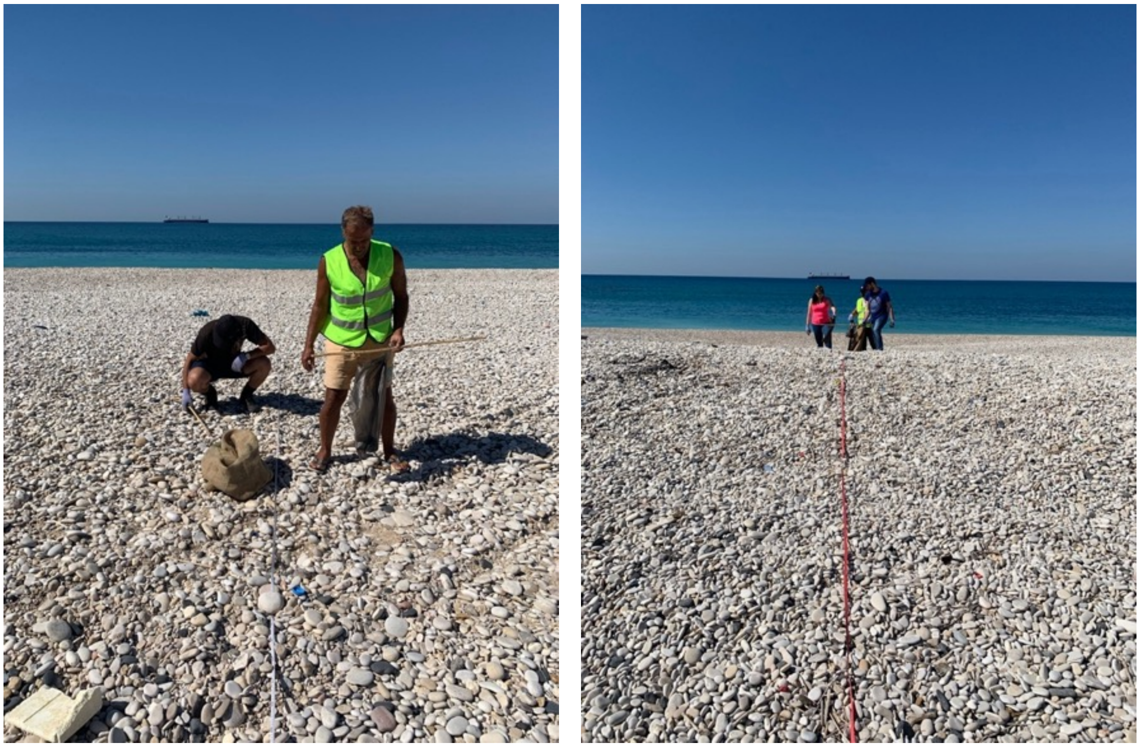
Figure 5.7: Site 21 – Khayareb during the First (Left) and Second (Right) Surveys

Source: World Bank.

Figure 5.8: Site 3 – Beddaoui during the First (Left) and Second (Right) Surveys

Source: World Bank.

Figure 5.9: The Team Working at Two of the Beaches during the CSIRO Survey



Source: World Bank.

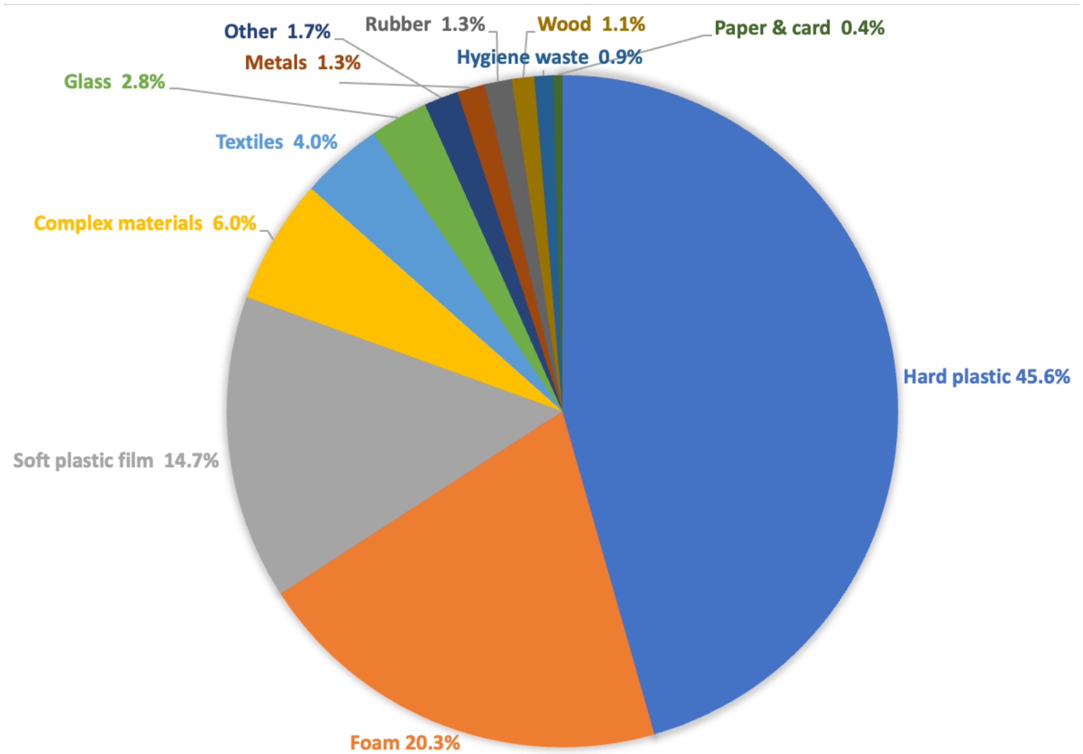
5.3 Materials

The section below describes in detail materials found on the various beaches during the first and second rounds of the surveys:

Spring

The total number of pieces of marine litter collected is presented in Figure 5.10, and the total weight of each material fraction is presented in Table 5.1.

Figure 5.10: Most Common Material Types by Count, Spring 2021



Source: World Bank.

Of the 21,958 pieces of marine litter that were collected across all sites, 17,665 (80.6 percent) were soft plastics (LDPE, PE, some PP); hard plastics (PET, HDPE, PS, some PP); and foam (expanded PS). By count, plastic is clearly the dominant material.

However, the comparison of count data (numbers) to weight data (in grams) adds a different perspective. Despite accounting for 80.6 percent of all items collected, hard and soft plastics represent only 40.5 percent of the total weight of items collected[1]. On the other hand, while textiles and others (mainly ceramics and construction materials) represent only 5.7 percent of items collected by number, they make up 39.6 percent of the total weight of items collected. Rubber, which comprised 1.3 percent of items collected, made up 5.4 percent of the total weight.

Table 5.1: Most Common Material Types of Marine Debris by Weight, Spring 2021

Rank	Material	Weight (g)	Percent
1	Hard plastic	73,225	24.9
2	Textiles	73,086	24.8
3	Other[a]	43,480	14.8
4	Soft plastic film	31,440	10.7
5	Rubber	15,845	5.4
6	Wood[b]	14,670	5.0
7	Foam	14,500	4.9
8	Glass	10,980	3.7
9	Hygiene and Covid-19 waste	9,960	3.4
10	Complex materials[c]	3,611	1.2
11	Metals	2,985	1.0
12	Paper and cardboard	690	0.2
	Total	294,472	100

Source: World Bank.
Note:
[a] The "Other" category is dominated by one item of furniture (20 kilograms) and a high number (346) of ceramic fragments. Other items may include construction materials.
[b] A large wooden pallet was encountered in one transect, which was estimated to weigh around 70 kilograms. For purposes of ranking, this one exceptional item has been removed.
[c] Items were categorized as "Complex" if they were made from several materials (such items include Tetra Paks, multilayer food packaging, bullet cartridges, and so forth).

Figure 5.11 Pile of Textiles Found on Site 3, in Beddaoui

Source: World Bank.

The discrepancies noted above are fairly intuitively resolved when considering the nature of the materials themselves: cloth, especially rope, absorbs water and thus would be unusually heavy. Rubber and glass are simply relatively heavy materials. Conversely, plastic pieces, especially soft plastics, are lightweight.

To conclude, plastics (specifically hard plastics) and textiles are the most problematic material types, considering both number of items and their weight, representing around 84.6 percent of all individual items found and 65.3 percent of litter by weight.

Fall

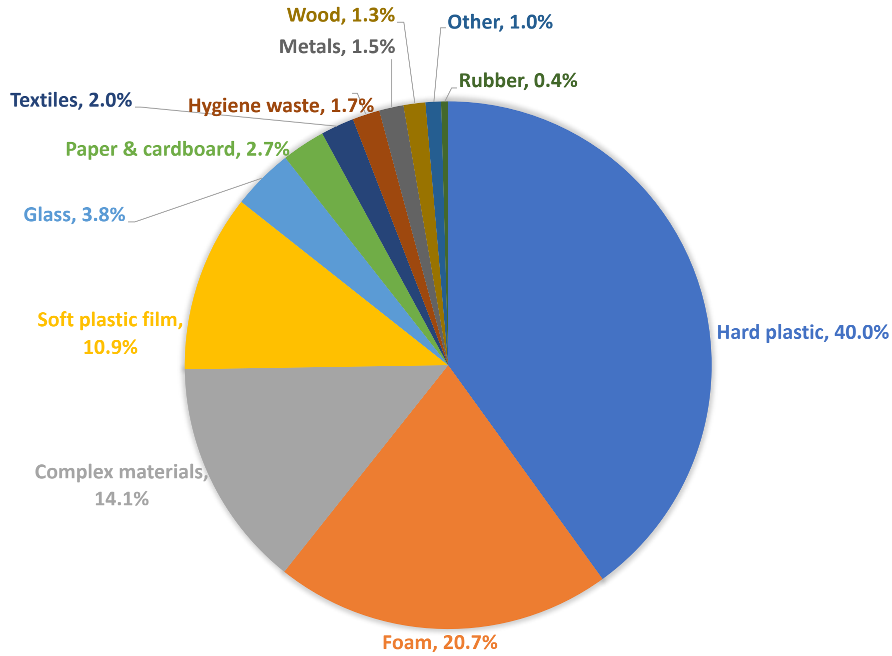
Table 5.2 and Figure 5.12 display the rankings of the materials type found in November 2021 are displayed by weight and by count respectively, in November 2021. The most commonly encountered material was hard plastic (PET, HDPE, PS, some PP, PVC) representing 40 percent of items by count and 22 percent by weight. When including other forms of plastic, namely soft plastic film (LDPE, PE, some PP), and foam (EPS), these percentages rise to around 74.8 percent of items by count and 33.7 percent by weight (see note 1).

Table 5.2: Ranking of Materials by Weight for the CSIRO Survey, Fall 2021

Rank	Material	Count	Weight (g)	Percent of total
1	Hard plastic	11,841	56,207	22.0
2	Textiles	604	46,362	18.1
3	Other	282	41,925	16.4
4	Glass	1,114	29,443	11.5
5	Wood	397	23,510	9.2
6	Soft plastic film	3,217	17,379	6.8
7	Foam	6,108	12,560	4.9
8	Rubber	126	6,915	2.7
9	Paper and cardboard	790	5,883	2.3
10	Metals	442	5,645	2.2
11	Complex materials	4,159	5,600	2.2
12	Hygiene waste	495	4,610	1.8
	Total weight (g)		256,039	100.0

Source: World Bank.

Figure 5.12: Most Common Material Categories Found in the CSIRO Survey, Fall 2021



Source: World Bank.

Plastic was the most common material found in May and November 2021, making up 80.6 percent and 74.8 percent of all items by count, respectively, and 40.5 percent and 33.7 percent of litter by weight, respectively. At both times, plastics represented the large majority of materials found (above 70 percent), justifying the underlying rationale for conducting this project—that is, placing primary focus on plastics pollution in the environment.

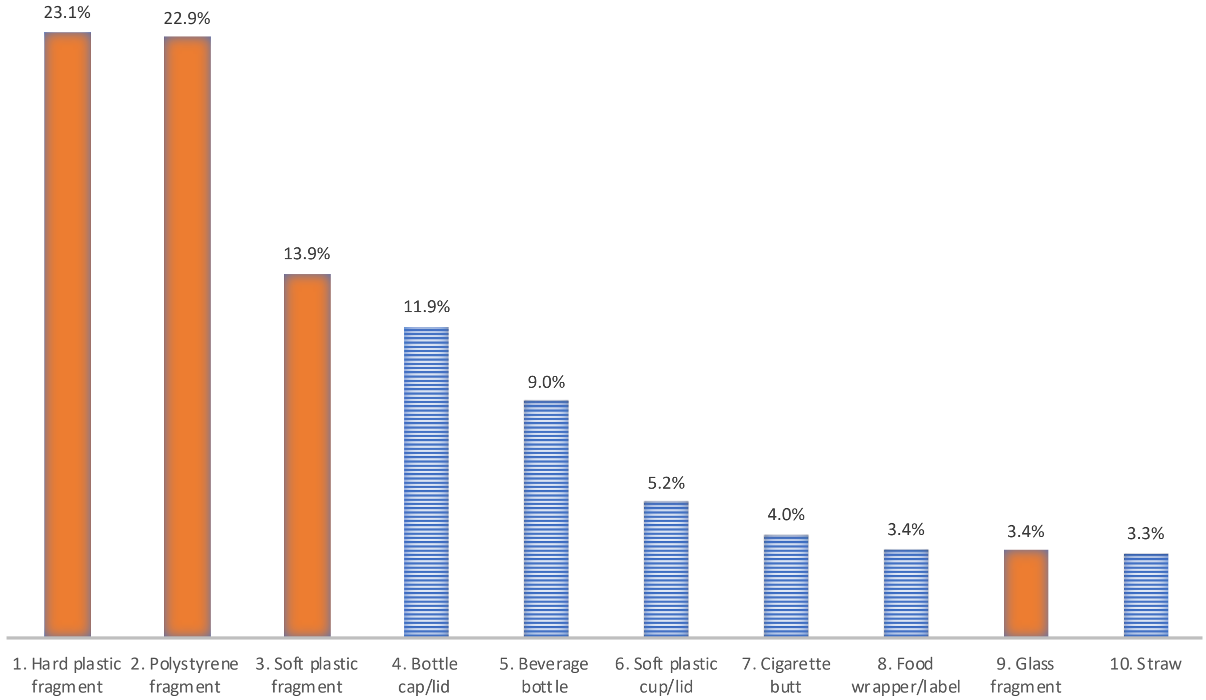
> Plastic was the most common material found in May and November 2021, making up 80.6 and 74.8 percent of all items by count, respectively, and 40.5 and 33.6 percent of litter by weight, respectively.

5.4 Items

Spring

The top 10 items found on the beaches in May 2021 are presented in Figure 5.13 by count and in Table 5.3, by weight.

Figure 5.13: Top 10 Most Common Item Types of Marine Debris Found on Lebanon's Beaches, by Count, Spring 2021



Source: World Bank.
Note: Orange bars represent fragments; blue striped bars represent whole items.

These 10 most abundant item types represent 17,342 of the 21,958 pieces collected (79.0 percent), while the remaining 4,597 items (21.0 percent) are divided between a further 61 item types. Items 1, 2, 3, and 9 are unidentifiable pieces, together comprising 10,962 items. They represent 63.2 percent of all items collected and approximately 59.0 percent of the weight of all litter collected. This is not unusual, since any item remaining in the ocean long enough degrades and breaks down into unidentifiable components. To find the most problematic items, the focus shifts to recognizable items.

Considering identifiable litter only, the most common items found were bottle caps/lids (11.9 percent), beverage bottles (9.0 percent), plastic cups/lids (5.2 percent), cigarette butts (4.0 percent), food wrappers/labels (3.4 percent), and straws (3.3 percent). All these items are SUPs[2]—items that are a typical of day outings by beachgoers. This correlates with the results of the Ocean Conservancy's International Coastal Clean Up 2020, which also found that cigarette butts, plastic beverage bottles, food wrappers (complex materials), and straws were amongst the top 10 items found on nearly 80,000 kilometers of coastline worldwide (Ocean Conservancy 2021).

Table 5.3: Top 10 Item Types by Weight, Spring 2021

Rank	Item type	Weight (g)	Percent of total
1	Wooden pallet	70,000	25.7
2	Shoes, sandals, flip flops	52,680	19.3
3	Beverage bottle	29,930	11.0
4	Hard plastic fragment	25,410	9.3

5	Soft plastic fragment	20,330	7.5
6	Furniture	20,000	7.3
7	Miscellaneous processed wood fragment	14,660	5.4
8	Miscellaneous textile fragments	14,506	5.3
9	Ceramics	14,430	5.3
10	Rubber fragments	10,835	3.9
	Diapers[a]	*9,200*	
	Total	272,781	100.0

Source: World Bank
Note: [a] If the first item, which is a statistical outlier with only one item weighing 70 kg, is removed from the analysis, diapers would be featured in the top 10 heaviest items, with 9,200 grams for 92 items.

When considering the most common items by weight, the heaviest item was a single wooden pallet, making up 25.7 percent of the total weight of litter collected. When removing this outlier item, diapers were the 10th heaviest item found, for a total count of 92.

Sandals/shoes (19.3 percent) were another significant fraction of the total weight. Other identifiable items included beverage bottles (11.0 percent), furniture (7.3 percent), and ceramics (5.3 percent).

Similar to the previous ranking by material types, the most numerous items were not necessarily the heaviest: Unidentifiable fragments of hard and soft plastics, wood, cloth, and rubber constituted 31.4 percent of the total weight of the top 10 items.

To conclude, unknown fragments of hard and soft plastics appeared to be the most prevalent items (by count) found on the Lebanese shoreline. Again, this shows and confirms that plastics are a major component of marine litter in Lebanon, justifying the interest and objectives of this project.

The top 10 most common items found in May 2021 were:

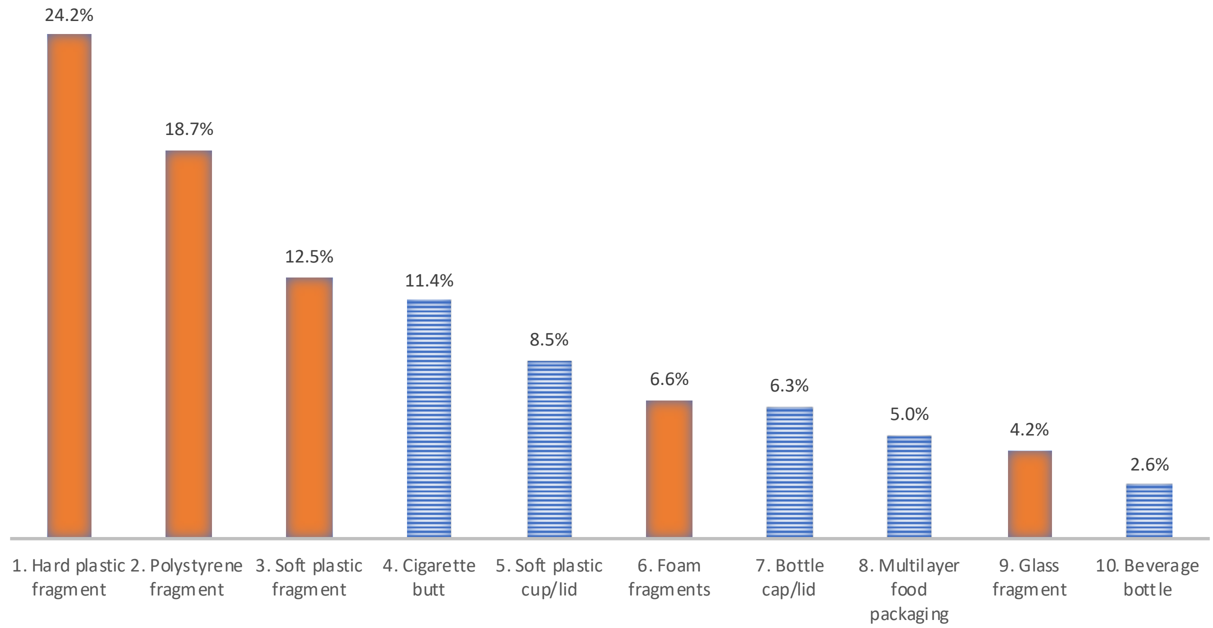
(1) Hard plastic fragments
(2) Polystyrene fragments
(3) Soft plastic fragments
(4) Bottle caps/lids
(5) Plastic beverage bottles
(6) Soft plastic caps/lids
(7) Cigarette butts
(8) Food wrappers/labels
(9) Glass fragments
(10) Straws

8/10 were plastics.

Fall

The list of most commonly encountered items by count is shown in Figure 5.14. The items are dominated by fragments of items rather than whole identifiable items, given the natural weathering and breaking down that litter undergoes in the marine environment. Therefore, various types of plastic fragments dominate the top 10 items ranking (62.0 percent of top 10 items total count), with hard plastic fragments making up 24.2 percent of the total top 10 items count.

Figure 5.14: Ranking by Count of the Top 10 Items Found during the CSIRO Survey, Fall 2021



Source: World Bank.
Note: Orange bars represent fragments; blue striped bars represent whole items.

Regarding the recognizable items, the most common pieces of marine litter encountered were cigarette butts, plastic cups, bottle caps/lids, multilayer food packaging, and beverage bottles—most of them being SUPs. Cigarette butts usually top the lists of the most common (recognizable) item of beach marine litter that is found. Consequently, it is not surprising that cigarette butts were the most frequently found (recognizable) item in this survey.

In the list (Table 5.4) of the top 10 items by weight that were found in the Fall 2021 CSIRO survey, most of the heaviest item categories were dominated by inherently heavier objects, such as shoes, ceramics, glass fragments, wood fragments, beverage bottles, and cement. Additionally, despite their much lower average weight per item compared to the previously cited heavy items, hard and soft plastic fragments ranked within the top 10 items by weight due to their high count (5,829 and 3,020, respectively).

Table 5.4: Top 10 Items by Weight Found during the CSIRO Survey, Fall 2021

Rank	Material	Count	Weight (g)	Percent of total
1	Shoes	335	30,467	16.9
2	Ceramic	235	25,980	14.4
3	Hard plastic fragment	5,829	23,800	13.2
4	Beverage bottle	621	16,885	9.4
5	Wood fragment	368	15,005	8.3
6	Glass beverage bottle	91	14,960	8.3
7	Clothing fragment	233	14,660	8.1
8	Brick/cement	35	13,350	7.4
9	Glass fragment	1,019	13,293	7.4

10	Plastic soft fragment	3,020	11,561	6.4
		Total	179,961	100.0

Source: World Bank.

The Top 10 most common items found in November 2021 were:

(1) Hard plastic fragments
(2) Polystyrene fragments
(3) Soft plastic fragments
(4) Cigarette butt
(5) Soft plastic bottle cap/lid
(6) Foam fragments
(7) Glass bottle cap/lid
(8) Multilayer food packaging
(9) Glass fragment
(10) Plastic beverage bottles

8/10 are plastics.

5.5 Polymers

Spring

All plastic items collected were further classified into polymer types. Each plastic item was categorized based on the polymer type that was its predominant constituent, since plastic items are usually made up of several polymer types. For example, toys are assemblies of separate plastic parts made of diverse polymers such as PP, PET, ABS, and so forth. Such items were classified into the polymer type that is typically their predominant constituent. The same applies for items made with a single polymer: For example, toothbrushes can be made from nylon, PET, or PP, but they were classified under “Other plastics” (which includes nylon) due to the higher proportion of toothbrushes manufactured using that polymer type. The “Other plastics” category also includes PVC, ABS, and the wider polyamides family. Some examples of item categorization are presented below:

- HDPE: Non-beverage bottle, bottle cap, lighter, lollipop stick;
- PET: Beverage bottle, packing strap;
- PP/PS: Food container, utensil, SUP cup/lid, toothbrush, pen, straw, fishing net, woven bag, string;
- LDPE: SUP bag, food wrapper;
- EPS: EPS food container, foam float/buoy; and
- Other plastics: SUP nargyle tip, PVC pipe, plastic sheet (tarpaulin type).

Of the total plastic collected, HDPE is the dominant polymer type with 35.4 percent by count and 27.5 percent by weight (Table 5.5). Items made from HDPE include beverage bottle caps, non-beverage bottles, fragments, and cigarette lighters. PP/PS is not far behind with 33.1 percent of the total count fraction, followed by LDPE at 17.4 percent. The remaining polymers (PET, EPS, and others) make up 14.1 percent of the total by count. The ranking by weight gives a different order: While HDPE at 27.5 percent comprises the largest fraction of polymers found, PET ranks second with 25.5 percent of the total weight.

Table 5.5: Most Common Polymer Types, Spring 2021

Ranking by count				Ranking by weight			
Rank	Polymer type	Count	Percent of total	Rank	Polymer type	Weight (g)	Percent of total
1	HDPE	6,254	35.4	1	HDPE	32,815	27.5
2	PP/PS	5,851	33.1	2	PET	30,410	25.5
3	LDPE	3,068	17.4	3	LDPE	22,900	19.2
4	PET	1,678	9.5	4	PP/PS	19,105	16.0
5	EPS	484	2.7	5	EPS	8,625	7.2
6	Other plastics	330	1.9	6	Other plastics	5,310	4.5
	Total	17,665	100		Total	119,165	100.0

Source: World Bank.

Fall

Table 5.6 presents the breakdown of plastic per polymer types from November 2021 survey. The same item classification that was used for the April 2021 survey was applied here.

The rankings by count and by weight are similar to the rankings of the spring survey. The total PP/PS by count overtakes HDPE and becomes the most found polymer with 41.0 of the total by count, but only the third polymer by weight (18.8 grams). This is expected, since the average weight of HDPE items is 17.3 grams in contrast to 9.7 grams for PP/PS. HDPE is the second-most found polymer with 33.5 of the total count and 33.0 percent of the total weight.

Table 5.6: Most Common Polymer Types, Fall 2021

Ranking by count					Ranking by weight		
Rank	Polymer type	Count	Percent of total	Rank	Polymer type	Weight (g)	Percent of total
1	Total PP/PS	9,313	41.0	1	Total HDPE	30,050	33.0
2	Total HDPE	7,593	33.5	2	Total PET	21,002	23.0
3	Total LDPE	3,023	13.3	4	Total PP/PS	17,165	18.8
4	Total EPS	1,609	7.1	3	Total LDPE	11,571	12.7
5	Total PET	666	2.9	5	Total EPS	6,625	7.3
6	Other plastics	484	2.1	6	Other plastics	4,763	5.2
	Total	22,688	100.0		Total	91,176	100.0

Source: World Bank.

5.6 Brands

The brand auditing of recognizable marine litter items is useful in many aspects. First, the audit provides an indication on the country of origin in which the litter was discarded. Second, brand auditing helps identify key manufacturers responsible for significant quantities of litter on Lebanon's beaches and provides scientific evidence for potential implementation of policy interventions, such as the Extended Producer Responsibility (EPR).

Spring

Brand identification was possible for 1,599 (7.3 percent) of the 21,958 items collected on the 24 beaches in May 2021, yielding 285 brands (see Table 5.7).

Table 5.7: Summary of Brand Auditing, Spring 2021

Number of items branded	1,599
Total items counted	21,958
Percentage of total items branded	7.3
Number of brands identified	285

Source: World Bank.

All pieces of litter collected were scrutinized for indications of their brand or manufacturer. However, only 7.3 percent of all items collected were identified into an item type and branded. These items would disproportionately be "young" items that have been in the marine environment for a relatively short amount of time and have had less time to degrade or lose their labelling.

Table 5.8 presents the breakdown by type of material. Resilient materials such as glass and complex materials have slightly higher percentages; cigarette packets, Tetra Paks, multilayer food packaging, and glass bottles were amongst the most identifiable items.

Table 5.8: Percentage of Items Branded per Item Category, Spring 2021

Category		Count
Cigarette packets	Total items	19
	Total branded	19
	Branded Percentage	100
Multilayer food packaging	Total items	392
	Total branded	389
	Branded Percentage	99.2
Tetra Paks	Total items	67
	Total branded	48
	Branded Percentage	71.6
Beverage bottle	Total items	1,569
	Total branded	309
	Branded Percentage	19.7
Glass Beverage Bottle	Total items	26
	Total branded	15
	Branded Percentage	57.7
Metal cans	Total items	93
	Total branded	32
	Branded Percentage	34.4
Plastic Bottle caps	Total items	2,061
	Total branded	292
	Branded Percentage	14.2
Metal bottle caps	Total items	62

Category		Count
	Total branded	35
	Branded Percentage	56.5
SUP cups/lids	Total items	904
	Total branded	186
	Branded Percentage	20.6
Cigarette butts	Total items	691
	Total branded	267
	Branded Percentage	38.6

Brands were more easily recognizable for cigarette packs (100 percent of the cigarette packs found permitted the identification of their brand), multilayer food packaging (99 percent), and Tetra Paks (72 percent), representing 28.5 percent of the total branded items. This can be explained by their materials' resistance to the beach environment and weather.

Since cigarette butts comprise the most branded items (25.0 percent) and feature in the top 10 items found, it is worth looking at hotspots for cigarette butts. Table 5.9 shows the top 10 sites where 96.2 percent of the total cigarette butts were found. From the table, there is a clear relationship between the high number of cigarette butts found, the number of daily visitors, the beach substrate, and when the approximation of when the last clean up (estimated from observation). First, the top 10 sites with the higher count of cigarette butts are all within or at the largest coastal urban settlements: Ramlet Al Baida, Saint-Simon, and Khalde are within or around Beirut; Saida Beach is to the north of Saida; Tripoli's site is in its center; Okaibeh is between Jounieh (to the south) and Byblos (to the north); Jbeil's site is also close to the city center; and Naqoura and Khayareb surround Tyre. Only Qalyaat (site 1), the closest beach to the Syrian border north of Lebanon, is located in a rural area.

The beaches of Ramlet Al Baida and Saida are the only beaches of the 24 sites visited that were estimated to be visited by between 101–1,000 beachgoers daily. This is expected since they are central beaches that the city dwellers of Beirut and Saida can easily access. These beaches also are each over 500 meters long, which is unusual in Lebanon due to the high coastal population density and rapid urbanization and coastal developments that occurred over the last decades, reducing accesses to the Mediterranean Sea.

Furthermore, the dominant beach substrate for the top 10 sites is sand; only Jbeil's Titanic Beach (site 9) has a mixed beach, with sandy areas and pebbles area. Sandy beaches are natural accumulation zones for marine litter as they act as temporal sinks and require specific beach management to prevent large deposits—and sinking—of litter, which affect the coastal ecosystems and biodiversity. Cigarette butts, which are light and small, tend to be covered by sand and sink when visitors walk close to them or wind blows. This sinking phenomenon leads them to remaining longer into the beach environment where they degrade, and can release toxins (such as cadmium, lead, and arsenic) and break down to microplastics if they reach the water and become a threat to marine life and ecosystems. Table 5.10 confirms this phenomenon, since 96.5 percent of cigarette butts were found on sandy beaches, in contrast to 3.5 percent for pebbles beach.

Table 5.9: Sites with the Most Cigarette Butts, Spring 2021

Rank	Site #	Site name (Caza)	No. of cigarette butts found	Beach substrate	Public access	Number of daily visitors	Last clean up
1	13	Ramlet Al Baida (Beirut)	210	Sand	Yes	101–1,000	Recently
2	18	Saida	164	Sand	Yes	101–1,000	Occasionally
3	22	Khayareb (Tyre)	82	Sand	Yes	0–100	Long time ago
4	12	Dbayeh (Matn)	67	Sand	Yes	0–100	Long time ago
5	4	Tripoli	45	Sand	Yes	0–100	Long time ago
6	14	Saint-Simon (Beirut)	31	Sand	Yes	0–100	Regularly
7	24	Naqoura (Tyre)	30	Sand	Yes	0–100	Long time ago
8	1	Qalyaat (Tripoli)	22	Sand	Yes	0–100	Long time ago
9	9	Jbeil (Byblos)	7	Pebble/ sand	Yes	0–100	Regularly
10	10	Okaibeh (Keserwan)	7	Sand	Yes	0–100	Recently

Source: World Bank.
Note: The "last clean up" (shown on the rightmost column) that occurred on the beach was estimated based on the observational assessment upon arrival at the beach to be surveyed.

Table 5.10: Number of Cigarette Butts on Sandy and Pebble Beaches, Spring 2021

Total cigarette butts (sandy beach)	667
Percent of total	96.5
Total cigarette butts (pebble beach)	24
Percent of total	3.5

Source: World Bank.

The country of origin was also recorded to capture the origin of marine litter on the Lebanese coastline. It is impressive to see that 97.6 percent of the total number of branded items originate from Lebanon itself, as shown in Table 5.11. Solid/plastic-waste leakage from improper waste management in urban centres, (uncontrolled) disposal sites, sewage disposal, and so forth are important sources of littering, as is shown in the results of plastic leakages from SWM systems in urban centres. However, with respect to beach litter, the top items found through the project's research show that the majority of the litter found is typical of beach visits (SUPs, cigarettes) and visitors who do not properly dispose of their waste before leaving the beach (see Tables 5.3 and 5.9). It was a common observation during the surveys that beaches lacked fundamental waste-disposal infrastructure such as simple bins. Titanic Beach in Byblos (site 9), for instance, which is over 500 meters long and receives hundreds of visitors daily in the summer, has only two bins of 140 litres each at its single entrance point.

Table 5.11: Country of Origin of Branded Marine Debris Found, Spring 2021

Country of origin	Number of items	Percent of total of total
Lebanon	1,561	97.7
Turkey	19	1.2
Syria	9	0.6
Israel	3	0.2
Unknown	2	0.1
Greece	1	0.1
Morocco	1	0.1
Iran	1	0.1
China	1	0.1
Total	1,599	100.0

Source: World Bank.

Turkey dominates all foreign sources of Lebanon's beach litter with 1.2 percent of total branded items. Lebanese team members confirmed that among the identified branded Turkish items are likely to be products newly arrived on the Lebanese market. Due to the recent economic crisis, it has become too expensive to import internationally renowned products and snacks, and Turkish industries may have seen an opportunity to export cheaper chocolates and biscuits into Lebanon.

Fall

Brand identification was possible for 3,074 (10.5 percent) of the 29,575 items collected on the 23 beaches in the fall 2021, yielding 305 brands (see Table 5.12).

Table 5.12: Summary of Brand Auditing, Fall 2021

Number of items branded	3,074
Total items counted	29,575
Percentage of total items branded	10.4
Number of brands identified	305

Source: World Bank.

In November 2021, 30 more brands were identified compared to the Spring survey (305 in November and 275 in May), likely due to the changing market of consumable goods (such as chocolates and sweets), caused by the economic crisis. 10.4 percent of all items found in November 2021 had a recognizable brand, compared to 7.3 percent in May 2021. This is still within the range of expectations, since a large number of items of marine litter have already been reduced to fragments and have no identifiable brand. The item categories with the highest number of recognizable brands were cigarette packets (99 percent), Tetra Paks (96 percent), glass beverage bottles (82 percent), and metal bottle caps (70 percent).

Table 5.13 shows the top 10 sites where 92.0 percent of the total cigarette butts were found. The table shows a clear relation between the high number of cigarette butts found, the number of daily visitors, the beach substrate, and when the last clean up occurred: the top 10 sites with the higher counts of cigarette butts are all located within or near the largest coastal urban settlements: Ramlet Al Baida, Saint-Simon, Khalde, and Dbayeh are in or near Beirut; Saida Beach is north of Saida; Tripoli Mina is in Tripoli; Nahr

Ibrahim is between Jounieh (to the south) and Byblos (to the north); and Naqoura, Abu el Asswad, and the Palestinian camp surround Tyre. Since the spring 2021 survey, the beach morphology of Ramlet Al Baida and Saida Beach remains unchanged, and they are still the only beaches of the 24 sites visited that were estimated to be visited by between 101–1,000 beachgoers daily. They are also still hotspots for local beachgoers, due to their sandy beaches and long shores (over 500 meters).

Table 5.13 Sites with the Most Cigarette Butts, Fall 2021

Rank	Site #	Site name (Caza)	No. of cigarette butts found	Public access	Number of daily visitors	Beach substrate	Last cleanup
1	13	Ramlet Al Baida (Beirut)	676	Yes	101–1,000	Sand	Long time ago
2	14	Saint-Simon (Beirut)	430	Yes	0–100	Sand	Long time ago
3	18	Saida	306	Yes	101–1,000	Sand	Long time ago
4	15	Khalde (Beirut)	279	Yes	0–100	Pebble	Long time ago
6	12	Dbayeh (Matn)	201	Yes	0–100	Sand	Long time ago
5	4	Tripoli	0	Yes	0–100	Sand	Long time ago
7	24	Naqoura (Tyre)	193	Yes	0–100	Sand	Long time ago
8	10	Okaibeh (Keserwan)	106	Yes	0–100	Sand	Recently
9	21	Khayareb (Saida)	94	Yes	0–100	Sand	Long time ago
10	22	Tyre	67	Yes	0–100	Sand	Long time ago

Source: World Bank.

Note: The "last clean up" (shown on the rightmost column) that occurred on the beach was estimated based on the observational assessment upon arrival at the beach to be surveyed. Clearly, nearly all beaches with the highest counts of cigarette butts had not been cleaned in a long time.

The dominant beach substrate for the top 10 sites is sand; only Khalde (site 15) is a pebble beach. As was the case with the May 2021 survey, cigarette butts, which are light and small, tend to be covered by sand and sink when visitors walk close to them or the wind blows. This is reflected in the lower amount of cigarette butts found on pebble beaches compared to sandy beaches (13.8 percent), compared to sandy beaches (86.2 percent), as shown in Table 5.14.

Table 5.14: Number of Cigarette Butts on Sandy and Pebble Beaches, Fall 2021

Total cigarette butts (sandy beach)	2,376
Percentage of total found	86.2
Total cigarette butts (pebble beach)	379
Percentage of total found	13.8

Source: World Bank.

Regarding the country of origin of branded items (Table 5.15), Lebanon dominates with 96.2 percent of the branded items originating from inland Lebanon, pointing to national mismanagement of solid waste and poor behaviour by the population rather than sea-based sources for marine litter. As mentioned regarding the spring 2021 survey, the mismanagement of SWM systems in coastal cities, which was investigated as part of this survey, is an important source of waste leakages into the environment. In addition, the poor behaviour of beachgoers and populations living in close proximity to the Mediterranean exacerbates the littering phenomenon.

Table 5.15: Countries of Origin of Marine Litter, Fall 2021

Country of origin	Number of brands	Percentage from total
Lebanon	300	96.2
Turkey	8	2.6
Total no. of brands	312	

Source: World Bank.

275 brands were identified in the Spring, compared to 305 in the Fall, of which 7.3 and 10.4 percent were recognizable respectively.

Notes

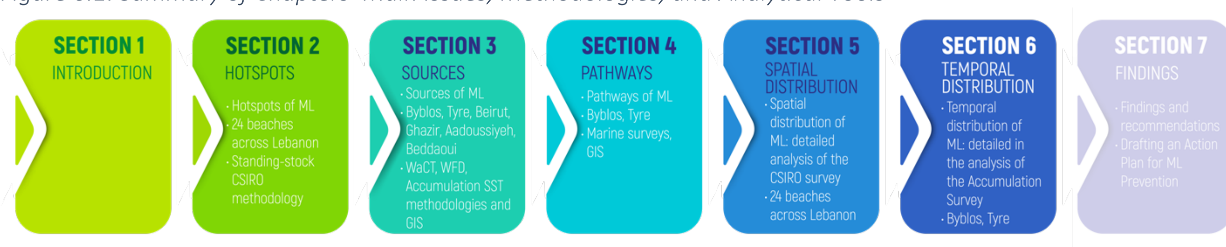
[1] This disparity between plastic representing 80 percent of items by count but only 40 percent by weight can be explained by the low weight of the average plastic item compared to some heavier materials such as shoes (#2 in the top materials by weight) and ceramics (included in the "Other" category, which is ranked #3 in the weight list).
[2] While cigarette butts are made of various components, their main component is cellulose acetate. They are further classified as SUPs for the obvious reason that they will not be used any further after the cigarette has been smoked and discarded.

References

Ocean Conservancy (2021) report: "We Clean On" 2021. https://oceanconservancy.org/wp-content/uploads/2021/09/2020-ICC-Report_Web_FINAL-0909.pdf

6 Temporal Accumulation

Figure 6.1: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools



Source: World Bank.

Project data were collected from four beaches (Chekka Beach, Titanic Beach, Litani River Mouth Beach, and Sour Beach). Data were collected every 24 hours over the course of eight days, the first time in spring 2021 and the second in fall 2021. The data were analysed to investigate the five indicators noted below:

1. Accumulation rate of litter (items per day);
2. Types of marine litter (in Tyre and Byblos);
3. Material type (top 10 materials identified—plastic, paper/cardboard, metal, and so forth—in Tyre and Byblos);
4. Plastic polymer (ranking— High-density polyethylene (HDPE), Low-density polyethylene (LDPE), Polypropylene (PP), Polyethylene Terephthalate (PET), Polystyrene (PS) and so forth —in Tyre and Byblos);
5. Wet versus dry side of the beach (offering insight into how much litter washes in from the sea versus how much is discarded directly from land).

The detailed results of each indicator are presented below.

6.1 Key Findings

Key Findings

Key Finding: Over 95 percent of identifiable marine litter items were sold in Lebanon.

Importance: This finding points to domestic waste management and poor behaviour as key issues.

Implication: Strengthening SWM systems and raising awareness amongst residents on the negative impacts of marine litter can help reduce marine litter. The brand audit also provides a basis for a potential Extended Producer Responsibility scheme.

6.2 Study Sites

During the first and second rounds of the surveys, two sites near Tyre and two sites near Byblos were selected to create a strong interface with the terrestrial surveys — Waste Wise Cities Tool (WaCT) and Waste Flow Diagram (WFD) —and to facilitate the analysis of plastic-leakage sources. For the second round of surveys, the same sites were studied to allow comparability of beach-litter data between two times of year. The locations of these sites are shown in Figure 6.2 (the site numbers are specific to this chapter and independent of the standing-stock survey presentation in the previous chapter). A description of ongoing activities at each site during the survey is presented below.

Figure 6.2: Map of the Four Sites for the Beach-Litter Accumulation Surveys, Near Byblos (Left) and Tyre (Right)

Source: World Bank.

<u>Titanic Beach</u> (34.1275, 35.6428) is a highly frequented pebble and sand beach in Byblos. The beach has only one paved access point from a parking lot, providing easy access for both the local population and visitors traveling from a distance. The back of the beach varies between cliffs and gentle hills, with its shore shape being straight for about 400 meters before becoming a cove spanning around 150 meters. It is mostly used for sunbathing, and despite the occasional clean ups organized by the municipality, its high utilization brings scattered litter on a daily basis. Based on field observations, it is estimated that, on average, more than a 100 people use this beach each day during the spring period, with significant peaks over weekends and holidays. (See Figure 6.3.)

Figure 6.3: Byblos Titanic Beach

Source: World Bank.

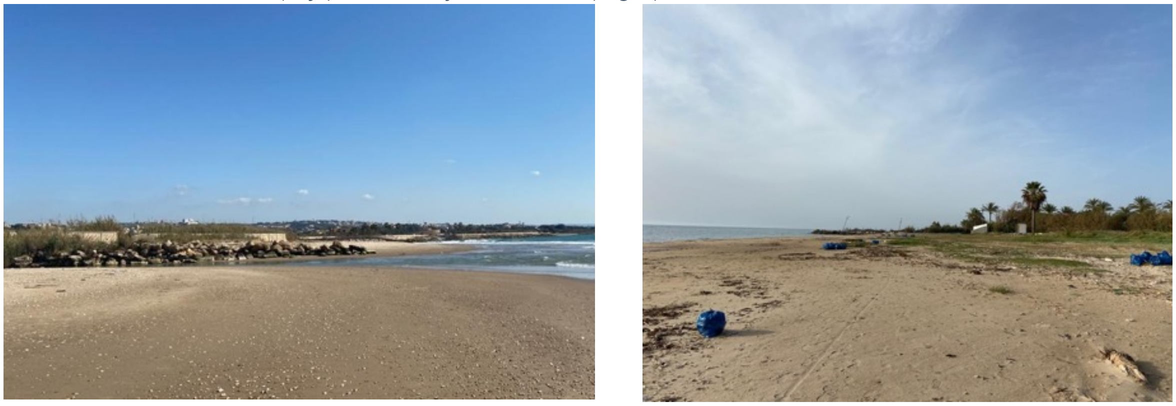
Chekka Crystal Beach (34.3219, 35.7232) is a pebble beach in the town of Chekka (approximate population 17,000), around 28 kilometers north of Byblos. Its long, straight shore sees few visitors, particularly during the winter, and we estimate (based on field observations) that fewer than 100 people use this beach daily in the spring season. (See Figure 6.4.)

Figure 6.4: Chekka Chrystal Beach

Source: World Bank.

The Litani River mouth (33.3399, 35.2446) has a rural sandy beach near the town of Qasmiyeh, around 15 kilometres north of Tyre. The is a public-access beach, but it is not often used by the general public for sunbathing or sporting activities; there is a private residence at one end of the beach. Anglers sit at the river mouth to fish in the fresh water before it enters the ocean, and there is occasional recreational use of the beach. We estimated that fewer than 10 people on average use this beach daily. (See Figure 6.5.)

Figure 6.5: Litani River Mouth (Left) and its Adjacent Beach (Right)



Source: World Bank.

Sour Beach (33.2598, 35.2093) is a highly frequented sandy beach on the southern shore of the town of Tyre. In high season, this beach can receive upwards of 1,000 visitors per day, and during the weekend days of this survey, many hundreds of visitors were observed as well as informal restaurants serving drinks directly on the beach. The beach is cleaned daily by the municipality in the summer and cleaned occasionally by NGOs outside of the high season. Sour Beach's area was larger during the second round of the survey because, subsequent to the spring survey, dominant vegetation at the back of the beach was removed, creating more space for visitors and a direct access from the road to the sand. (See Figure 6.6.)

Figure 6.6: Tyre Public Beach (Left) with an Old Lifeguard Tower (Right)

Source: World Bank.

6.3 Accumulation Rates

The accumulation rates by count and by weight for each beach during the first and second rounds of the surveys are presented in Table 6.1. The accumulation rates were derived for each beach after holding the Day Zero Cleanup: in the spring, 1,493 kilograms of solid waste were cleared at Titanic Beach, 280 kilograms at Chekka Crystal Beach (1,773kg collected in Byblos in total), 1,120 kilograms at Litani River Mouth Beach, and 416 kilograms at Sour Beach (1,536kg collected in Tyre in total). Accumulation rates for each item type are presented in Section 6.4. On Day Zero of the November 2021 survey, 448 kilograms of marine litter were collected on Titanic Beach in Byblos, 185 kilograms were collected on Chekka Crystal Beach, 407 kilograms on the Litani River Mouth Beach, and 105 kilograms on Sour Beach.

In Tyre, the average accumulation rate by count increased from 1,492 to 2,472 items per day from the first to the second survey, with disparities between the beaches: While the accumulation rate at Litani River Mouth decreased, the accumulation rate at Sour Beach doubled. It may be counterintuitive that the Litani River Mouth Beach had a lower accumulation rate during the second round of surveys: It was expected that rains would wash waste down along the Litani River to the mouth of the river, causing waste to accumulate on the beach. However, the lack of rainfall prior to the start of the study and the post-summer cleanups organized by the municipality may be the main reasons for the beach's cleanliness at the time of the spring survey.

In Byblos, the average accumulation rate decreased from 1,990 to 1,782 items per day. This is mainly influenced by the cleaner state of Titanic Beach in the second round compared to the first round, with an accumulation rate that fell from 3,134 items per day to 785 items per day (Table 6.1.)

Table 6.1: Accumulation Rates during First and Second Rounds of Surveys for Each Beach/Site

City	Site name	Rate of marine litter accumulation by count (items/day)		Rate of marine litter accumulation by weight (kg/day)	
		1st round	2nd round	1st round	2nd round
Tyre	Sour Beach	2,080	4,268	18.5	7.4
Tyre	Litani River Mouth Beach	903	676	15.0	12.8
	Average for Tyre	*1,492*	*2,472*	*16.7*	*10.1*
Byblos	Titanic Beach	3,134	785	22.3	10.4
Byblos	Chekka Crystal Beach	846	778	10.3	6.0
	Average for Byblos	*1,990*	*782*	*16.3*	*8.2*
	Overall average	1,741	1,627	16.6	9.2

Source: World Bank.

It is thought-provoking to notice the beaches with the higher number of daily visitors (Sour beach and Titanic beach) also have higher rates of marine litter accumulation. Various factors can influence litter-turnover rates, such as the type of litter material, weather conditions, proximity to landfill sites, and so forth. At the time of the study, the biggest influence was likely the number of visitors, as discussed in Section 6.4, due to the higher accumulation rates found during weekends.

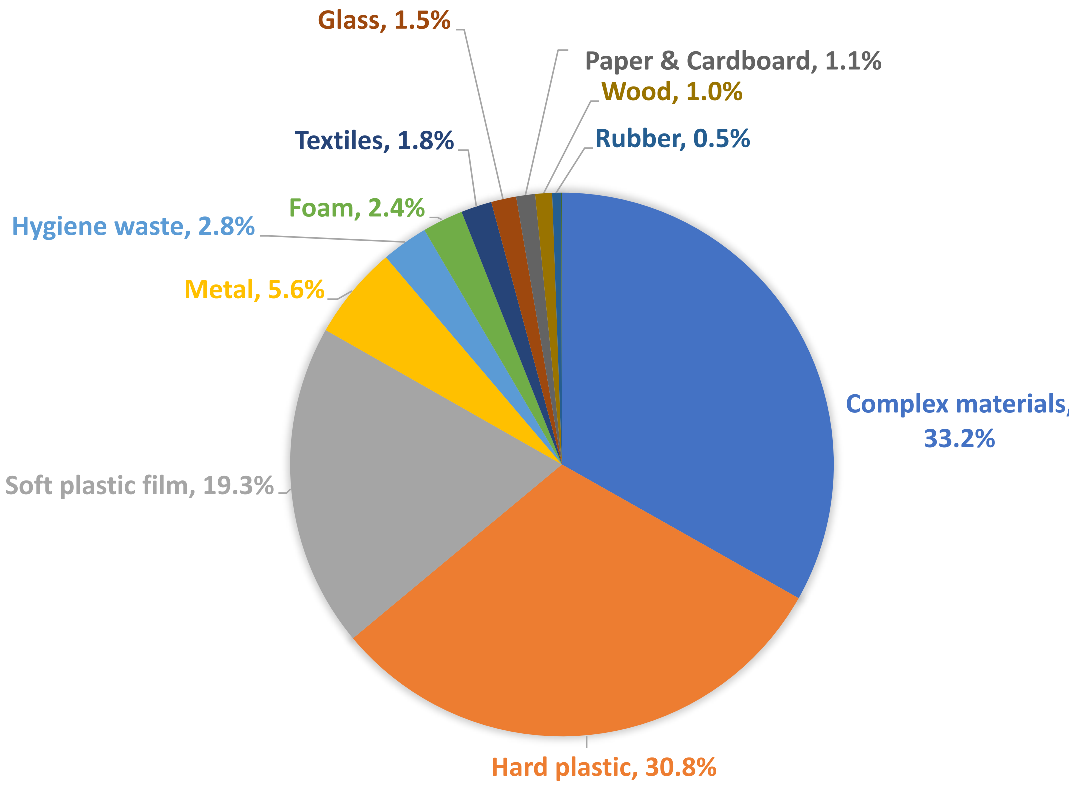
Sour beach had the highest marine litter accumulation rate in the fall (3,134items/day; 7.4kg/day), and Titanic beach had the highest marine litter accumulation rate in the spring (3,134items/day; 22.3kg/day)

6.4 Materials

Spring

The total number of items of marine litter collected in Tyre and Byblos is presented in Figures 6.7 and 6.8. The total weight of each type of material is presented in Tables 6.2 and 6.3.

Figure 6.7: Most Common Material Types in Tyre, by Count, Spring 2021



Source: World Bank.

Table 6.2: Most Common Material Types in Tyre, by Weight, Spring 2021

Tyre			
Rank	Item type	Weight (g)	Percentage of total
1	Hard plastic	52,065	22.2
2	Soft plastic film	49,910	21.3
3	Textiles	33,105	14.1
4	Glass	32,215	13.7
5	Wood	23,660	10.1
6	Hygiene waste	17,820	7.6
7	Complex materials	10,315	4.4
8	Metal	6,661	2.8
9	Foam	4,320	1.8
10	Paper & cardboard	2,705	1.2
11	Rubber	1,455	0.6
12	Other	180	0.1
	Total	234,411	100

Source: World Bank.

Of the 20,883 items collected in Tyre, 10,957 (52.5 percent) were foam; soft plastics (LDPE, PE, some PP); and hard plastics (PET, HDPE, PS, some PP). With complex materials, plastics were clearly the dominant materials by count in the spring survey (85.7 percent).

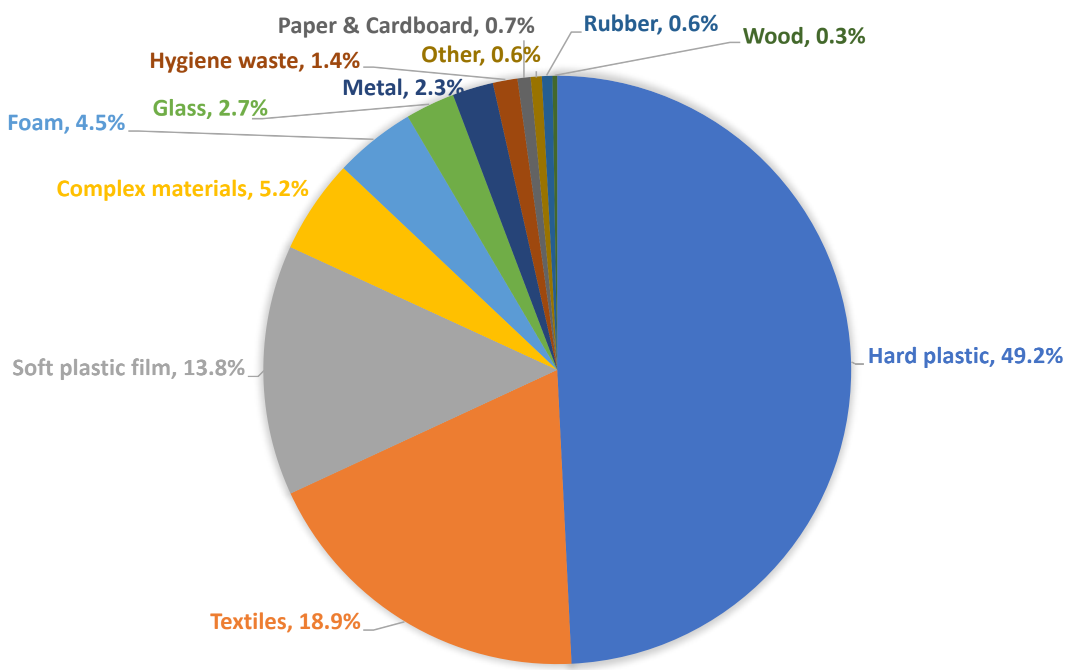
Similar to the standing-stock survey results, weight data add perspective here: Despite accounting for 52.5 percent of all items collected, hard and soft plastics and foams represent only 45.3 percent of the total weight of items collected. On the other hand, despite representing only 3.3 percent of collected items by count, textiles and glass make up 27.9 percent of the total weight of collected items, and wood, representing 1.0 percent of items collected, made up 10.1 percent of the total weight.

As was explained in the results of the standing-stock survey, these discrepancies are fairly intuitively resolved when considering the nature of the materials themselves: Cloth, especially rope, absorbs water and would thus be unusually heavy. Rubber and glass are simply relatively heavy materials. Conversely, plastic pieces, especially soft plastics, are lightweight.

Tar, which reached the Lebanese coast as a consequence of a nearby February 2021 oil spill, was generally found and removed during the Day Zero Cleanup. Only small amounts were found on Day 1 on Titanic Beach, which were most likely residues prior to the cleanup. This may indicate that nearly two months after the oil spill, tar stopped accumulating on the beaches in the Tyre area.

A similar approach can be taken for the results in Byblos. Of the 27,865 items collected, 18,683 (67.5 percent) were foam and hard and soft plastics by count. As high amounts of hard plastic fragments were collected, bigger items may have been discarded some time ago and have been degrading since on the beach. Textiles were also predominant, with 5,227 items collected (18.9 percent). Hard plastics was also the heaviest load of debris found (38.7 percent) despite their lower average weights per items, followed by textiles (21.7 percent). Soft plastics were only the sixth heaviest load, with 4.6 percent of the total weight. Glass and rubber, while despite representing only 3.3 percent of items collected by number, make up 18.7 percent of the total weight of items collected.

Figure 6.8: Most common material types in Byblos, by count, Spring 2021



Source: World Bank.

Table 6.3: Most Common Material Types in Byblos, Spring 2021

Byblos			
Rank	Item type	Weight (g)	Percentage from total
1	Hard plastic	80,547	38.7
2	Textiles	45,235	21.7
3	Glass	26,885	12.9
4	Rubber	12,065	5.8
5	Other	10,065	4.8
6	Soft plastic film	9,531	4.6
7	Complex materials	5,546	2.7
8	Metal	5,540	2.7
9	Foam	4,590	2.2
10	Wood	3,740	1.8
11	Paper & cardboard	2,500	1.2
12	Hygiene waste	2,045	1.0
	Total	208,289	100.0

Source: World Bank.

Foam (which includes EPS and PS fragments) was present in abundance during the Day Zero Cleanup, specifically insulating/carrier Styrofoam. Hundreds of thousands of small pieces accumulated in the rocky backshore of the beach, where they were hard to distinguish between small stones having similar colour patterns. The small fragments also indicates that the foams had been accumulating for a long time. Bigger, cleaner fragments were also found, showing that the beach is regularly used for Styrofoam dumping. (See Figure 6.9.)

To conclude, plastics (and specifically hard plastics) and textiles are the most problematic material types in Byblos, considering both number of items and their weight.

In both Tyre and Byblos, hard plastics, soft plastics, and foams made up the majority of the marine litter collected by count (52.5 and 67.5 percent respectively).

Figure 6.9: Examples of Foam Found on Titanic Beach's Dry Sand

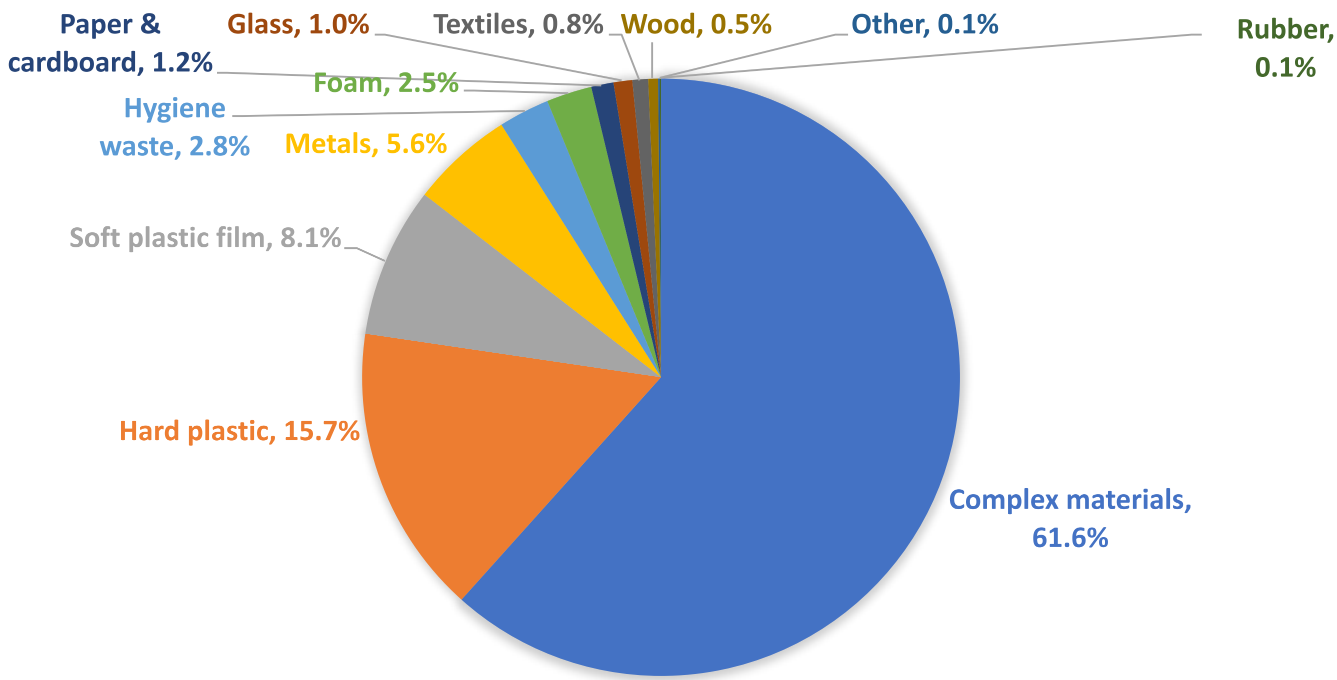
Source: World Bank.

Fall

During the November 2021 accumulation survey, complex materials (cigarette butts, multilayer food packaging, Tetra Paks, and so forth), were the most found materials on Sour Beach and the Litani river Mouth Beach (61.6 percent) (see Figure 6.10). This is due to the major proportion of cigarette butts found, as shown in the section on the most common items. Hard plastics, soft plastics and foam made up only 26.3 percent of the total count, compared to the 52.5 percent found during the first round of surveys. This drop is due to the daily clean up that occurred during the summer months until mid-October, a few days before the start of the accumulation survey. The cleanups, organized by the municipality, cleared the beach every day of large items improperly disposed of by visitors. By the end of the cleanup period, a majority of the remaining items on the beach are small and harder to see and collect. Due to the sandy landscape of the beach, they have been accumulating and sinking in the sand since the beginning of the summer period[1].

Table 6.4 shows the ranking of the material by weight. Hard plastics, soft plastics, and foam form 45.5 percent of the total weight, while complex materials represent only 10.0 percent of the total weight. This is because they are mostly represented by cigarette butts, who were found to be 0.58 gram on average. Textiles were amongst the heaviest materials, making up 9.8 percent of the total weight. Although textiles are usually light items, the fact that they can absorb water makes them heavier, and contrasts with their lower count fraction.

Figure 6.10: Most Common Material Types in Tyre, by Count, Autumn 2021



Source: World Bank.

Table 6.4: Most Common Material Types in Tyre, by Weight, Fall 2021

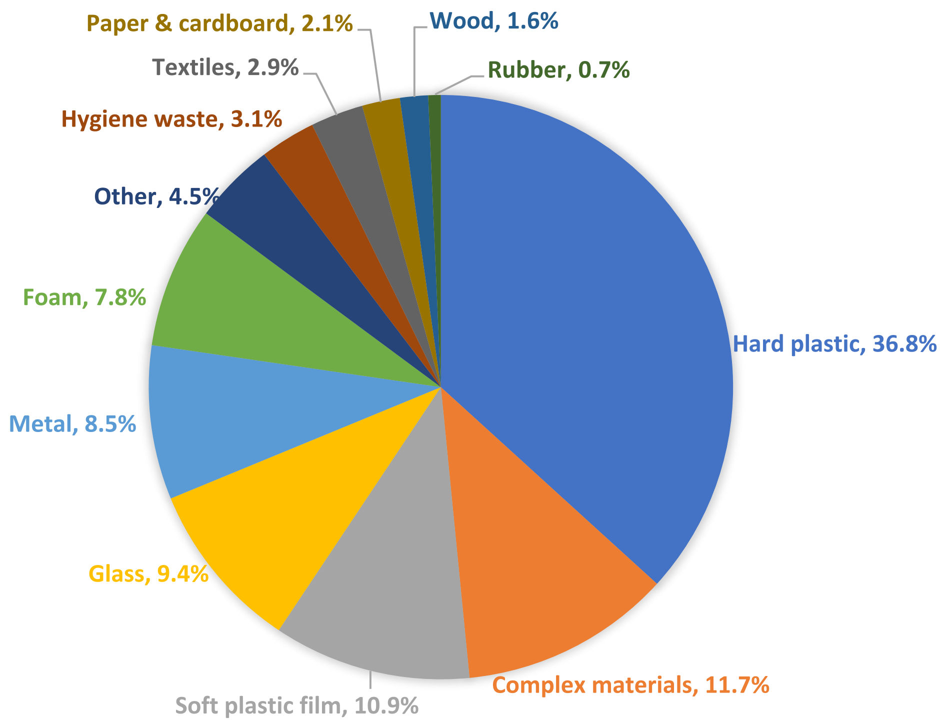
Tyre			
Rank	Material type	Weight (g)	Percentage from total
1	Hard plastic	37,705	27.2
2	Soft plastic film	20,535	14.8
3	Complex materials	13,900	10.0
4	Textiles	13,615	9.8
5	Glass	12,052	8.7
6	Rubber	10,415	7.5
7	Metals	6,710	4.8
8	Wood	6,195	4.5
9	Foam	4,775	3.4
10	Other	4,440	3.2
11	Paper & cardboard	4,390	3.2
12	Hygiene waste	3,931	2.8
	Total	138,663	100.0

Source: World Bank.

In Byblos, hard plastics, soft plastics, and foam represented 55.5 percent of the total materials by count while making up only 25.0 percent of the total weight, as shown in Figure 6.11 and Table 6.5. Complex materials come in second position, with 11.7 percent of the total count and only 2.6 percent by weight. Glass and metals were also found in high proportion (9.4 percent and 8.5 percent, respectively). "Other" materials top the materials found by weight due to the few but heavy ceramics found on Byblos Titanic

Beach, which averaged 87 grams per item—the highest average weight amongst all items found. The ceramics found on Titanic Beach and at Chekka Beach, typical of house floors, are likely discarded from construction sites nearby.

Figure 6.11: Most Common Material Types in Byblos, by Count, Autumn 2021



Source: World Bank.

Table 6.5: Most Common Material Types in Byblos, by Weight, Fall 2021

Byblos			
Rank	Material type	Weight (g)	Percentage of total
1	Other	45,470	38.7
2	Hard plastic	22,725	19.3
3	Wood	9,435	8.0
4	Metal	9,368	8.0
5	Glass	9,267	7.9
6	Textiles	5,796	4.9
7	Soft plastic film	3,890	3.3
8	Paper & cardboard	3,075	2.6
9	Complex materials	3,020	2.6
10	Foam	2,755	2.3
11	Rubber	1,495	1.3
12	Hygiene waste	1,290	1.1
	Total	117,586	100.0

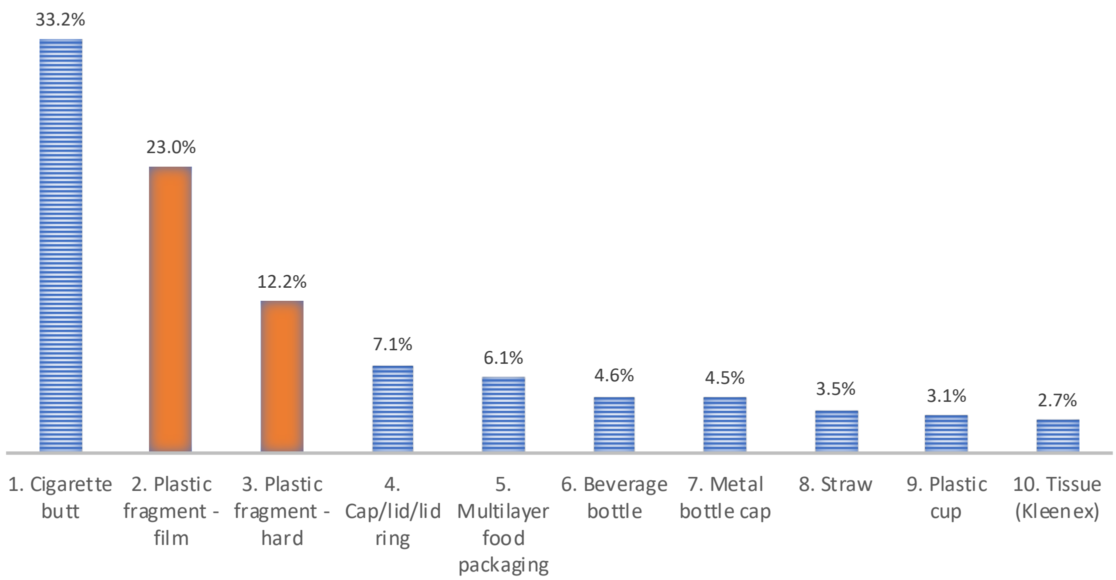
Source: World Bank.

6.5 Items

Spring

The top 10 items found on the beaches in Tyre are presented in Figure 6.12 by count and in Table 6.6 by weight.

Figure 6.12: Top 10 Most Common Item Types of Marine Debris in Tyre, by Count



Source: World Bank.
Note: Fragments represented in orange; intact items in blue.

These 10 most abundant item types represent 16,663 out of the 20,883 pieces collected (79.8 percent), while the remaining 4,022 items (20.2 percent) are divided between a further 53 item types.

From Figure 6.12, only 2 item types are unidentifiable pieces (items #2 and #3), together representing 5,870 items (35.2 percent) of the top 10 items collected by count, and 60.7 percent by weight. This is not unusual, as any item remaining in the ocean long enough degrades and break down into unidentifiable components. However, this is not helpful in our objective of identifying the most problematic items.

Meanwhile, the most common items found, considering identifiable litter only, were cigarette butts (33.2 percent), plastic caps/lids (7.1 percent) and multilayer food packaging (6.1 percent). Cigarette butts largely dominate the overall items fraction by count, and they also enter the top 10 of items by weight (1,920g), despite their relatively lower weight compared to other items. As was discussed previously, cigarette butts often make the shortlist to the top items found on beaches. The Ocean Conservancy declared in its 2021 International Coastal Cleanup report[2] that it collected nearly a million cigarette butts worldwide during its cleanup initiative.

Table 6.6: Top 10 Items Found in Tyre, by Weight (Spring 2021)

Rank	Item	Weight (g)	Percentage Weight
1	Soft plastic fragment	49,375	48.1
2	Plastic beverage bottle	25,920	25.2
3	Hard plastic fragment	12,950	12.6
4	Multilayer food packaging	4,420	4.3
5	Cap/lid/lid ring	2,610	2.5
6	Plastic cup	2,590	2.5
7	Cigarette butt	1,920	1.9
8	Metal bottle cap	1,530	1.5
9	Tissue (Kleenex)	1,060	1.0
10	Straw	370	0.4
	Total	102,745	100.0

Source: World Bank.

Figure 6.13: Plastic Bottle Lying on the Wet Sand on the Litani River Mouth Beach, Spring 2021

Source: World Bank

Table 6.7 presents the accumulation rate of the top 10 materials, for the dry and wet parts of the beach. There are two advantages of capturing the accumulation rate of each item on each side of the beach, since doing so enables (a) making assumptions on the potential sources for the predominant items composing marine litter; and (b) reflecting on whether the littering of specific items is continuous or occasional.

For each item in the table, the higher accumulation rate by count (for the dry or wet part) is shown in bold orange, to help recognizing the part on the beach where they were most found.

From the table it is clear that the accumulation rates are higher on the dry part of the beach, by count and by weight. This is expected as land-based activities are responsible for around 80 percent of marine litter on Tyre's beaches. The accumulation of marine litter (by count) on the supratidal part of the beach was significantly higher than on the intertidal area. For example, tissues accumulated at the rate of 63.9 items per day on the dry part of the beach, compared to 1.3 items per day on the wet part of the beach: nearly 50 times more. Straws are another exceptional example, as they accumulate nearly 15 times more on the dry side of the beach (78.6 items per day) than on the wet side of the beach (5.4 items per day), clearly demonstrating the link to direct littering by beach visitors. Coincidentally, bottle caps and plastic beverage bottles also have a higher dry accumulation rate (150.9 and 86.9 items per day respectively), which are found nearly 9 times more and 4 times more on the dry side respectively. Cigarette butts have the highest count accumulation rate, with 623.1 items collected daily on the dry side, compared to 166.3 items on the wet side.

Table 6.7: Dry and Wet Accumulation Rates for the Top 10 Items in Tyre, Spring 2021

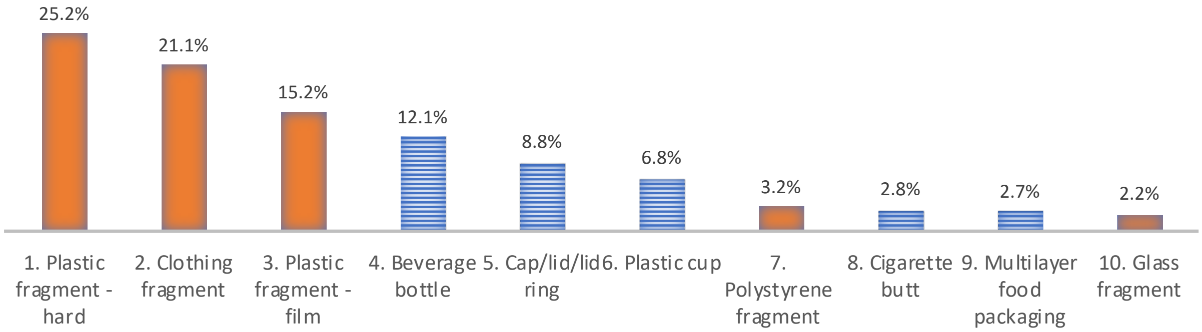
Rank	Item type	Dry accumulation rate (items/day)	Wet accumulation rate (items/day)	Ratio of dry to wet
1	Cigarette butt	623.1	166.3	3.7 to 1
2	Soft plastic fragment	272.1	275.0	1.0 to 1
3	Hard plastic fragment	189.4	102.0	1.9 to 1
4	Cap/lid/lid ring	150.9	17.7	8.5 to 1
5	Multilayer food packaging	107.4	38.7	2.8 to 1
6	Beverage bottle	86.9	22.3	3.9 to 1
7	Metal bottle cap	82.3	24.0	3.4 to 1
8	Straw	78.6	5.4	14.5 to 1
9	Plastic cup	46.3	26.9	1.7 to 1
10	Tissue (Kleenex)	63.9	1.3	49.7 to 1

Source: World Bank.

In Byblos, a total of 27,865 items were collected, weighing 228.4kg. Of this fraction, 23,790 (85.4 percent) were part of the top 10 items by count, shown in Figure 6.14. Hard and soft plastic fragments, plastic cups, plastic caps, cigarette butts, beverage bottles and multilayer packaging are common items found with the beaches in Tyre and are most likely brought to the beach by visitors, as they come to enjoy the seaside.

Once again, unidentifiable items form the Top 3 found items: 9,598 fragments of soft and hard plastics make up 40.3 percent of the top 10 items by count, and 40.4 percent by weight. Such fragments may be residues from toys, furniture, or larger objects, but it is difficult to link these fragments to a source with confidence. The higher counts of hard plastic fragments in Byblos compared to Tyre (nearly twice as much) may suggest a specific source for that pollution, such as a dumping of hard plastic items a while ago. Soft plastic fragments were most often broken-down pieces of old SUP bags or food wrappers. Clothing fragments also take a predominant fraction of the top 10 items by count (21.2 percent) and are likely clothes that have been forgotten by visitors over time.

Figure 6.14: Top 10 Most Common Item Types of Marine Debris in Byblos by Count, Spring 2021



Source: World Bank.

Clothing fragments are also the second most item found by weight (31.3 percent). As the majority was found on the wet sand (and therefore most likely originated from the Mediterranean Sea), the fragments' weights were recorded after having dried, to reflect their original weight rather than their weight when soaked in water. With hard plastic fragments making up 34.4 percent by weight of top 10 items, clothing and hard plastic fragments alone represent 65.7 percent of the top 10 items by weight. Interestingly, all items featured in the ranking by count feature in the ranking by weight, which is expected as the top 10 items make up over 85 percent of the total items found, by count (Table 6.8.)

Table 6.8: Top 10 Items Found in Byblos, by Weight, Spring 2021

Byblos			
Rank	Item	Weight (g)	Percentage Weight
1	Hard plastic fragment	38,571	34.4
2	Clothing fragment	35,170	31.3
3	Beverage bottle	11,150	9.9
4	Glass fragment	7,420	6.6
5	Soft plastic fragment	6,811	6.1
6	Cap/lid/lid ring	4,460	4.0
7	Multilayer food packaging	4,173	3.7
8	Plastic cup	2,868	2.6
9	Polystyrene fragment	1,285	1.1
10	Cigarette butt	290	0.3
	Total	112,198	100.0

Source: World Bank.

Table 6.9 presents the accumulation rate of the top 10 materials, for the dry and wet parts of the beach. For each item in the table, the higher accumulation rate by count (for the dry or wet part) is shown in bold orange to help recognizing the part on the beach where they were most found.

Table 6.9: Dry and Wet Accumulation Rates for the Top 10 Items in Byblos, Spring 2021

Rank	Item type	Dry accumulation rate (items/day)	Wet accumulation rate (items/day)	Ratio of dry to wet
1	Hard plastic fragment	639	216	3.0 to 1
2	Clothing fragment	188	529	0.4 to 1
3	Soft plastic fragment	314	203	1.5 to 1
4	Beverage bottle	363	47	7.7 to 1
5	Cap/lid/lid ring	286	12	23.6 to 1
6	Plastic cup	178	53	3.4 to 1
7	Polystyrene fragment	101	7	14.7 to 1
8	Cigarette butt	72	24	3.0 to 1
9	Multilayer food packaging	70	21	3.3 to 1
10	Glass fragment	67	9	7.3 to 1

Source: World Bank.

From the table, it is clear that the accumulation rates are higher on the dry part of the beach, by count and by weight. This is expected as 80 percent of the marine litter found on Byblos's beaches was found on the dry side of the beaches. Only clothing fragments have a higher accumulation rate on the wet side of the beach compared to the dry side of the beach (529 items per day and 188 items per day, respectively). All other items have higher accumulation rates on the dry side of the beach, indicating that they would have been discarded on land, rather than having been brought in by the sea.

Caps and lids were found nearly 24 times more on the dry side of the beach (286 items per days) than on the wet side of the beach (12 items per day), pointing at poor behaviour from beach visitors as the main cause of their littering.

Polystyrene fragmented from food or fragile items packaging was also found predominantly on the supratidal area (101 items per day compared to seven items per day on the intertidal area), indicating a commercial source of the littering. However, the fragmented patterns of the polystyrene and the low average weight per item (1.7 grams) also shows that it has been degrading for some time in the beach environment, showing that the dumping of polystyrene crates/packaging may be an occasional event rather than a regular practice.

Plastic beverage bottles and glass fragments are other items mostly found on the dry side of the beach (7.7 and 7.3 times more numerous on the dry side respectively). Overall, all items—expect for clothing fragments and soft plastic fragments—were found to be three times more numerous on the dry side compared to the wet side of the beach. (See Table 6.9.)

Figure 6.15: Polystyrene Fragments in Titanic Beach

Source: World Bank.
Note: The fragments, found during both surveys, have a color and size similar to pebbles, making it hard for surveyors to differentiate between them.

In May 2021, the top 10 most common items found in Byblos were the following:

(1) Hard plastic fragment
(2) Clothing fragment
(3) Soft plastic fragment
(4) Plastic beverage bottle
(5) Cap/lid
(6) Plastic cup
(7) Polystyrene fragment
(8) Cigarette butt
(9) Multilayer food packaging
(10) Glass fragment

6/10 are plastics.

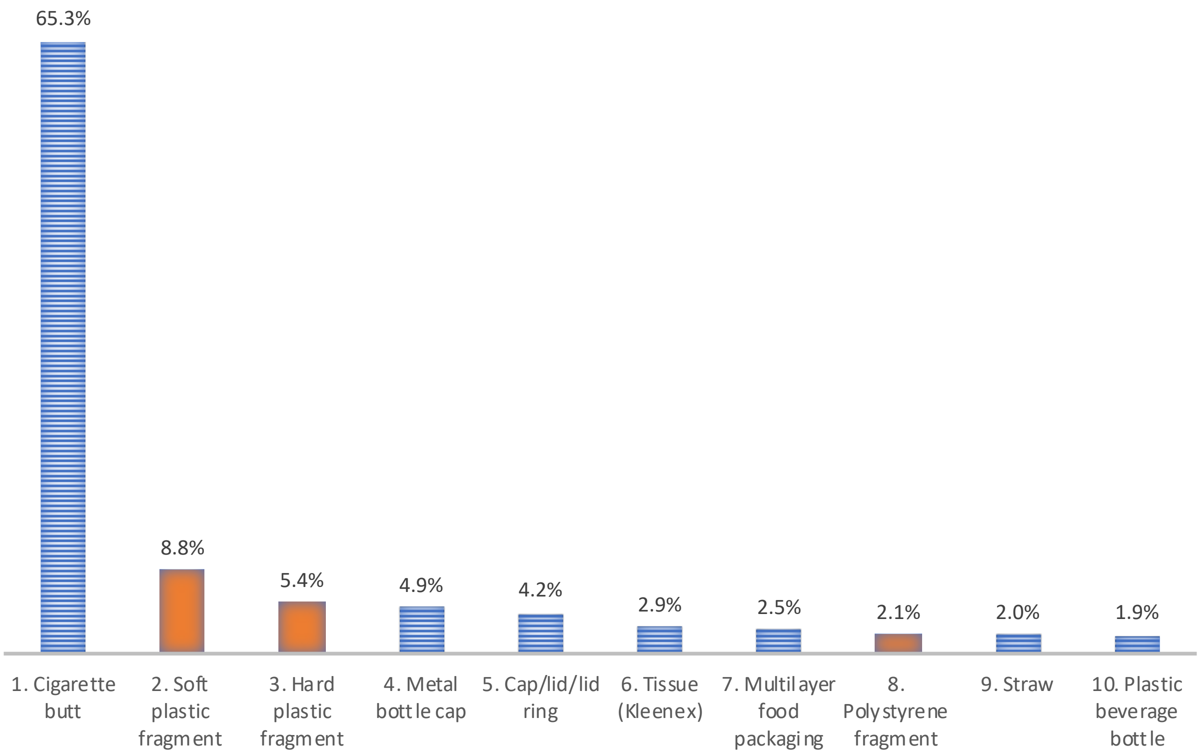
Fall

Figure 6.16 and Table 6.10 list the top 10 items that were found from both beaches in Tyre, by count and by weight respectively. Cigarette butts are the most found item, representing 65.3 percent of the top 10 items collected and corresponding to an average of 2,830 butts found daily. A large fraction of cigarette butts was found on Sour Beach, and it is likely that these items are residues from the touristic summer period, which witnessed thousands of visitors daily. Due to the sandy nature of the beach, the cigarette butts can easily be covered in sand and start degrading slowly. When looking at the item ranking by weight, cigarette butts still feature in the top 10 items as the eighth-heaviest item, despite their low average weight (0.3g) compared to other items.

Other items listed in the top 10 ranking by count are mainly SUPs (plastic caps, beverage bottles, straws, multilayer food packaging[3]) and plastic fragments (soft, hard, and polystyrene), although their number is significantly less than cigarette butts.

Plastic beverage bottles top the table of the top 10 items by weight (23.8 percent of the total top 10 items weight), closely followed by soft plastic fragments (20.6 percent), despite their low average weight per item (6.0 grams) compared to the glass bottles (44 grams).

Figure 6.16: Top 10 Items Found in Tyre by Count, during the Accumulation Survey, Fall 2021



Source: World Bank

Table 6.10: Top 10 Items by Weight in Tyre, Fall 2021

Rank	Item type	Weight (g)	Percentage Weight
1	Plastic beverage bottle	23,140	23.8
2	Soft plastic fragment	20,025	20.6
3	Tires	10,325	10.6
4	Shoes	9,875	10.1
5	Glass bottle	8,380	8.6
6	Hard plastic fragment	6,330	6.5
7	Processed wood/timber	6,130	6.3
8	Cigarette butt	5,660	5.8
9	Multilayer food	4,175	4.3
10	Glass fragment	3,377	3.5
	Total	97,417	100

Source: World Bank.

Table 6.11 shows that in November 2021, all the top 10 items found in Tyre (by count) were found on the dry side of the beach. A similar result was obtained in the spring 2021, as only soft plastic films were found more often on the wet part of the beach.

Cigarette butts, which beat all records for the number of items found in the entire project implementation, accumulated at a rate of 18,315 daily, and were 11 times more present on the supratidal area compared to the intertidal area. The number of tissues, metal bottle caps, and straws was 37, 36 and 34 times higher respectively on the dry side of the beach compared to the wet side of the beach. Due to this impressive difference and the single-use nature of this items, beach tourism would be a privileged assumption as the source for these items. Hard plastic fragments are another item predominantly found in the dry side (17 times more with 1,553 items daily accumulating), while other plastic fragments accumulated a little more evenly (4 times more for soft plastic polystyrene fragments).

Table 6.11: Dry and Wet Accumulation Rates for the Top 10 Items in Tyre, Fall 2021

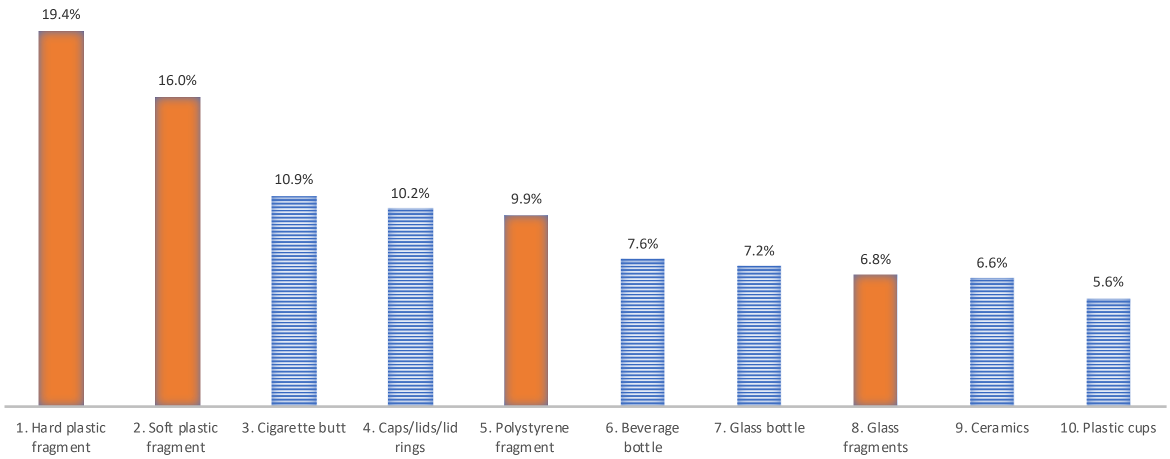
Rank	Item Type	Dry accumulation rate (items/day)	Wet accumulation rate (items/day)	Ratio of dry to wet
1	Cigarette butt	18,314	1,626	11 to 1
2	Soft plastic fragment	2,159	540	4 to 1
3	Hard plastic fragment	1,553	94	17 to 1
4	Metal bottle cap	1,468	41	36 to 1
5	Cap/lid/lid ring	904	384	2 to 1
6	Tissue	849	23	37 to 1
7	Multilayer food packaging	501	264	2 to 1
8	Polystyrene fragment	500	128	4 to 1
9	Straw	607	18	34 to 1
10	Plastic beverage bottle	462	103	4 to 1

Source: World Bank.

In Byblos, the top 10 items represented 67.2 percent of the total items found on both beach (7,358 items). SUPs are the principal recognizable items found (cigarette butts[4], bottle caps, beverage bottles, plastic cups), as shown in Figure 6.17. Plastic fragments also occupy a predominant position in the ranking, with 45.3 percent of the total top 10 count attributed to hard, soft, and polystyrene fragments.

When looking at the item ranking by weight in Table 6.12, ceramics dominate (49.4 percent of the total top 10 weight) due to their high average weight per item (57 grams).

Figure 6.17: Top 10 Items Found in Byblos by Count, Fall 2021



Source: World Bank.

Table 6.12: Top 10 Items by Weight in Byblos, Fall 2021

Rank	Item	Weight (g)	Percentage Weight
1	Ceramics	44,930	49.4
2	Beverage bottle	9,245	10.2
3	Fragment hard metal	7,178	7.9
4	Hard plastic fragment	6,740	7.4
5	Glass bottle	5,820	6.4
6	Processed wood/timber	5,595	6.2
7	Soft plastic fragment	3,670	4.0
8	Glass fragment	3,447	3.8
9	Polystyrene fragment	2,160	2.4
10	Carpet	2,155	2.4
	Total	90,940	100

Source: World Bank.

To try capture the sources for each item, the accumulation rate by count of the top 10 materials, for the dry and wet parts of the beach, were computed and are presented in Table 6.13. For each item in the table, the higher accumulation rate by count (between the dry or wet part) is shown in bold orange, to help recognizing the part on the beach where they were most found.

Every day in Byblos, the accumulation of marine litter (by count) on the supratidal part of the beach was significantly higher than on the intertidal area. For example, glass bottles (exclusively used for beer and spirits) accumulated at the rate of 507 items per day on the dry part of the beach, compared to 23 items per day on the wet part of the beach: over 22 times as many. A similar comparison can be made for hard plastic fragments (1,335 items per day on the dry part compared to 90 items per day on the wet part) and cigarette butts (707 items per day on the dry part compared to 93 items per day on the wet part). Overall, SUP items are found between 5 and 12 times as many on the dry side of the beach. Consequently, the table shows that the top 10 items tend to accumulate on the dry part of the beach at a high rate, which could be due to the direct littering of beaches by visitors. Except for polystyrene fragments, each item was found 5 to 22 times more on the dry side compared to the wet side of the beach. The table at the end of Chapter 7 summarizes the findings from Chapters 5 and 6 regarding the sources, pathways, and transport mechanisms of the items studied in this project.

Table 6.13: Dry and Wet Accumulation Rates for the Top 10 Items in Byblos, Fall 2021

Rank	Item type	Dry accumulation rate (items/day)	Wet accumulation rate (items/day)	Ratio of dry to wet
1	Hard plastic fragment	1,335	90	14.8 to 1
2	Soft plastic fragment	1,064	111	9.6 to 1
3	Cigarette butt	707	93	7.6 to 1
4	Caps/lids/lid ring	692	59	11.7 to 1
5	Polystyrene fragment	420	306	1.4 to 1
6	Plastic beverage bottle	466	91	5.1 to 1
7	Glass bottle	507	23	22.0 to 1
8	Glass fragment	376	124	3.0 to 1
9	Ceramic	406	79	5.1 to 1
10	Plastic cup	336	73	4.6 to 1

Source: World Bank.

In November 2021, the top 10 most common items found in Byblos were the following:

(1) Hard plastic fragment
(2) Soft plastic fragment
(3) Cigarette butt
(4) Cap/lid
(5) Polystyrene fragment
(6) Plastic beverage bottle
(7) Glass beverage bottle
(8) Glass fragments
(9) Ceramics
(10) Plastic cups

6/10 are plastics.

6.6 Polymers

Spring

Due to the objectives of this project being oriented on plastic pollution, the team has identified the most prevalent polymer types for Tyre and Byblos separately (in Tables 6.14 and 6.15).

The classification of items by polymer type for the Accumulation survey was performed based on the assumption mentioned above in the report; these items are made of several polymers or can be manufactured from different plastic types, so items were classified in the polymer type from which they are usually predominantly made. Examples of polymer classification were presented in Section 5.4.

In Byblos, 18,683 plastic items were collected, of which 44.0 percent was HDPE. LDPE items, which include shopping bags, food wrappers and fragments, reached nearly 20.0 percent of the total count, followed by PET and PP/PS, making up 32.4 percent of the total. When looking at the ranking by weight, HDPE is still principally the heaviest polymer load (64.0 percent). PET, PP/PS, and LDPE have similar weight fraction (12.6 percent, 9.9 percent, 7.5 percent respectively) and EPS and other plastics complete the picture with 6.0 percent of the total weight.

Table 6.14: Most Common Polymer Types in Byblos, by Count and by Weight, Spring 2021

Rank by count				Rank by weight			
Rank	Polymer type	Count	Percentage of total	Rank	Polymer type	Weight (g)	Percentage of total
1	HDPE	8,219	44.0	1	HDPE	60,616	64.0
2	LDPE	3,697	19.8	2	PET	11,950	12.6
3	PET	3,113	16.7	4	PP/PS	9,376	9.9
4	PP/PS	2,929	15.7	3	LDPE	7,081	7.5
5	EPS	484	2.6	5	EPS	3,305	3.5
6	Other plastics	241	1.3	6	Other plastics	2,340	2.5
	Total	18,683	100		Total	94,668	100

Source: World Bank.

In Tyre, the two most common polymers by count were LDPE (35.0 percent) and HDPE (32.2 percent). However, the weight fraction of LDPE surpasses largely the fractions of all other polymers, getting to 46.5 percent, while PET remains well below at 24.5 percent of the weight fraction.

Table 6.15: Most Common Polymer types in Tyre, by Count and by Weight, Spring 2021

Ranked by Count				Ranked by Weight			
Rank	Polymer type	Count	Percentage of total	Rank	Polymer type	Weight (g)	Percentage of total
1	LDPE	3,834	35.0	1	LDPE	49,440	46.5
2	HDPE	3,524	32.2	2	PET	25,995	24.5
3	PP/PS	2,226	20.3	3	HDPE	18,815	17.7
4	PET	786	7.2	4	PP/PS	7,205	6.8
5	EPS	306	2.8	5	EPS	3,485	3.3
6	Other plastics	281	2.6	6	Other plastics	1,355	1.3
	Total	10,957	100.0		Total	106,295	100.0

Source: World Bank.

Fall

In the second round of surveys in Byblos, 6,073 plastic items were collected, of which 36.0 percent was HDPE. PP items overtook LDPE items by count compared to the first round of surveys, with 1,772 items (29.2 percent) and 1,175 (19.3 percent), respectively. PET items made up 10.2 percent of the total, while other plastics and EPS together formed 4.5 percent of the total plastic items collected. When looking at the ranking by weight, PET was the heaviest polymer load (33.0 percent), followed by HDPE (31.1 percent) and PP/PS (18.2 percent). (See Tables 6.16 and 6.17.)

Table 6.16: Most Common Polymer Types in Byblos, by Count and by Weight, Fall 2021

Rank by count				Rank by weight			
Ran k	Polymer type	Cou nt	Percentage of total	Ran k	Polymer type	Weight (g)	Percentage of total
1	HDPE	2,23	36.8	1	PET	9,700	33.0
2	PP/PS	1,77	29.2	2	HDPE	9,145	31.1
3	LDPE	1,17	19.3	3	PP/PS	5,350	18.2
4	PET	617	10.2	4	LDPE	3,670	12.5

5	Other plastics (nylon, PVC)	140	2.3	5	Other plastics (nylon, PVC)	910	3.1
6	EPS	132	2.2	6	EPS	595	2.0
	Total	6,07	100.0		Total	29,370	100.0

Source: World Bank.

In Tyre, the same ranking by count was obtained. HDPE also dominated with 2,969 items (32.6 percent of the total) followed by LDPE with 2,699 items (29.7 percent) and PP/PS (23.0 percent). The top polymer by weight was PET (37.6 percent).

Table 6.17: Most Common Polymer Types in Tyre, by Count and by Weight, Fall 2021

Rank by count				Rank by Weight			
Rank	Polymer type	Count	Percentage of total	Rank	Polymer type	Weight (g)	Percentage of total
1	HDPE	2,969	32.6	1	PET	23,705	37.6
2	LDPE	2,699	29.7	2	LDPE	20,025	31.8
3	PP/PS	2,092	23.0	3	HDPE	9,435	15.0
4	PET	639	7.0	4	PP/PS	5,095	8.1
5	Other plastics (nylon, PVC)	476	5.2	5	EPS	3,035	4.8
6	EPS	222	2.4	6	Other plastics (nylon, PVC)	1,720	2.7
	Total	9,097	100.0		Total	63,015	100.0

Source: World Bank.

6.7 Brands

Spring

After all items were categorized, counted, and weighed, all recognizable items were branded. A summary of the brand auditing is proposed in Table 6.18. The breakdown of brand categories per item type is also proposed in Table 6.19.

Table 6.18: Summary of Branding in Tyre and Byblos (Spring 2021)

	Tyre	Byblos
Number of brands identified	328	246
Number of items branded	5,844	2,595
Total items counted	20,883	48,793
Percent of total items branded	28.0	5.3

Source: World Bank.

In Tyre, 28.0 percent of the total number of items was branded, compared to 5.3 percent in Byblos. Identifiable brands would disproportionally be “young” items that have been in the marine environment for a relatively short amount of time and have had less time to degrade or lose their labelling.

Table 6.19: Number of Brands Audited per Item Type in Tyre and Byblos, Spring 2021

Item type	Number of brands identified	
	Tyre	Byblos
Plastic beverage bottle	36	20
Glass beverage bottle	27	14
Metal can	15	15
Plastic bottle cap	37	39
Metal bottle cap	21	20
Plastic cup	2	11
Cigarette butt	24	15
Cigarette packet	9	10
Multilayer food packaging	148	92
Tetra Pak	9	10
Total	328	246

Source: World Bank.

The breakdown per material type is given in Table 6.20. Resilient materials such as metals and complex materials have slightly higher percentages as they can better withstand the seaside environment; cigarette packets and butts, Tetra Paks, multilayer food packaging and metal bottle caps were amongst the most identifiable items in both locations. One may notice the low percentage of glass beverage bottles in Byblos: the majority of glass bottles found on Chekka Crystal Beach were mere fragments of glass bottles, making it hard to determine the brand.

Table 6.20: Percentage of Items Branded per Item Category, in Tyre and Byblos

Item type	Branding	Tyre	Byblos
Beverage bottle	Total items	764	13,989
	Total branded	255	265
	Branded percentage	33.4	10.2
Glass beverage bottle	Total items	135	19,538
	Total branded	129	119
	Branded percentage	95.6	0.6
Metal can	Total items	285	798
	Total branded	27	77
	Branded percentage	9.5	12.7
Plastic bottle cap	Total items	1,180	6,550
	Total branded	365	754
	Branded percentage	30.9	17.1
Metal bottle cap	Total items	744	513
	Total branded	523	194
	Branded percentage	70.3	29.3
SUP cup/lid	Total items	512	4,481
	Total branded	20	217
	Branded percentage	3.9	7.6
Cigarette butt	Total items	5,526	960
	Total branded	3,954	444
	Branded percentage	71.6	45.7

Cigarette packet	Total items	63	511
	Total branded	61	65
	Branded percentage	96.8	12.6
Multilayer food packaging	Total items	1,023	4,811
	Total branded	464	402
	Branded percentage	45.4	21.3
Tetra Pak	Total items	87	746
	Total branded	46	52
	Branded percentage	52.9	4.9

Source: World Bank.

In Tyre, the top 10 brands identified represented 4,308 of the 5,844 branded items collected (73.7 percent). It is fascinating to notice that six brands in the top 10 are cigarettes. This proportion is affected by the previously described bias whereby "young" litter is more likely to display an identifiable brand, so these numbers should not be extrapolated to the full dataset.

Figure 6.18: Cigarette Butts Found during a Daily Sampling at Sour Beach

In Byblos, the top 10 brands identified represented 1,154 of the 2,595 branded items collected (44.4 percent), with a diverse set of items. One specific cigarette brand was the most commonly found item, with 19.2 percent of the total items from the top 10 brands.

Over 95 percent of identifiable items were sold in Lebanon, pointing to domestic waste management as a key issue.

Fall

Similar to the spring 2021 survey, all collected items on the Tyre and Byblos beaches were categorized, counted, and weighed, and all recognizable items were branded. A summary of the brand auditing and the breakdown of brand categories per item type is presented in Table 6.21.

Table 6.21: Summary of Branding in Tyre and Byblos, Spring 2021

	Tyre	Byblos
Number of brands identified	278	199
Number of items branded	17,291	1,619
Total items counted	34,595	10,942
Percent of total items branded	50.0	14.8

Source: World Bank.

Just like in the spring of 2021, more items were branded in Tyre (50.0 percent) compared to Byblos (14.8 percent). This is due to the higher number of recognizable items in Tyre (cigarette butts, metal bottle caps, multilayer food packaging), compared to Byblos, where more fragmented items of hard and soft plastics were found.

Table 6.22 shows the number of new brands that were found during the second round of surveys, compared to the first round. In Byblos, 78 new brands were registered, including 50 for multilayer food packaging, and 7 plastic bottle caps. In Tyre, 87 new brands were identified, predominantly for multilayer food packaging (55) and cigarette butts (29). The newly branded items do not necessarily reflect that a new product has entered the market since spring 2021, but that the brand was not found at the same location during the previous survey. For example, in Byblos, the Galaxy chocolate bar (multilayer food packaging) was found for the first time in the Fall 2021; however, the Galaxy brand has been sold in Lebanon since before the start of the survey.

Table 6.22: Number of Brands Audited per Item Type in Tyre and Byblos, Fall 2021

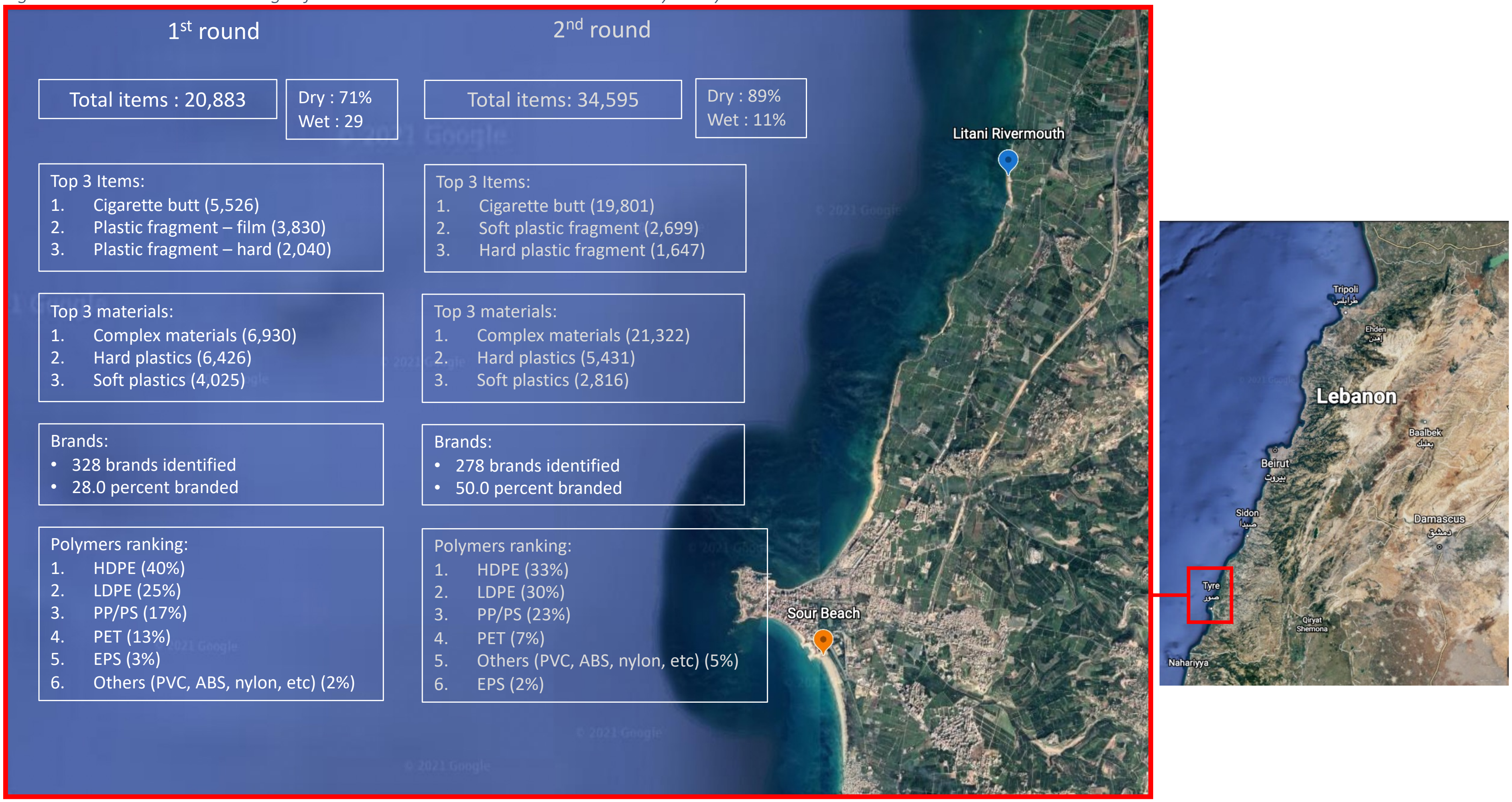
	Tyre		Byblos	
Item type	Spring 2021	Number of new brands in Fall 2021	Spring 2021	Number of new brands in Fall 2021
Plastic beverage bottle	18	3	15	5
Glass beverage bottle	12	1	1	0
Metal can	16	6	1	5
Plastic bottle cap	20	4	26	7
Metal bottle cap	17	0	14	5
Plastic cup	2	0	3	0
Cigarette butt	49	29	14	4
Cigarette packet	7	0	11	0
Multilayer food packaging	125	44	106	50
Tetra Pak	12	2	8	2
Total	278	87	199	78

Source: World Bank.

6.8 Comparison between the Spring and Fall Surveys

Figures 6.19 and 6.20 summarize the combined findings of the accumulation surveys in both Tyre and Byblos respectively, that were held in April and October 2021. The rankings are shown based on count.

Figure 6.19: Summarized Findings of the First and Second Accumulation Surveys in Tyre



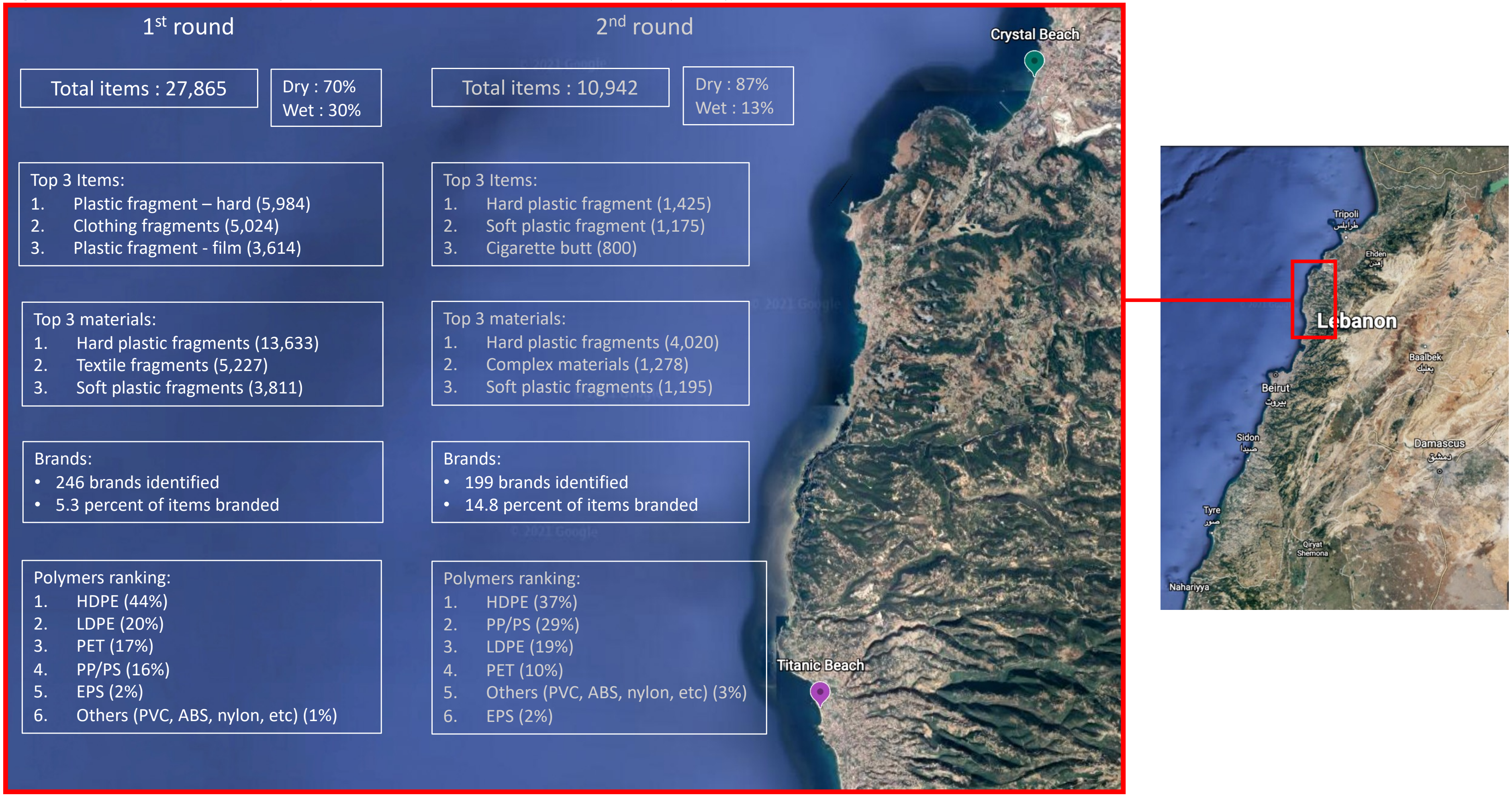
Source: World Bank.

In Tyre, the total number of items found grew from 20,883 to 34,595 items between April and October 2021, with a similar ranking of the top three items found: cigarette butts; soft plastic fragments, and hard plastic fragments. The number of cigarette butts showed the highest growth (from 5,526 to 19,801 items), which may be due to the combination of the beach's sandy substrate allowing lighter items to sink, and the post-touristic summer season, which showed a high affluence of beachgoers. The top three materials, complex materials and hard and soft plastics top the chart both times. Complex materials characterized the most-found items, reflecting the high numbers of cigarette butts found. In the hard-plastics category, unknown fragments (HDPE) and bottle caps were the most commonly found items, regardless of the season. Similarly, the high amounts of soft plastic fragments (LDPE) reflected the degraded single-use plastic bags and labels, which had been degraded in the coastal/beach environment for a while. It is suspected that a lower amount of soft plastic fragments was found in the second survey partly because the vegetation on the back of a segment of Sour Beach had been removed, which prevents litter to be caught in it, and rather fly away.

The polymers ranking remains nearly unchanged, with HDPE, LDPE, and PP/PS polymers occupying the top-three places in the rankings in April and October 2021. The ranking was derived by classifying the items under the polymer that may dominate. For example, toys are assemblies of separate plastic parts made of diverse polymers such as PP, PET, ABS, and so forth. Such items were classified in the polymer type from which they are usually predominantly made. The same applies for items made with a single polymer. For example, toothbrushes can be made from nylon, PET, or PP, but were classified under "Other plastics" (which included nylon) due to the higher proportion of toothbrushes manufactured using that polymer type. The "Other plastics" category also includes PVC, ABS, and the wider polyamides family.

In Byblos, the total number of items found fell from 27,865 items in spring to 10,942 in fall. Hard plastic fragments remained the most-found item and, along with soft plastic fragments, remained in the top-three most-found items. It is not surprising then that hard and soft plastics are amongst the most-found materials, beside textile fragments in the first round and complex materials in the second. As in Tyre, the polymer ranking remained constant in Byblos.

Figure 6.20: Summarized Findings of the First and Second Accumulation Surveys in Byblos



Source: World Bank.

Notes

[1] Sandy beaches tend to behave like temporal sinks for marine litter. See detailed explanation in Section 5.5.

[2] Ocean Conservancy. 2021. International Coastal Cleanup report. https://oceanconservancy.org/wp-content/uploads/2021/09/2020-ICC-Report_Web_FINAL-0909.pdf

[3] While multilayer food packaging can be made from different materials (plastics, aluminium, paper, and so forth), here, such packaging is considered single-use plastic (SUP), since it is usually used once and discarded, and often made mainly of plastics. The brand audit confirms the single-use aspect of these items, since the most often found multilayer food packaging items were for chocolate bars and crisps.

[4] The classification of cigarette butts into the "plastics" category follows the classification proposed in both the CSIRO and Accumulation methodologies. It was further decided to include them as single use, since they would not be reused after the cigarette has been smoked.

[5] According to the WHO (World Health Organization) Regional Office for the Eastern Mediterranean Lebanon's Tobacco Industry profile.
https://applications.emro.who.int/docs/Fact_Sheet_TFI_2017_EN_20149.pdf?ua=1

7 Findings and Recommendations

Figure 7.1: Summary of Chapters' Main Issues, Methodologies, and Analytical Tools

Source: World Bank.

Key Findings

Key Finding: Plastic is omnipresent along the Lebanese coastline, affecting all coastal communities. Uncollected waste, direct littering by beach goers and uncontrolled disposal sites are the main sources of marine litter.

Importance: Interventions for marine litter prevention in Lebanon must involve the mobilization of local and national authorities.

Implication: Short-, medium-, and long-term actions include intensifying beach cleanup initiatives, setting up and implementing a marine litter monitoring strategy, understanding waste leakage from uncontrolled dumpsites along riverbanks, investigating legal and economic interventions, and finalizing the national Action Plan for marine litter prevention.

7.1 Summary of Findings

The sources, hotspots, and pathways of marine litter in Lebanon in 2021 were determined through a set of terrestrial, beach, and marine surveys.

Hotspots of marine litter found in the spring and fall surveys were similar, especially around urban areas (Tripoli and Saida). Overall, plastic was omnipresent on Lebanon's beaches. Of the 51,514 items collected during the standing-stock survey in both seasons, 76.0 percent were hard, soft, or foam plastics. Of the 23 sites studied in the fall, 14 sites had higher marine litter-densities compared to the spring survey, due to a) the lack of beach cleanup after the summer months, and b) new settlements close to the beaches studied, specifically for the two emerging hotspots of Saint-Simon in Beirut and Dbayeh.

Concerning the sources of marine litter, first, the Waste Flow Diagram (WFD) surveys highlighted that large amounts of plastics are entering the sea through solid waste management (SWM) activities: The coastal cities release on average 1.1 kilogram per person of plastic every year to water systems, making them an important potential land-based source of marine litter. Plastic leakages occurred predominantly from uncollected waste, which reaches the marine environment through the drainage and sewerage systems, or through other pathways such as wind or rivers.

Second, GIS analysis has shown that there has been a potential increasing number of uncontrolled disposal sites located within 500 meters of river shores (73 potential new sites since 2017), which could be potential land-based sources of marine litter, with rivers being the main pathways to the sea. It is strongly suspected that these sites could be important point sources of plastic waste emissions; however, calculating the impact of rivers in transporting litter to the sea was not part of this project's scope.

Third, to further understand the fate of uncollected waste and the potential origin of marine litter, the indicative marine surveys were conducted in the spring. A total of 3,672 items was recorded on the surface waters of Tyre and Byblos, where 1,708 were plastics (47 percent), while 1,947 small floating particles (53 percent) were difficult to identify. Marine litter density on the seafloor was found to be the highest in Byblos (14,166 items/km^2) compared to Tyre (6,667 items/km^2), which makes sense considering the results of the accumulation beach surveys in spring, that more items were found in Byblos (27,865) compared to Tyre (20,883). Small floating particles demonstrate that the items had been degrading in the marine environment for some time and could have originally been dumped in the sea by sea-based sources (cargo ships, recreational boats, and so forth) or reached the sea from a land-based source. Regarding microplastic in sediments, results show that the Lebanese coast is similarly contaminated with no statistical significance found between analysed sites.

Lastly, when looking at the beach environment through the accumulation surveys, on average, over 95 percent of the items branded during the accumulation survey originated from Lebanon. When looking at the accumulation rates of the top 10 items found, seven times as many items were found in Byblos and 12 times as many items in Tyre were found on the dry versus wet side of the beach, pointing at misbehaviour by beach visitors. Cigarette butts, hard and soft plastic fragments were the top three items (by count) found in Tyre and Byblos, both in spring and fall. Single-use plastics (SUPs) such as straws, multilayer packaging, water/soda bottles, and so forth were also predominant, pointing to beachgoers as the main source of marine litter on beaches.

From the above findings, it is clear that land-based sources—such as uncollected waste and uncontrolled dumps along riverbanks—should be targeted to reduce and eventually eliminate all plastic leakages to the (marine) environment from these sources. While more research is needed to understand potential sea-based sources of marine litter in Lebanon, the short-term focus for the local and national authorities should be on promoting measures that improve beaches' cleanliness and on enforcing penalties against beach visitors displaying poor behaviour.

To summarize, it is clear that plastic leakages into the environment come from three main sources:

1. Direct littering by beach visitors. Touristic activities close to the Mediterranean Sea are amongst the most predominant land-based sources of plastic leakages and therefore marine litter into the sea.
2. Uncollected waste within cities. The collection coverages of Tyre and Byblos (78 percent and 82 percent, respectively) are lower than for upper-middle-income countries, which usually have collection coverages close to 100 percent. The uncollected waste ends up in the environment on land or water systems, or in drainage systems, or is burned.
3. Uncontrolled disposal sites along riverbanks. A detailed review of the UNDP (2017) map of disposal sites and additional satellite imagery revealed around 73 potential new disposal sites located on the banks of Lebanese rivers leading to the Mediterranean Sea.

A summary for each source of marine litter is presented below (Table 7.1). The sections following Table 7.1 discuss recommendations for future monitoring and research, which will further this baseline survey findings presented in this report.

Table 7.1. Summary Regarding Sources of Marine Litter

Uncollected waste	Uncollected waste leaks into the environment because (a) collection services do not cover the entire municipal area, (b) residents and tourists improperly dispose of their waste, and/or (c) waste leaks from uncontrolled disposal sites. In the areas where the WFD was applied, collection coverage was generally high (above 95 percent). Tyre had the lowest collection coverage (78 percent) followed by Byblos (82 percent), leading to 22 percent and 18 percent, respectively, of the generated waste remaining uncollected. When looking at collection practices, leakage potential from collection containers is the highest, since it was observed in most cities that the collection bins remain open to the environment. It was observed that residents dispose of their waste in containers, but waste rapidly overflows, spreads to the bins' surroundings, and leaks into the environment via wind, rain, and/or human transportation. Despite a regular collection service, waste accumulates rapidly and overflows around the bins, where it can be blown away by wind (if waste items are light and uncontained in a bin bag), taken by animals, or simply remain uncollected. Moreover, Lebanon's current economic crisis is pushing a substantial number of scavengers to search for recyclables in waste bins, leading to waste spreading around the bins. Despite the generally high leakage potential of collection containers, there was no major evidence of systemic failure of the SWM post-collection regimes up until the point of disposal. The study also revealed that water systems are the most common fate for uncollected waste (usually the Mediterranean Sea), followed by land. Drains and sewerage systems are not believed to be a predominant pathway for marine litter, since dumping into drains was not witnessed to be a common practice.
Beachgoers	The nature of the items (SUPs such as straws, food packaging, and so forth) found on the beaches, the higher accumulation rates for the most found items on the dry side versus the wet side of the beach, and the lack of wear and tear from the marine environment suggest that the litter is improperly disposed of by residents and tourists. This finding diminishes the likelihood that inland dumpsites are major sources of such litter. However, inland disposal sites that are located close to river shores are likely to be problematic sources of marine litter, specifically during the rainy season, with rivers becoming the predominant pathway for marine litter.
Uncontrolled disposal sites	Although the kinds of items found on the beach are predominantly disposed of by beach visitors, waste can easily escape uncontrolled disposal sites and enter the riverine system before finishing its course on the river mouth's beach and in the sea. The outcomes of satellite imagery analysis strengthen the findings of the beach surveys. The Litani River ranks third in the number of uncontrolled disposal sites, with 10 located within 500 meters of its banks. An beach marine litter accumulation rate of 15 kg/day was found at the Litani River mouth in April 2021, which was the third-highest accumulation rate found of the four studied sites. The marine surveys revealed that Byblos is affected by marine litter, where approximately 5.9 kg/capita/year of plastic leaks into the environment. Water systems are the most common fates for plastic leakages, with 2.9 kg/capita/year ending up in the water system. The Nahr Ibrahim River flows into the Mediterranean Sea to the south of Byblos, carrying litter to the estuary and marine surface waters along the city shores, driven northward by prevalent currents and wind. Tyre is affected by a similar amount of plastics leaking into the environment (3.2 kg/capita/year), but seemingly a lower fraction ends up on marine surface water (1.1 kg/capita/year). Unlike the Nahr Ibrahim, the Litani estuary is north of Tyre, and therefore does not in general affect the surface water along the city shores. Although rivers seem to be the main pathways of plastic waste to the Mediterranean Sea, direct discharge of stormwater and strong winds can bring uncollected waste from other systems to the coastline and to the Mediterranean Sea. Further research is needed to understand better the contribution of rivers to marine litter.

Source: World Bank.

7.2 Recommendations for Further Monitoring and Research

Further monitoring and research are recommended to be carried out in future years, and under a variety of initiatives, to better understand the sources, pathways, and hotspots of marine litter. This section highlights key areas of interest for the future.

Future work on marine litter in Lebanon should focus on the potential of the identified uncontrolled dumpsites to release litter into rivers. Surveys should carry out a closer analysis of estuaries and on disposal sites close to river shores by looking at their volume and composition, amongst other factors. This will draw a clearer picture of the roles of rivers as potential sources and pathways of marine litter in Lebanon. Once the leakage potential of disposal sites to river pathways has been identified, it will be possible to understand which pathways dominate at the national level and to then introduce remedial measures.

As coastal rivers carry waste leaked from disposal sites, marine litter in the marine waters and on beaches close to river mouths will likely increase. The results obtained from the underwater (seafloor and sediments) and surface-water surveys in this project were indicative since they were limited in time and space and most likely did not fully capture the extent of marine litter pollution on the seafloor. For a better understanding, regular surveys for marine litter on the seafloor, in surface waters and in sediments should be carried out on a monthly basis, for at least one year. Sampling activities should be intensified before and after rainstorms, especially for the seafloor and surface waters to evaluate the contribution of rivers to marine litter, since distribution of marine litter is affected by factors including wind and wave action, currents, and weather. A clear monitoring program for at least one year for marine litter on the seafloor and surface waters is essential to better understand quantities and types of marine litter, and their potential impacts on coastal marine ecosystems.

Floating and seafloor plastic litter breaks down into microplastics, considered the most damaging type of marine litter to the marine ecosystem. Microplastic pollution should be given increased attention because of its implications for food security and the impact it has on the sustainability of coastal marine biological resources. Microplastics have been shown to negatively affect the life history of organisms, reducing their reproductive and growth potential as well as releasing contaminants into the flesh that eventually reaches consumers. In addition, such bio-concentration of pollutants will lead to economic impacts on fishermen communities and up the fisheries-sector value chain.

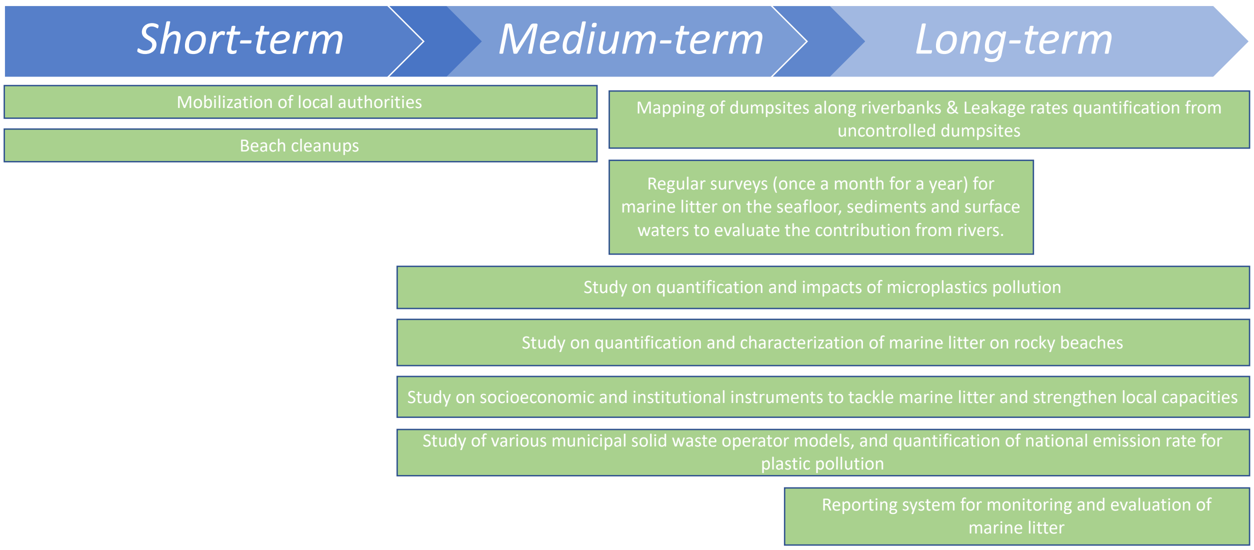
Quantifying temporal trends in anthropogenic litter on rocky shorelines would complete the picture drawn by the beach surveys. In this project, marine litter on sandy and pebble beaches was collected, sorted, categorized, and weighed. Lebanon's coastline is also made of rocky beaches, which were not included in the scope of this project. Beach substrates are an important factor when studying marine litter accumulation since, for example, rocky beaches may yield different marine litter composition compared to pebble and sandy beaches, due to the high wave action likely to fragment large items into smaller pieces.

Further Waste Wise Cities Tool (WaCT) and WFD assessments would add to the data sets. The performance of waste management systems varies between municipalities, depending on multiple factors. Achieving the goal of determining a national emissions rate for plastic pollution to the environment/water systems has not been possible within the scope of the current project. Further resources are needed to profile a statistically significant number of municipal waste management systems, representing different geographical and socioeconomic situations, and different municipal solid waste operator models (GIZ 2015).

In addition to scientific investigations on the sources, pathways, and hotspots of marine litter in Lebanon, socioeconomic and institutional dimensions could be investigated to complement the findings of the baseline. For example, legal instruments to tackle SUPs and further discussions to strengthen local institutional capacities and governance could be beneficial.

In the meantime—that is, before any further quantitative assessment can be carried out—immediate actions can be taken. Beach cleanups and mobilization by local authorities of initiatives focusing on the prevention and mitigation of marine litter should be supported. The baseline assessment has developed results against which any future monitoring initiative should be benchmarked, so local authorities should be empowered to take action and report to the national level. A harmonized reporting system for monitoring and evaluation of marine litter will be helpful for effective—and efficient—implementation.

Figure 7.2: Recommendations for Further Research and Monitoring in the short-, medium-, and long-terms



Source: World Bank.

7.3 Recommendations for Strategic Action

Based on findings from the baseline assessment surveys and a wider stakeholder consultation, a process has been initiated and has allowed the development of a draft Action Plan for Marine litter Prevention, which will be finalized as more policy dialogue is taking place in Lebanon in the coming months. The draft action plan provides suggestions for the necessary shifts in national policies, regulations, finance, and institutional framework for marine litter prevention, including needed stakeholder engagement.

The draft Action Plan for Marine litter Prevention builds upon the socioeconomic benefits of establishing policies to prevent marine litter and promotes waste prevention and resource efficiency as well as sustainable waste management. It further promotes effective wastewater treatment and stormwater management in order to effectively prevent marine-plastics pollution. The draft action plan also stresses the importance of awareness raising and educational activities including strengthening the engagement of all stakeholders while supporting removal and remediation actions. Relevant measures and activities for each of the aforementioned areas are presented for both local and national levels.

Several actions were identified as part in the draft action plan, and these include awareness-raising activities and applying and enforcing extended producer responsibility in conjunction with bans on unnecessary and damaging products and activities. Recommended actions also include economic incentives targeting consumption as well as improved legislation and improved transparency and product labelling. Finally, recommended actions call for waste-management measures in conjunction with research into product design to facilitate reuse, repair, and recycling while improving implementation of existing legislation.

The draft action plan developed priority actions to respond to the root causes of marine litter; those priority actions are summarized in Table 7.2 below. These actions will be finalized based on further consultation with all concerned stakeholders.

Table 7.2. Proposed Actions as Part of the Draft Action Plan for Marine litter Prevention

Proposed Action	Description
SHORT-TERM ACTIONS	
Institutional support to MoE for Marine litter Prevention	• Provide needed support to MoE to mainstream marine litter prevention in policy and institutional action in Lebanon through improving coordination, information, and funding on marine litter (ML). This will also allow continuous updating on the levels of marine litter pollution through follow-up of the terrestrial waste surveys (Waste Wise Cities Tool (WaCT) and Waste Flow Diagram (WFD)). • Conduct marine surveys focused on determining the types of waste that end up in marine waters and assessing their pathways from the sources identified. • Monitor sewage and watercourses for microplastics.
Implement ML-prevention actions in the pilot areas	• Support local authorities in developing and implementing awareness campaigns for ML prevention. This will be done through regular cleanup campaigns and will include, among other campaigns, “fishing for litter” and other incentives to encourage action and develop new products from waste. This will also allow local authorities to identify priority measures for the adoption of an integrated approach to solid waste management.
MEDIUM-TERM ACTIONS	
Economic incentives/ taxes targeting consumption	• Use economic incentives to make market signals part of the solution—that is, ensure that plastic has a price and is therefore more widely recognized as a valuable resource through, for example, applying deposit refunds to bottles and charges/taxes to plastic bags, disposable cutlery, and other single-use items.
Waste-management measures	• Enact legislation and provide and foster investment in waste-collection infrastructure (at ports), waste-management infrastructure, and wastewater-treatment facilities.
Ban SUPs	• Ban single-use plastics (SUPs) such as plastic bags, cotton-bud sticks, cutlery, plates, straws, beverage stirrers, food and beverage containers made of expanded polystyrene, beverage containers made of expanded polystyrene, and beverage cups made of expanded polystyrene.
LONG-TERM ACTIONS	
Research into product design	• Conduct and support research into product design to facilitate reuse, repair, remanufacture, and recycling, and complement this by providing more information on the plastic composition of products.
Transparency and labelling	• Improve transparency regarding the chemicals contained in plastics to help with decisions on remanufacture and recycling. • Improve transparency regarding which personal-care and cosmetic products (PCCPs) do, and which do not, contain plastics. • Explore the implications of additives such as flame retardants, plasticizers, pigments, fillers, and stabilizers.
Improved legislation	• Provide clear definitions of polymers, waste, and secondary raw materials. • Incentivize manufacturers to design their products and packaging to fit into existing recycling systems.
Improved implementation	• Improve implementation of existing legislation on the release of litter from terrestrial sources and at sea (consider the International *Convention* for the Prevention of Pollution from Ships (MARPOL)[1], port reception facilities, and so forth).

Source: World Bank.

Notes

[1] https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx#:~:text=The%20International%20Convention%20for%20the,2%20November%201973%20at%20IMO.

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Appendix A Methodologies for Terrestrial, Marine, and Beach Surveys

This project's two terrestrial waste surveys, the Waste Wise Cities Tool (WaCT) and the Waste Flow Diagram (WFD), were developed hand-in-hand and complement each other (the WaCT and WFD are described in subsequent paragraphs). Both surveys were conducted consecutively and in the same two cities. A final selection from among the four candidates (Batroun, Byblos, Tripoli, and Tyre) was made in consultation with the Project Steering Committee during fieldwork preparations in March 2021, with Byblos and Tyre emerging as the chosen hubs for primary data collection (for the WaCT, WFD, marine litter accumulation surveys).

The site-selection criteria identified for the two terrestrial surveys are the following:

- Located in the country's most populous cities (excluding Beirut, which has been extensively studied);
- Has either a perennial river running through the city or a major coastal disposal site (including recently closed sites), since these are major leakage risks; and
- Maximizes geographic representation—that is, the sites would not be near each other.

Terrestrial Survey: Waste Wise Cities Tool (WaCT) (UN-Habitat 2020)

Developed by Wasteaware, a member of the RWA Group, for UN-Habitat, the WaCT is a comprehensive step-by-step tool to assess the flows of waste within a city and to report on SDG Indicator 11.6.1 ("Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities"[1]).

Survey team

A survey team consisting of four research specialists, eight field assistants, and two drivers conducted each WaCT survey, with the research specialists overseeing both surveys. The drivers and field assistants were recruited from the communities in which the surveys took place.

Schedule

The two WaCT surveys took place over a period of 14 days immediately before Ramadan, to avoid distortions in waste-generation rates caused by this festive period. Two surveys were conducted in parallel, slightly staggered to allow research specialists to travel between sites for critical stages in the surveys. The Step by Step Guide to the WaCT includes a standard workplan in Table 5 and a timeline in Section 2.2, which were followed.

Methodology

The methodology for the WaCT is described in detail in the Step by Step Guide to the WaCT. The full methodology was followed with the sole modification that areas for the household surveys in step 2 were chosen from areas most at risk of leaking waste to the sea. Final site selection was done in close consultation with city officials in the selected cities.

Target indicators

The WaCT survey collected data on the following indicators:

- Household waste generation per capita (kg/person/day);
- Waste-recovery rate per city (kg/day); and
- Waste-collection rate per city (kg/day).

The above indicators were disaggregated to the following variables:

- Material type (plastic, paper/cardboard, metal, and so forth);
- Plastic polymer (HDPE, LDPE, PP, PET, and so forth);

- and
- Income level (for household waste and waste received by disposal sites).

Equipment

The list of equipment required is presented in Tables 7, 8, 12, and 13 of the Step by Step Guide to the WaCT. This includes special personal protective equipment (PPE) required due to COVID-19.

Terrestrial Survey: Waste Flow Diagram (WFD) (GIZ 2019)

Developed by GIZ, the University of Leeds, EAWAG, and Wasteaware, the WFD assesses and quantifies the leakages of plastic waste from cities, based on data collected by the WaCT. This allowed the identification of major pathways and means of release of marine litter entering the ocean, given their close link to sources.

Survey team

The survey team for the WFD is dramatically reduced when compared to the WaCT survey, since only the four research specialists were needed to conduct the WFD assessment.

Schedule

Given that the WFD is primarily based on expert assessments, much of the work was done in parallel to the WaCT survey, thus saving time. For example, when visits to recovery facilities were conducted as part of step 4 of the WaCT, observations for the WFD were performed during those same visits to save time and maximize efficiency.

Methodology

The methodology for the WFD is described in detail in the WFD User Manual, and a Portal is available to learn more about the methodology (https://wfd.rwm.global) and view data from around the world (https://wfd-data.rwm.global). The full methodology was followed, in the same areas as the WaCT.

Target Indicators

The WFD returns data on the following indicator: plastic leakage to the environment (kilogram per day). That indicator can be disaggregated to the following variables: (a) leakage point (source), and (b) leakage destination.

Equipment

The WFD does not require any additional equipment aside from some survey-specific data sheets, which were prepared in advance.

Beach Litter Surveys: CSIRO Standing Stock (Schuyler 2020)

Developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), an Australian public research institute, for their Global Plastic Pollution Baseline Project, this methodology has been implemented in over 20 countries worldwide and was selected by the United Nations Environment Programme (UNEP) for their program to monitor marine litter.

Survey team

A survey team of six field assistants, one driver, and one research specialist was required to complete the standing stock survey, which occurs over seven days.

Site Selection

The following 24 sites were identified at random on the Lebanese coast, each evenly spaced apart by around 10 kilometers.

Schedule

On Day 1, the survey team reported to a designated location to receive training on both marine litter survey methodologies. The survey team received copies of the methodologies in advance in order to accelerate their onboarding process.

On Day 2, the survey team set out early in the morning to begin the data collection. For the standing stock survey, 24 sites were visited over the following six days, at a pace of four sites per day. Depending on the site-specific challenges encountered, each site took 1–1.5 hours to sample, with the remaining time each day dedicated to travel between sites. The sites were sampled in a north-to-south pattern; therefore, the training day (Day 1) was organized in the north of the country to accelerate the start of fieldwork on the morning of day 2.

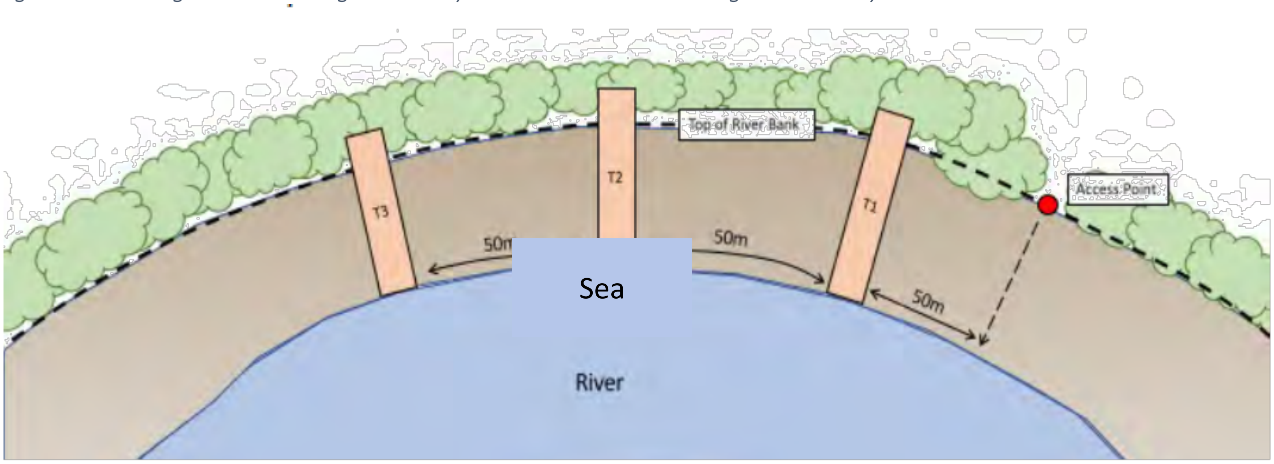
On Day 7, the survey team sampled the 24th site and reached the southern end of the country. At this point, the team split in half in order to move towards the accumulation survey.

Methodology

The standing stock survey aimed to visit 24 sites, which were selected as the nearest suitable locations to random points. This semi-random approach minimizes bias and allows for the entire shoreline to be sampled, while permitting some expert input to select micro-sites where data can be collected. The following sequence of actions was repeated at each site:

1. On arrival at the site, the survey team drove as closely as they could to the GPS marker and covered the remaining distance by foot. Safety was the primary consideration. Consequently, if a GPS marker could not be accessed safely (for example, if a marker was at the bottom of a cliff), the survey team selected the closest site that was reasonably and safely accessible.
2. Upon arrival at the GPS marker (or the closest possible replacement site), one member of the survey team determined the location of the first transect using any random mechanism, such as throwing a stick over their shoulder and making transect 1 where the stick landed. This first transect was a minimum 50 meters away from the access point to the beach.
3. Each site consisted of at least three transects. The exact location of the first transect, as described above, was selected at random to avoid any selection bias (for example, "there's lots of visible litter here so let's sample here"). Transects 2 and 3 were located a minimum of 50 meters away from transect 1 and selected using the stick-throwing technique, thereby covering a minimum of 100-meter stretch of beach.
4. If the beach had different habitat types (for example, a sandy area, a rocky area, and a vegetated area), then the survey team strove to place one transect in each, selecting the exact final location at random. At each transect, GPS positions were noted and pictures taken both at the bottom and top of the transect for future reference and as a memory aid during data analysis. (See Figure A1.1.)

Figure A1. 1: Diagram Illustrating the Survey Transects in the Standing Stock Survey



Source: Schuyler, QA. Et al (2018).

5. Transects were marked using a tape measure laid out in a straight line from the water's edge (wherever that was with the tide at that present moment) and ending 2 meters into the dominant vegetation line at the top of the beach—this was designed to capture any litter entrapped in the vegetation. Small sticks were used to pin down the tape measure in case of wind. Members of the research team were instructed to avoid stepping within the transect prior to surveying it, since this could trample or bury existing litter.
6. The transects were 2 meters wide, 1 meter on each side of the tape measure, and ran the full length from the water's edge to 2 meters into the vegetation. Each surveyor carried a pre-cut 1-meter length of string to verify if certain borderline pieces of litter were withing the transect or not. To sample the transect, two people stood shoulder-to-shoulder at the water's edge and slowly walked up the length of the transect, carefully observing the beach for any litter. The three transects were sampled simultaneously by teams of two or three surveyors. Only items visible from a standing position were considered.
7. One surveyor held the pen and the data sheet and marked down the items per the categories on the data sheet. The second surveyor held a bag and collected any object with recognizable markings on it that could realistically be brand audited, as well as any non-identifiable objects so long as collecting them did not substantially slow down the survey. The objective of this was to perform a brand audit on all items with recognizable markings and to collect as much litter as possible while surveying transects—but without considerably delaying the survey. For example, a cluster of many dozen small pieces of unidentifiable pieces of litter would not be collected by the surveyors if they determined this would slow them down considerably. This is a compromise between the ethical desire to remove as much litter as possible and the practical need to not compromise the timeline of the survey.
8. Each evening upon arrival at the lodging of team members, all identifiable objects from each site were brand audited. This did not take very much time since most of the marine litter was unidentifiable; therefore, the entire survey team rotated to do this task so that individual members were responsible for only one or two evenings of work.
9. In case all three transects returned zero items of litter, additional transects were selected at further 50-meter intervals from the first three transects, up to a maximum of six transects or until a single piece of litter was found. This was to reduce the risk of reporting false negatives—that is, reporting zero litter at a site when in reality the transects were "unlucky" and happened to return no litter.
10. In case a transect contained an enormous amount of litter, a subsample would be justified. For this, the surveyors decided on a subsection—that is, 50, 25, or 10 percent of the beach to sample and to extrapolate from later. This was only done for extremely littered beaches, once again to avoid long delays in survey time.

Target indicators

The standing stock survey returned data on the following indicator: Density of litter per linear meter of shoreline (items per meter).

"Linear meter of shoreline" represents the *length* of shoreline, as opposed to the *area* (in square meters) of the beach. "Density per linear meter" yields distinctly different results than would be obtained if beach *width* as opposed to *length* were the measure used. For example, 2,000 items found on 1,000 meters of a beach that is 1 meter wide would yield a density of 2 items/m^2. In contrast, a 100-meter-wide beach would produce a density of 0.02 items/m^2, or one-one hundredth of the linear measure. Wider beaches may indeed collect more litter than narrow beaches. However, such a result is highly unlikely to be a linear relationship because litter tends to accumulate in a linear manner at the high-tide line. Therefore, it is more prudent to ignore the variability in the width of beaches and study the density per linear meter of shoreline.

The indicator of "density of litter per linear meter of shoreline (items per meter)" was disaggregated to the following variables:

- Item type (for the top 10 items identified);
- Material type (plastic, paper/cardboard, metal, and so forth);

- Plastic polymer (HDPE, LDPE, PP, PET, and so forth); and
- Location (by site).

Equipment

The following equipment was procured in advance of the survey:

- Data sheets (100);
- 50-meter tape measures (4);
- Large sturdy bags for litter collection (50);
- Clipboards (4); and
- Large (5 x 5 meters) plastic tarp.

Beach Survey: Sustainable Seas Trust (SST) Accumulation Survey (SST 2020)

Survey team

The same survey team of eight field assistants (two groups of four each) and one research specialist conducted the accumulation survey. The research specialist divided time between the two groups.

Site selection

Four sites were selected from five candidate sites based on the following criteria:

- Sites must be paired two-by-two to allow two teams to simultaneously cover two sites each per day;
- Sites must be located on sandy beaches; and
- Sites should be matched with the terrestrial waste survey sites.

The candidate sites for the survey were Batroun, Byblos, Litani River Mouth, Tripoli, and Tyre. Final site selection was concluded in April 2021 in consultation with the Project Steering Committee and following site visits to each candidate site by survey research specialists.

Schedule

The accumulation survey took place over 11 days, including one "Day Zero" preparing the sites and 10 days of consecutive data collection. Following the completion of the standing stock survey, the group was given two days of rest during which half of the group relocated to the second field site, in the north of the country. The survey began at 8 AM every day without interruption for 11 days. The survey teams visited two sites each per day, one in the morning and one in the afternoon.

Methodology

The methodology used for the survey was developed by the Sustainable Seas Trust and is described in detail in Section 3.5 of the Marine Litter Monitoring Manual published by the SST in September 2019.

1. At each site, a 600-meter stretch of beach was demarcated: a 500-meter transect with two 50-meter buffer zones on each side. All sites were marked with signposts announcing the ongoing scientific study and asking the public to refrain from picking up any litter. During the Day Zero cleanup, hotels and businesses along the exact stretch of beach were briefed about the study, and any informal beach cleaners that were encountered in the area were also briefed.
2. On Day Zero, the entire 600-meter stretch was cleaned of all visible litter, from the water's edge to the dominant vegetation at the top of the beach. Extra help was hired to do this, since dirty beaches can take a long time to clean. If time allowed, the litter collected on Day Zero was brand audited and weighed as per the methodology in the SST manual. However, this was not part of the accumulation survey; therefore, these were extra data that were collected only if the Day Zero cleanups were not too lengthy.
3. Daily from Day 1 to Day 10, the survey team revisited both sites at the same time and collected all new litter that appeared. The team distinguished litter collected above and below the high tide line—that is, in the wet versus the dry sand. All litter collected each day was brand audited (if brand information was legible) and weighed per fractions established in the SST method.

4. All litter collected, once audited and weighed, was disposed of at a landfill or at some other well-established waste-collection site.

<u>Target indicators</u>

The accumulation survey returns data on the following indicators: (a) density of litter per linear meter of shoreline (items per meter), and (b) accumulation rate of litter per linear meter of shoreline (items per meter per day).

As stated previously regarding the CSIRO standing stock survey, the same applies here for the SST accumulation survey: "Linear meter of shoreline" represents the *length* of shoreline, as opposed to the *area* (in square meters) of the beach. "Density per linear meter" yields distinctly different results than would be obtained if beach *width* as opposed to *length* were the measure used. For example, 2,000 items found on 1,000 meters of a beach that is 1 meter wide would yield a density of 2 items/m^2. In contrast, a 100-meter-wide beach would produce a density of 0.02 items/m^2, or one-one hundredth of the linear measure. Wider beaches may indeed collect more litter than narrow beaches. However, such a result is highly unlikely to be a linear relationship because litter tends to accumulate in a linear manner at the high-tide line. Therefore, it is more prudent to ignore the variability in the width of beaches and study the density per linear meter of shoreline.

The above indicators were disaggregated to the following variables:

- Item type (for the top 10 items identified);
- Material type (plastic, paper/cardboard, metal, and so forth);
- Plastic polymer (HDPE, LDPE, PP, PET, and so forth);
- Location (by site); and
- Wet versus dry side of the beach (offering insight into how much litter washes in from the sea versus how much is discarded directly from land).

<u>Equipment</u>

The following equipment list was procured in advance of the survey in addition to the equipment previously procured for the standing stock survey:

- Additional data sheets (100);
- Additional large sturdy bags for litter collection (50); and
- One additional large (5 x 5 meter) plastic tarp.

Remote Sensing and Satellite Imagery Analysis

The UNDP (2017) map showed municipal solid waste (MSW) disposal sites for all of Lebanon. This map was provided by the MoE and was used to locate MSW disposal sites along rivers. A new map, the "Basemap", was generated. It included the UNDP (2017) disposal sites and added newly identified disposal sites to locate main sources of high risk of leakage into rivers discharging into the sea. This allowed a ranking of rivers based on the number of disposal sites within 500 meters of their shores, as well as a ranking of rivers with the highest density of disposal sites within 500 meters of their shores. If possible, the variation in number of disposal sites was also assessed.

<u>Selection of MSW disposal sites</u>

- Minimum disposal-site size of 10 x 10 m^2
- Visible through satellite imagery; and
- 500-meter stretch on each side of riverbanks, or to the nearest peak or ridge, whichever is first.

<u>Selection of river basins</u>

Fifteen of Lebanon's 17 coastal perennial rivers were considered for analysis. The Al Kabir River was excluded for security reasons since it represents the northern border between Lebanon and Syria, and Al Assi River was also excluded since it flows through Syria and Turkey and discharges into the Turkish coast.

Methodology

The Basemap also located major landfills in Lebanon's coastal zone, the shoreline, rocky shores (terraces), sandy beaches, coastal bathymetry, protected areas, and slopes of the study area amongst other layers of interest (see Table A1.1 below). Production and analysis were carried out with the use of the Esri ArcGIS Pro 2.7.1. Based on the results, some disposal sites were selected for field validation taking into consideration accessibility, safety, and size

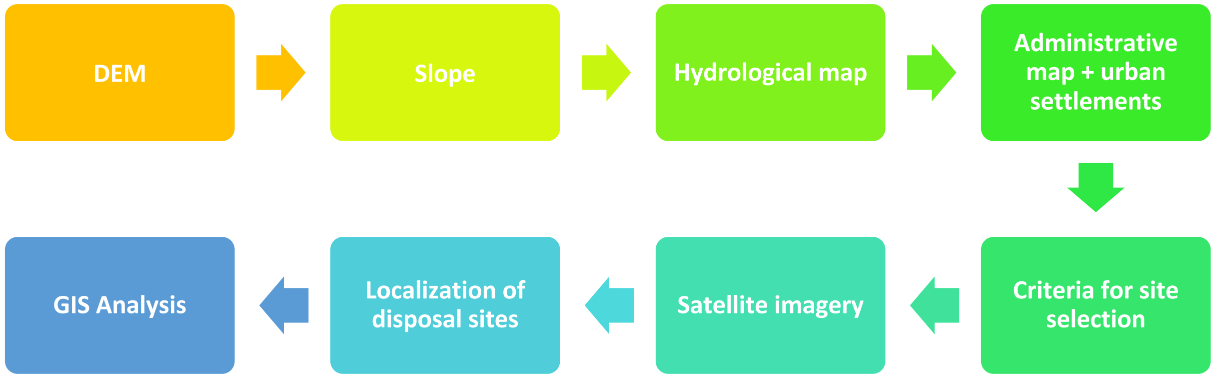
Table A1. 1: Basemap's Categories and their Associated Descriptions and Uses

Data category	Description	Use
Disposal site	Location of disposal sites in the study area (UNDP (2017) map)	Base for MSW disposal sites
Coastal zone	Bathymetry, rocky shores, sandy beaches, shoreline, coastal evolution, satellite images, and so forth (IoE-UoB)	Geographical description of the coastal zone
Administrative		
Urban settlements	Landcover/land use map of 2017 for the study area (1/50,000; MoE)	Mapping of the settlements in the study area
Mohafaza and Caza limits	Cadastral limits within each governorate (Mohafaza) and district (caza) (CDR)	Locating disposal sites within administrative management units
Topography (Digital Elevation Model-DEM)		
Slope	10-meter resolution	Site-selection criteria
Natural resources		
Protected areas	Including protected valleys, natural reserves, and other protected marine and terrestrial areas (RAMSAR, MPA, and so forth; MoE)	Location relative to identified disposal sites
Sensitive sites	Ecological and cultural sites (ERML 2013); sites included in "Lebanon's Marine Protected Area Strategy" (MoE/IUCN 2012)	Location relative to identified disposal sites
Hydrology	Landcover/land use map of 2017 including rivers and water bodies (hydrological map) for the study area (1/50,000; MoE)	Mapping of the rivers and main water bodies in the study area
Risks		
Evolution	Shoreline evolution (comparative study 1962 – 2010; IoE-UoB)	Changes in shoreline's length/erosion/accretion/sea filling
Erosion	Erosion risk in the study area (IoE-UoB)	Potential high-risk leakage areas
Flood	Flood risk in the study area (IoE-UoB)	Potential high-risk leakage areas
Forest fires	Fire-risk map in the study area (IoE-UoB)	Potential high-risk leakage areas

Source: World Bank.

Mapping and analysis of MSW sources was be conducted as follows (see Figure A1.2 below): Slopes were extracted from the Digital Elevation Model (DEM) and overlaid with the hydrological and administrative layers. Satellite imagery was then used to identify new MSW disposal sites within the study area according to the selection criteria and added to the layer of MSW disposal sites produced by UNDP (2017). All layers were combined into the Basemap for the identification and localization of disposal sites for further GIS analysis (namely for leakages). Extracted data were included in the WaCT and WFD surveys.

Figure A1. 2: Process for Mapping and Analysis of Municipal Solid Waste (MSW) Sources



Source: World Bank.

Indicative Marine Surveys: Marine Litter on the Seafloor

The study area of interest for marine litter is between 0- and 20-meters depth due to its proximity to the leakage points on shore. Underwater visual line transect surveys were used to estimate marine litter density on the seafloor (JCR 2013).

Survey team

The survey team consisted of one field assistant, one research specialist, one senior research specialist, two scuba divers, and one boat skipper for each mission, for a total of four missions.

Schedule

Each site was be sampled once. On each trip, the team surveyed two transects in each of the selected sites.

Site selection

Coastal waters were selected in Byblos and Tyre to correspond to the survey sites for beach-litter accumulation.

Methodology

The method for surveying relied on two different approaches (Ioakeimidis et al. 2015; Interreg 2018; JCR 2013): (a) underwater remotely operated vehicles (ROVs); and (b) trained scuba divers. For both methods, the nature of the bottom habitat and the biodiversity that was encountered were recorded.

- ROV: The Gladius ROV (see Figure A1.3) was operated in a live-boat mode, allowing the ROV and the support working vessel to be moved simultaneously. The videos were viewed and marine litter items identified. Litter density was calculated as items/km^2. Statistical tests were used to correlate marine litter abundance with (a) distance from the coastline, (b) water depth, and (c) distance from population centres. In brief, two randomly assigned transect lines of 1 kilometre each parallel to the shore at depths of 10 and 20 meters were sampled. The coordinates for the beginning and end of the transect were be recorded using GPS and/or marked with buoys.
- Scuba diving: Two divers swam along a predefined length on a transect belt (tape/rope/string) and collected litter items found on the transect belt for further analysis (that is, litter like plastics that can be easily transported to the surface). Large items (tires, barrels, and so forth) were recorded. In brief, two randomly assigned transect lines of 50 to 100 meters each parallel to the shore at depths of 10 and 20 meters were sampled. Results were expressed as litter density (items/m^2 or items/100 m^2). The coordinates for the beginning and end of the transect were recorded using GPS and/or marked with buoys.

Figure A1. 3: Gladius Underwater Remotely Operated Vehicle (ROV)

Litter classification

Litter was classified according to the litter categories from MEDITS litter for Mediterranean and Black Sea (JRC 2013): plastic, rubber, metals, glass/ceramics, textiles/natural fibres, wood (processed), paper/cardboard, other (specify), unspecified.

Accommodation, food, and transport

The survey team was provided with all the necessary resources (transportation, boat, low-cost accommodation for the duration of the survey, meals, scuba diving equipment, and so forth). IoE-UOB's vehicle (Nissan X-Trail 4x4) was available to the team for all field activities.

Equipment

The following equipment was available for surveying activities:

- Gladius ROV;
- Garmin VIRB XE underwater camera;
- ELAC HydroStar 4300 single beam echosounder;
- GPS;
- Laptop;
- Diving gear (as needed);
- Ropes and buoys; and
- Safety gear (vests, first aid, and so forth).

Indicative Marine Surveys: Marine Litter in Sediments

Indicative assessment of marine litter in sediments was carried out ON the same 50- to 100-meter transect belts as those for marine litter assessment on the seafloor by scuba divers. This was restricted to a maximum depth of 20 meters.

Survey team

The survey team consisted of one field assistant, one research specialist, one senior research specialist, two scuba divers, and one boat skipper for each mission for a total of four missions.

Schedule

Each site was be sampled once. On each trip, the team surveyed two transects in each of the selected sites.

Site selection

Sites were the same as for the survey of marine litter on surface waters.

Methodology

Sediments was collected by scuba divers and/or a sediment grab. A total of 3 kilograms of sediments was collected from three sampling points per transect belt (1 kilogram per sampling point at the start, middle, and end of the transect belt) to be processed at IoE-UOB's laboratory. Transect belts parallel to the shore at depths of 10 and 20 meters were sampled. Samples were sieved down to 63 µm and visual identification and counting of marine litter were undertaken. Results were expressed as particles per kilogram of sediment.

Equipment

The following equipment was available for surveying activities:

- Eckman grab
- Sediment sieve
- Garmin VIRB XE underwater camera
- ELAC HydroStar 4300 single beam echosounder
- GPS
- Laptop
- Ropes and buoys
- Diving gear (as needed)
- Collection jars
- Safety gear (vests, first aid, and so forth)
- Cooler (sediment sample preservation)

Indicative Marine Surveys: Marine Litter on Surface Waters

Indicative assessment of marine litter on surface waters was carried out at the same sites as those for marine litter assessment on the seafloor by scuba divers. Transect belts were designated according to surface currents in the area.

Survey team

The survey team consisted of one field assistant, one research specialist, one senior research specialist, and one boat skipper for each mission for a total of four missions.

Schedule

Each site was sampled once. On each trip, the team surveyed one transect belt for one hour in the coastal waters of the selected sites.

Site selection

Sites were the same as for the survey of marine litter on surface waters.

Methodology

Floating marine litter was quantified according to transect belts by dedicated boat-based observers. The transect belt overlays the direction of the marine surface current that carries floating litter. The path was recorded by a GPS and mapped. Observation of floating marine litter within the belt was for one hour at speeds of two knots and a width of approximately 6 meters (3 meters on each side). The unit of reporting was items/km^2 (JCR 2013). The type of material (plastic, wood, rubber, and so forth) of the floating litter was noted if visually identifiable from the boat.

Equipment

The following equipment was available for survey activities:

- Digital camera
- Binoculars
- GPS
- Safety gear (vests, first aid, and so forth)

Notes

[1] https://sdg.data.gov/11-6-1/

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Appendix B CSIRO Sites

Site #	Site name	Caza	Mohafaza	GPS Lat	GPS Long
1	Qalyaat	Aakar	Aakar	34.5924	35.9884
2	Mazraat Aartousi	Minniyeh-Danniyeh	North Lebanon	34.5022	35.9426
3	Beddaoui	Tripoli	North Lebanon	34.4600	35.8665
4	Tripoli	Tripoli	North Lebanon	34.4464	35.8125
5	Qalmoun	Tripoli	North Lebanon	34.3913	35.7918
6	Chekka	Batroun	North Lebanon	34.3219	35.7232
7	Koubba	Batroun	North Lebanon	34.2663	35.6586
8	Berbara	Byblos	Mount Lebanon	34.2053	35.6402
9	Jbeil	Byblos	Mount Lebanon	34.1292	35.6418
10	Okaibeh	Keserwan	Mount Lebanon	34.0615	35.6427
11	Ghazir	Keserwan	Mount Lebanon	34.0095	35.6444
12	Dbayeh	Matn	Mount Lebanon	33.9452	35.5910
13	Ramlet Al Baida	Beirut	Mount Lebanon	33.8811	35.4794
14	Saint-Simon	Beirut	Mount Lebanon	33.8622	35.4828
15	Khalde	Beirut	Mount Lebanon	33.7801	35.4720
16	Damour	Chouf	Mount Lebanon	33.7236	35.4458
17	Jadra	Chouf	Mount Lebanon	33.6267	35.3996
18	Saida	Saida	South Lebanon	33.5803	35.3833
19	Zahrani	Saida	South Lebanon	33.4930	35.3332
20	Saksakeye	Saida	South Lebanon	33.4357	35.2737
21	Khayareb	Saida	South Lebanon	33.3589	35.2474
22	Tyre	Tyre	South Lebanon	33.2838	35.2168
23	Deir Qanoun El Ain	Tyre	South Lebanon	33.2187	35.2090
24	Naqoura	Tyre	South Lebanon	33.1469	35.1588

Source: World Bank.

Appendix C Litter Categories for the Mediterranean Sea and Black Sea

A. Plastic	B. Rubber	C. Metals	D. Glass/ceramic	E. Textiles/natural fiber	F. Wood (processed)	G. Paper/cardboard	H. Other	I. Unspecified
A1. Bag	B1. Tyre	C1. Beverage can	D1. Bottle	E1. Clothing				
A2. Bottle	B2. Other (glove, shoe, etc.)	C2. Other food can/wrapper	D2. Pieces of glass	E2. Large piece (carpets, etc.)				
A3. Food wrapper		C3. Middle size container	D3. Ceramic jar	E3. Natural rope				
A4. Sheet		C4. Large metallic object	D4. Large object					
A5. Other plastic object		C5. Cable						
A6. Fishing net		C6. Fishing related						
A7. Fishing line								
A8 Other fishing related								
A9. Rope/strapping band								
A10. Sanitaries (diaper, etc.)								

Size Categories	
A	<5x5 cm = 25 cm^2
B	<10x10 cm=100 cm^2
C	<20x20 cm = 400 cm^2
D	<50x50 cm = 2,500 cm^2
E	<100x100 cm = 1 m^2
F	>100x100 cm => 1 m^2

Source: Adapted from JRC 2013.

Reference

JRC. 2013. Guidance on Monitoring of Marine Litter in European Seas. http://ies.jrc.ec.europa.eu/. doi:10.2788/99475.