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D3.2 Report on processed Plastic Pirates' data fed into existing data portals and resulting analyses

Title: Report on processed Plastic Pirates' data fed into existing data portals and resulting analyses
Date: 29/11/2025
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Executive summary

This report documents the collection, verification, consolidation, publication, and initial interpretation of data generated through the "Plastic Pirates – Go Europe!" citizen science initiative between 2022 and 2024[1]. Over 800 school groups across 13 European countries conducted samplings along 390 rivers and waterbodies, collecting data on plastic litter from riverbanks and surface waters.

The verified national datasets were harmonised according to FAIR principles and international standards resulting in consolidated, quality-assured datasets. The final datasets have been published on Zenodo under open-access licences and integrated into European data infrastructures, including the Integrated Marine Information System and Marine Data Archive developed by the Flanders Marine Institute (VLIZ), with ongoing integration efforts targeting EMODnet, the European Atlas of the Seas, and the EU Digital Twin of the Ocean.

While the project, as a Coordination and Support Action (CSA), does not have the mandate to produce scientific analysis of the data, this report gives and overview of the data gathered, outlines potential research questions, methodological approaches, and policy linkages that could be pursued based on the collected data. The deliverable demonstrates how large-scale citizen science can contribute meaningfully to open science, environmental monitoring, and public engagement across Europe.

[1] *The data collected in 2025 is openly available as raw data upon request. Local research partners in the participating countries are processing, consolidating, and verifying the remaining datasets. Once this work is completed, the existing Zenodo records will be updated accordingly.*

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1. Data Collection and Verification

Data collection in the "Plastic Pirates – Go Europe!" initiative followed a harmonised protocol as defined in the Plastic Pirates action booklet and described in Deliverable D3.1. School classes and youth groups across Europe participated in biannual sampling campaigns (spring and autumn) between 2022 and 2024. The collected data was submitted via a web-based form on the Plastic Pirates website, accompanied by photographs and relevant metadata (e.g. location, date, group type, and weather conditions).

Each sampling group worked according to predefined methodological steps, which covered different zones of the riverbank and river surface, including foreshore, backshore, riverbank crown, and floating litter zones. Microlitter samples were collected using a custom-built fine-meshed net and analysed in the laboratory.

Upon submission, the raw data underwent a multi-stage expert validation process coordinated by local partners and scientific institutions in the participating countries. Experts reviewed the uploaded images and cross-checked them with the submitted data entries. Metadata was verified for completeness and consistency, and all textual entries were translated into English. In cases of missing or unclear data, the responsible institutions contacted the respective school groups to resolve the issue.

Microlitter samples were analysed in certified laboratories to determine particle characteristics such as size, colour, shape, and suspected polymer type. The identification process helped distinguish between plastic and non-plastic particles and was used to improve the reliability of the microlitter dataset.

All verified data were transferred into a common verification template developed by the Kiel Science Factory (Germany). This template standardised the structure of submitted datasets and ensured consistency across all participating countries. The verification process is described in more detail in Deliverable D3.1 and is based on the methodological framework outlined by Kiessling et al. (2019).

The verification phase also included initial quality screening to flag missing values, internal inconsistencies, or deviations from the defined methodology. Data not meeting minimum quality thresholds were excluded from further consolidation. This process aimed to prepare a clean, consistent dataset suitable for FAIR-compliant consolidation and integration into open data repositories.

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2. Data Consolidation and FAIR Compliance

The data consolidation steps were in close coordination with local research partners and special support by the VLIZ Marine Data Centre (VMDC; VLIZ, Belgium). The goal of this process was to ensure high-quality, standardised datasets aligned with the FAIR principles (Findable, Accessible, Interoperable, Reusable), in line with European open science policy and international data management standards.

Data harmonisation and quality assurance

Verified national datasets were collected from local project partners using a common data verification template. Following an initial review for completeness and internal consistency, data were harmonised and standardised based on international marine litter protocols. Key elements included:

- ISO 8601 date formatting
- Georeferencing in decimal degrees (EPSG 4326)
- Use of controlled vocabularies for polymer types (e.g. NERC Vocabulary Server)
- Mapping of litter types to the Joint List and/or OSPAR classifications
- Harmonisation of river names and sampling zone terminology

The harmonised datasets were merged into a unified, consolidated dataset. Final quality control included checks for:

- Consistency and completeness across variables
- Geospatial validity (e.g. bounding box checks)
- Logical coherence of recorded parameters (e.g. weight ranges, group type)

Where issues could not be resolved through clarification with data providers, entries were excluded to maintain dataset quality. All processing steps are documented in detailed README files accompanying the datasets, including:

- File structures and field descriptions
- Methodological context
- References to the sampling protocols and verification steps

Publication and FAIR-compliant access

The consolidated datasets are now publicly available via the Zenodo open access repository, each with a unique DOI and licensed under Creative Commons Attribution (CC BY 4.0):

- Riverbank macrolitter dataset: https://doi.org/10.5281/zenodo.15535434
- Floating macro-, meso- and microlitter dataset: https://doi.org/10.5281/zenodo.15535538

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These records include discovery metadata describing the temporal and geographic coverage (2022–2024; participating countries), measured parameters (item counts, weights, litter types, polymer types, suspected sources), and acknowledgement of the participating school groups, coordinators and data experts.

In parallel, metadata records were created in the Integrated Marine Information System (IMIS)[2]. These records are machine-readable and accessible via the MarineInfo catalogue, with links to the corresponding Zenodo DOIs. Metadata records for the underlying raw data of each country are also available in IMIS and linked to the archived files in the Marine Data Archive (MDA)[3]. The raw data remains under restricted access but can be requested through VLIZ with approval from DLR-PT and national partners. This layered data structure supports transparency and reproducibility by preserving the full data lifecycle.

Data integration and future visibility

To ensure further scientific uptake, the consolidated dataset has also been submitted to EMODnet Data Ingestion. Once assessed, marine-relevant subsets may be integrated into the thematic portal EMODnet Chemistry, while other components remain discoverable via EMODnet's central catalogue.

Sampling points will be displayed in the European Atlas of the Seas, and discussions are ongoing with the European Digital Twin of the Ocean (EU DTO) to explore inclusion in the EDITO data ecosystem. Additional freshwater data repositories, such as the forthcoming Riverine Litter Database developed under the INSPIRE project, are also being considered as long-term hosting solutions.

Peer-reviewed data publication

To further consolidate the dataset's visibility and reuse, a peer-reviewed data paper is under preparation. Led by VLIZ, in collaboration with DLR and local partners in the participating countries, the paper will describe:

- The context and scope of data collection
- The verification and harmonisation processes
- The structure and scientific relevance of the published datasets

The paper will be submitted to an open access journal and serve as a citable reference, while acknowledging the contributions of the school groups, data verifiers, and coordination teams involved.

[2] *Integrated Marine Information System (IMIS): Information system, developed and maintained by VLIZ, that provides and links metadata information on people, institutes, projects, datasets, publications and events related to marine, estuarine and coastal topics. IMIS provides a direct link to the dataset or gives more information on how to access data in case of restricted access. Via this system, datasets can be made findable and accessible in the MarineInfo metadata catalogue. Also, a DOI service for data publication is coupled to IMIS (via an agreement with DataCite).*

[3] *Marine Data Archive (MDA): Online secured data repository that can be used as a closed or open access repository by individuals, consortia, working groups, projects and institutes to archive data files. The development, backup and maintenance of the MDA is an institutional activity of VLIZ. It ensures long-term preservation of the data. The VLIZ Marine Data Centre (VMDC) is accredited by the ISC (International Science Council) as a World Data Center since 2011 and by IODE (International Oceanographic Data and Information Exchange) as a National Oceanographic Data Centre (NODC) for Belgium since 2019.*

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3. Data Overview

The consolidated Plastic Pirates dataset covers sampling activities from four major campaigns conducted between autumn 2022 and autumn 2024. Data were collected by school classes and youth groups in up to 13 European countries. The dataset includes observations of macrolitter on riverbanks, floating meso- and microlitter on rivers, and metadata on sampling location, group type, and suspected waste sources. Verified and standardised data were published via Zenodo and archived in multiple interoperable formats.

Geographic coverage and participation

In total, **771 individual verified sampling activities** were reported between 2022and 2024. The number of samplings per country shows wide geographic coverage and national differences in participation rates. Out of the total number of 1211 samplings, some were invalid or incomplete and had to be discarded, some were merged into one sampling as the sampling was held in close vicinity to each other by the same sampling group, some only implemented group A or group B of the sampling protocol, which leads to a total of **440 samplings excluded** from the verified and consolidated dataset.

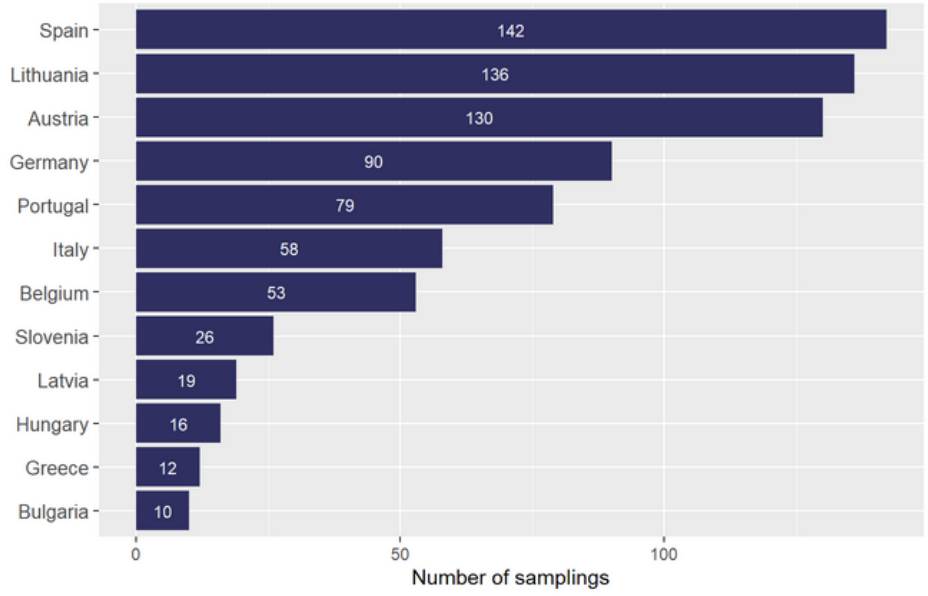


Figure 1: Number of Sampling per Country

This table illustrates the geographic engagement of participating countries in the Plastic Pirates initiative. Spain, Lithuania, and Austria reported the highest number of samplings, each exceeding 130, which indicates strong national coordination and active involvement of schools and youth groups. Germany, although the origin country of the initiative, reported fewer samplings (90), due to a more selective approach to sampling locations. Countries with lower sampling numbers, such as Greece, Bulgaria, Latvia, and Hungary, reflect different structural factors: later entry into the initiative, only pilot-level participation and lack of national funding after the pilot phase. These disparities have to be considered when evaluating representativeness and data comparability across countries.

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Plastic weight collected per country

The total amount of plastic waste collected per country varied significantly (see Figure 2). Spain and Portugal recorded the highest total plastic mass, with over 700 kg each, while other countries collected smaller but still substantial quantities.

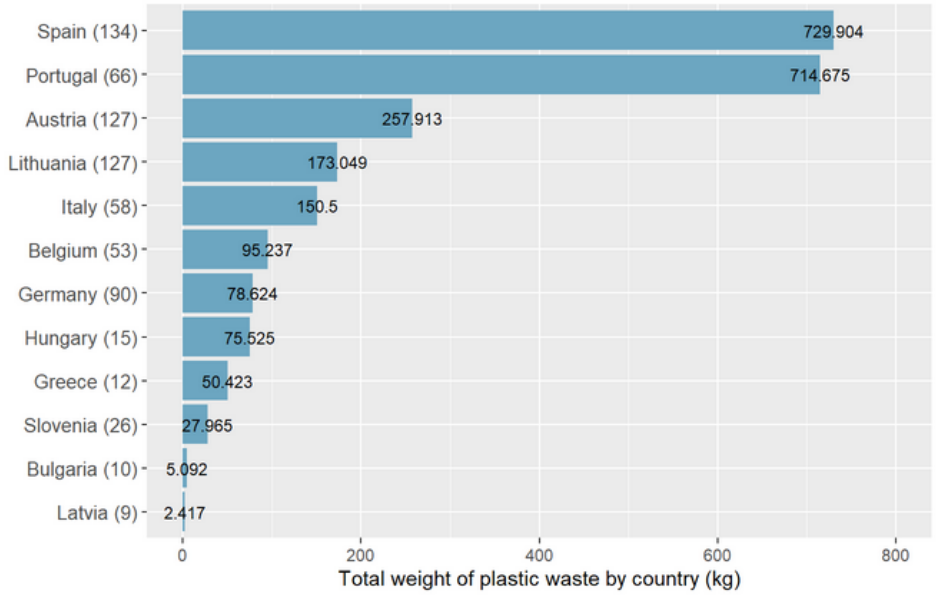


Figure 2: Total Plastic Waste Collected per Country

The total weight of collected plastic varies significantly between countries. Spain and Portugal each exceeded 700 kg, despite a notable difference in sampling numbers (Spain: 134; Portugal: 66), suggesting that sampling locations in Portugal might have been extremely polluted with particularly heavy plastic litter, though not necessarily with a greater overall quantity of pollution. Austria, Lithuania, and Italy also reported substantial totals. Germany, in contrast, collected just 78.6 kg from 90 samplings, which might reflect lower litter levels or less heavy litter and different site selection criteria. The very low totals from Latvia and Bulgaria result mainly from lower sampling intensity, but might also be an indicator for cleaner environments.

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Mean plastic weight per sampling

When normalised by sampling activity, the mean plastic weight per sampling shows which countries faced the heaviest pollution loads on average (see Figure 3).

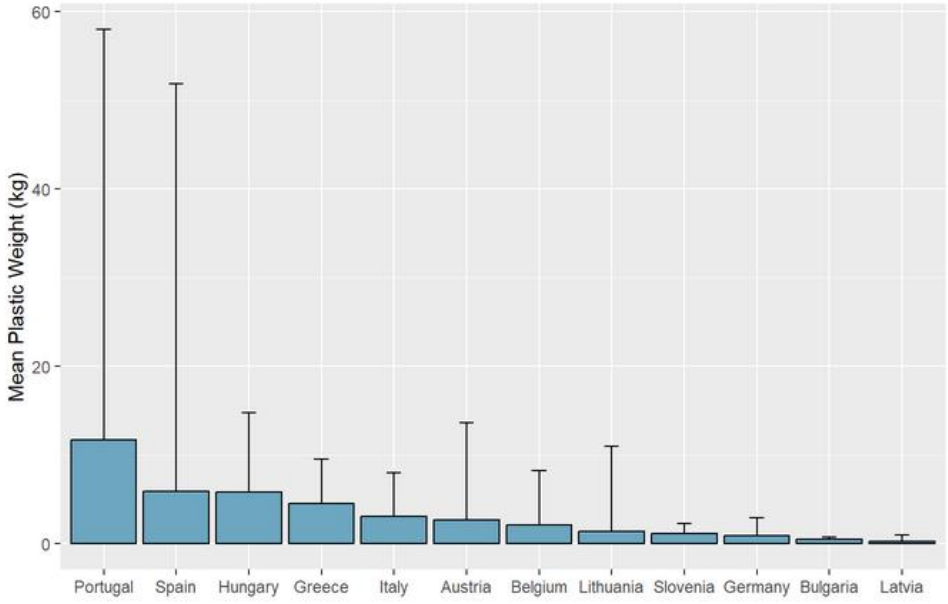


Figure 3: Mean Plastic Weight per Sampling per Country

This figure highlights the average amount of plastic collected per sampling event, offering a clearer view of pollution intensity per site. Portugal stands out with the highest mean weight per sampling, followed by Spain, Hungary, and Greece. These values suggest that certain sampling sites in these countries were located in high-impact or poorly managed areas. The relatively low averages in Germany, Bulgaria, and Latvia, along with their narrow variance, indicate consistently cleaner or more regulated sites. This metric is particularly useful for identifying local pollution hotspots and guiding targeted policy interventions.

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Proportion of plastic vs. other waste

The share of plastic waste relative to other waste materials varies across countries (see Figure 4).

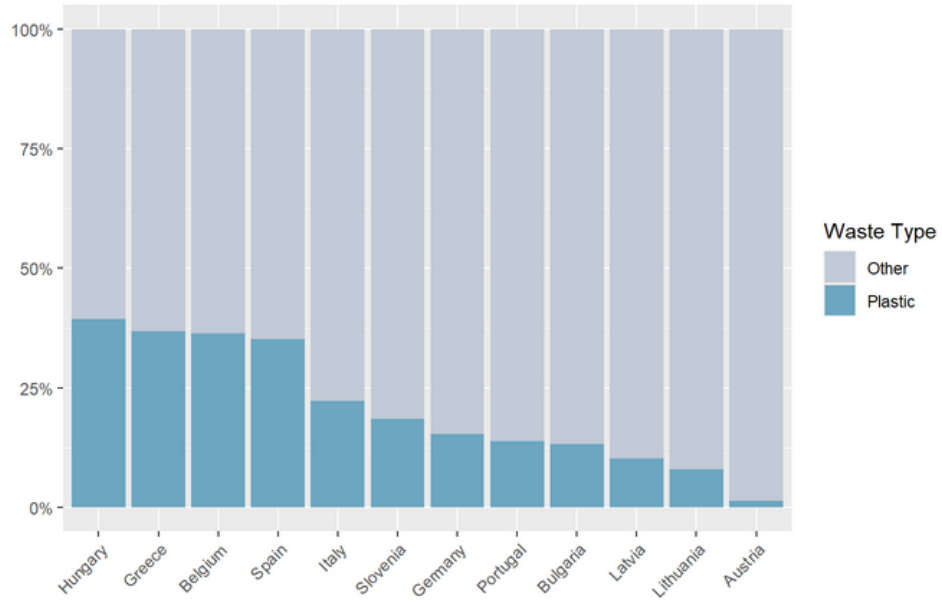


Figure 4: Proportion Plastic vs. Other Waste by Country, by Weight

The plastic proportion relative to total waste varies widely across countries. Hungary, Greece, Spain, and Belgium reported that plastic constituted more than one-third of the total weight. In contrast, Austria, Lithuania, and Latvia recorded lower plastic shares, indicating a higher presence of materials like paper, glass, or metal. These results may reflect local consumption habits, national waste policies, or differences in what was collected and classified during sampling. This data also has relevance for evaluating the local effectiveness of anti-littering strategies and packaging regulations.

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Composition of litter types

The dataset also captures the distribution of different litter materials across all sampling campaigns (see Figure 5).

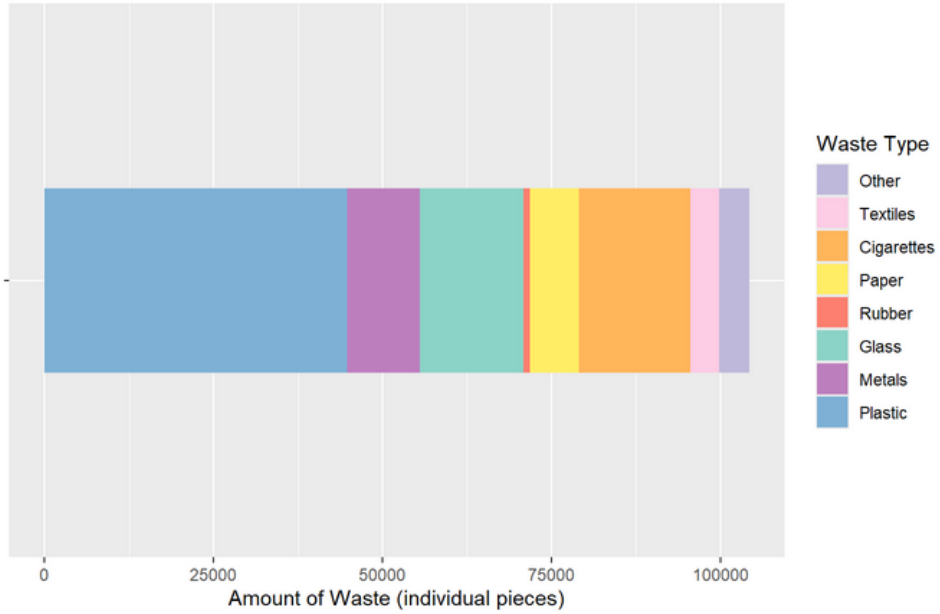


Figure 5: Distribution of Litter Types throuhout the Countries

Plastic clearly dominates the collected litter types by item count, followed by metal, glass, rubber, textiles, and paper/cardboard. The range of materials found points to diverse sources and usage patterns. For example, high proportions of rubber may indicate car-related waste; glass and metal likely derive from drink containers and packaging. The presence of textiles and cigarette waste suggests improper disposal by recreational users. The variety of litter categories supports deeper categorisation and risk assessment in future research and contributes to comprehensive environmental monitoring.

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Absolute Number of SUPs and Other Plastics per Country

Differentiation between single-use plastics (SUPs) and other plastic items provides further insights.

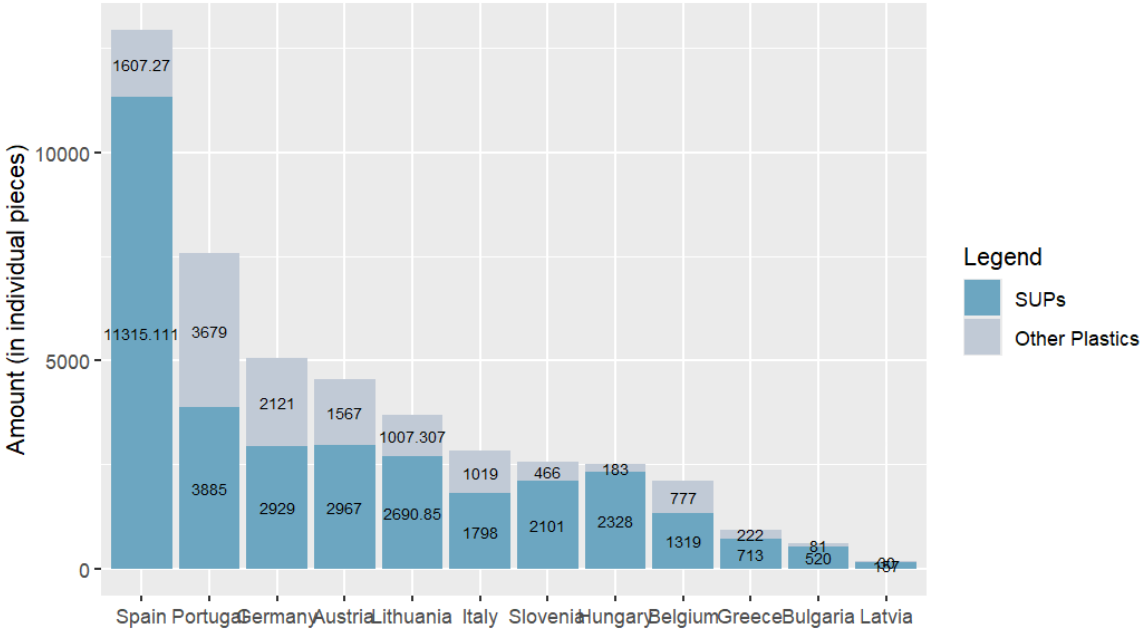


Figure 6: Distribution of Single Use Plastics per Country

Spain recorded an exceptionally high number of single-use plastic (SUP) items—over 11,000—which formed the bulk of all plastic waste. In Portugal, Germany, Austria, and Lithuania, the distributions between SUPs and other plastics were more balanced. Hungary showing a particularly high number of SUP items in relation to other kinds of plastics. This suggests broader consumption patterns, more diverse pollution sources or ineffective measures to stop SUP items from entering the environment. These figures offer a valuable baseline for assessing the national implementation of the EU Single-Use Plastics Directive (EU 2019/904).

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Proportion of SUPs among all plastics

The relative dominance of SUPs in plastic waste composition is further illustrated in Figure 7.

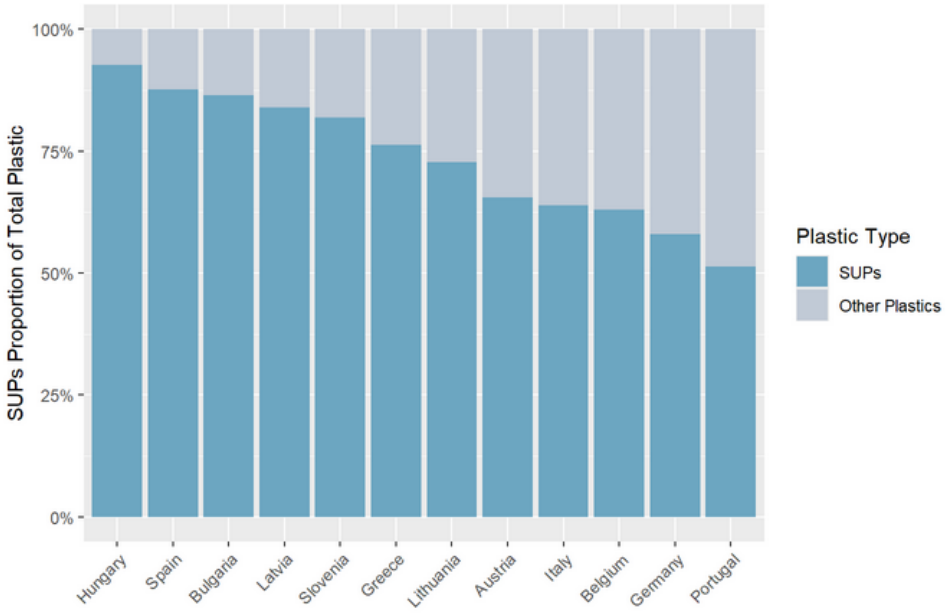


Figure 7: Proportion of SUPs from All Plastics by Country, by Piece

In Hungary, Spain, and Bulgaria, over 90 % of plastic items were single-use plastics, indicating strong dominance of disposable consumption patterns. Even in countries like Portugal, Germany, and Belgium, SUPs accounted for more than half of plastic items. These patterns may reflect differences in consumer behaviour, waste management infrastructure, and the effectiveness of national awareness campaigns. In countries with lower SUP shares, broader litter categorisation and item diversity may be playing a role. The results reinforce the need for SUP-specific monitoring and reduction strategies.

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Floating Litter by Country (Macro- and Microlitter)

A subset of the dataset documents floating litter collected from the surface of rivers.

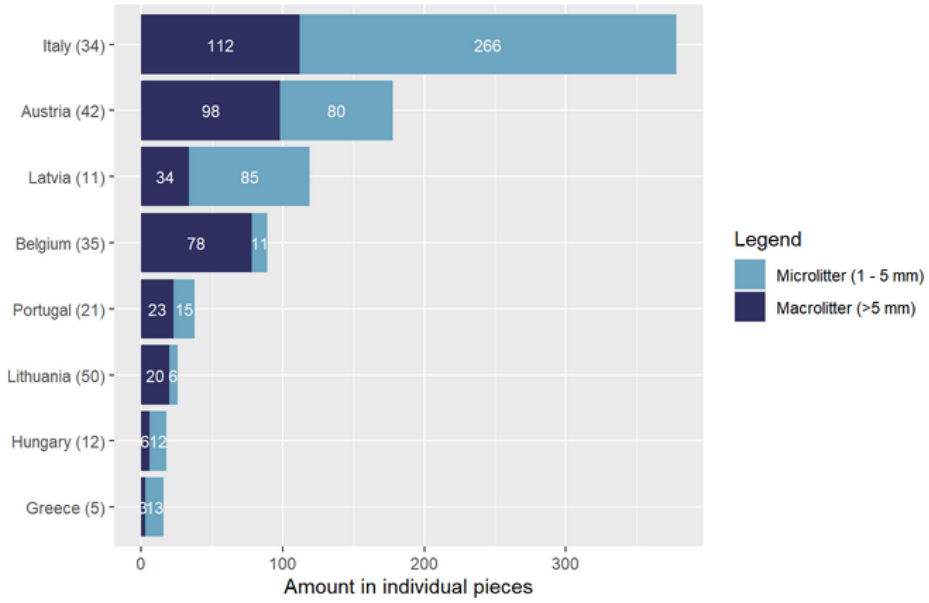


Figure 8: Number of Floating Plastics Collected per Country

Italy and Austria reported the highest total counts of floating litter, with Italy showing a particularly large number of microlitter particles (266). Latvia, with only 11 samplings, nevertheless reported a high microlitter count (85), indicating possible hotspots or focused sampling efforts. Lithuania, Hungary, and Greece reported lower floating litter counts, which stems from cleaner water bodies, fewer campaigns, or limited resources for lab analysis. This data is highly valuable for understanding plastic dispersion on river surfaces and needs to be further analysed in a comprehensive scientific study.

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Suspected litter sources

Each sampling group also estimated the likely sources of observed litter, based on their contextual knowledge see Figure 9: Sources by country and Figure 10: Aggregated source types.

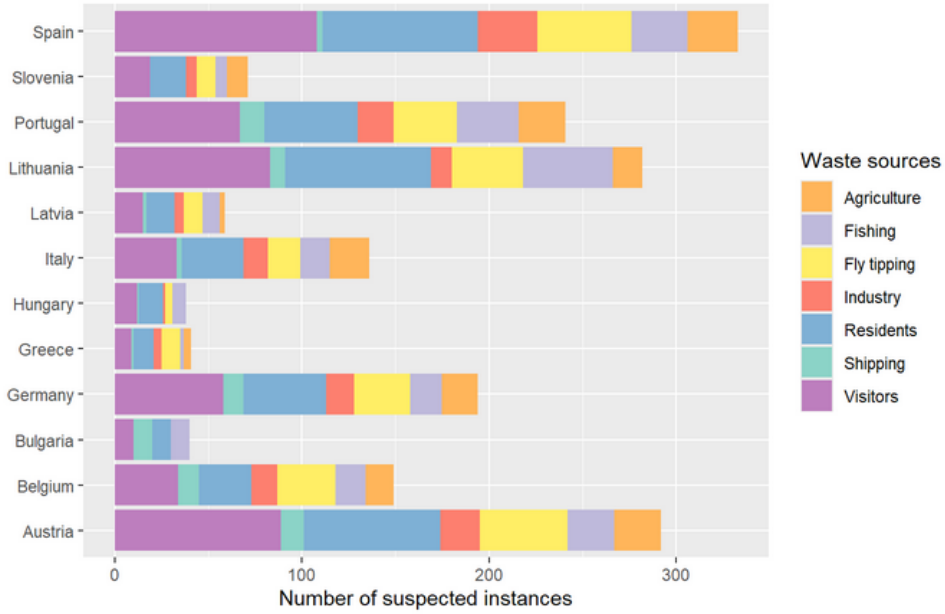


Figure 9: (Suspected) Riverine Waste Sources per Country

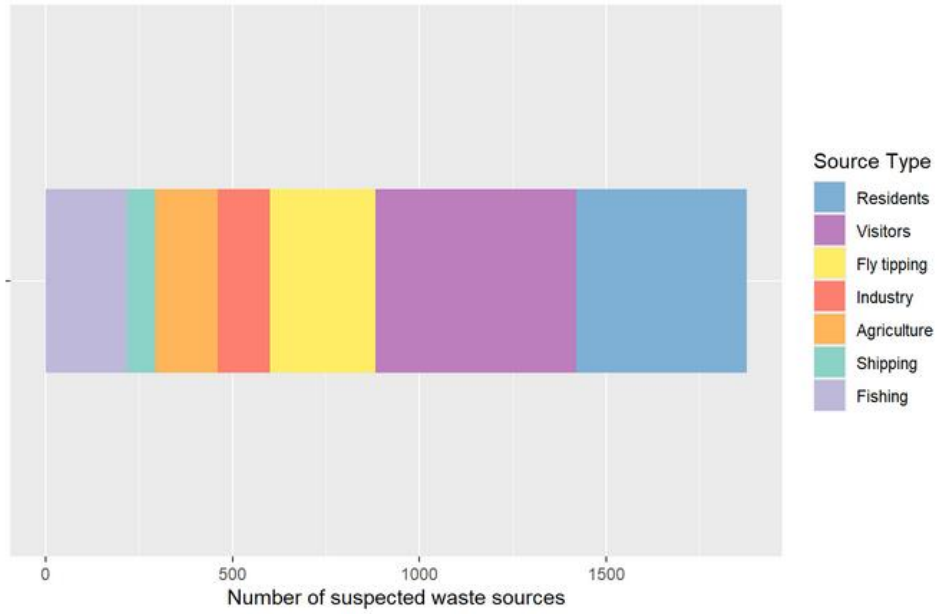


Figure 10: Breakdown of Suspected Source Types

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The most frequently reported suspected sources of litter were visitors (recreational users) and residents, followed by fly tipping (illegal dumping). This indicates that most litter likely originates from daily human activity rather than industrial processes. Fishing, agriculture, shipping, and industry were cited less frequently, though they were noted in certain countries (e.g., shipping in Belgium, agriculture in Portugal). These self-reported perceptions provide valuable context and point to socio-environmental factors behind littering behaviour. They complement quantitative data and can inform local stakeholder dialogues and behaviour change strategies.

Number of rivers sampled

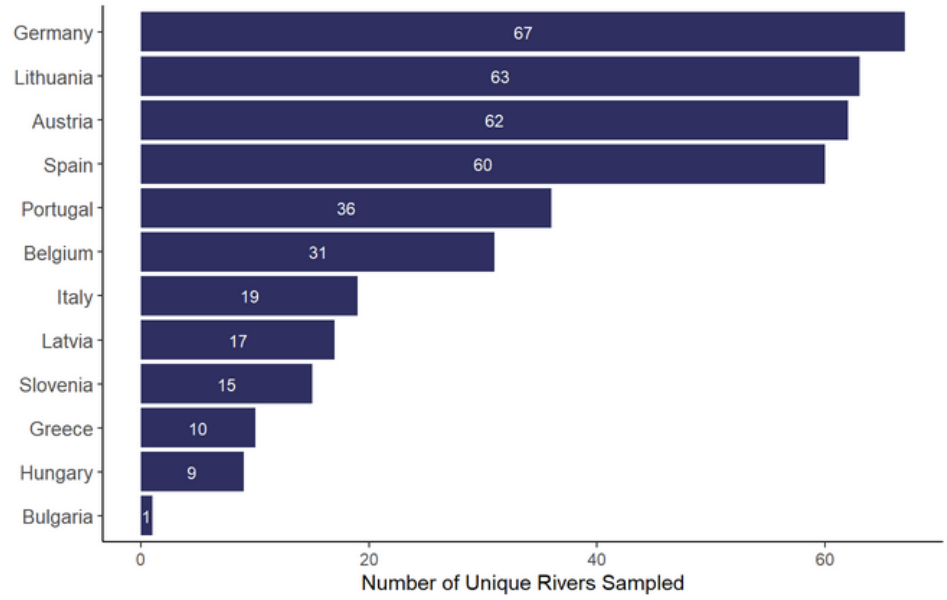


Figure 11: Number of Sampled Rivers per Country

Germany, Lithuania, Austria, and Spain reported sampling at over 60 different rivers, indicating broad geographic coverage and high variability in sampling sites. This wide river base strengthens the scientific robustness of the dataset. Portugal and Belgium reported sampling at 30–35 rivers, which is noteworthy relative to their size and suggests an efficient national deployment. Countries like Hungary, Greece, and Bulgaria, with fewer than 10 rivers sampled, had a more limited spatial footprint, again due to a lack of national follow-up funding, weather constraints like droughts, but also due to a limited number of national rivers like in the case of Greece.

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4. Data Analysis and Research Questions

The consolidated dataset resulting from the "Plastic Pirates – Go Europe!" initiative enables a wide range of scientific analyses, both qualitative and quantitative. It offers a geographically diverse and standardised evidence base covering multiple types of plastic litter across riverbanks and surface waters, as well as perceived sources and contextual metadata. The scientific potential lies not only in mapping current pollution levels but also in exploring temporal trends, source attribution, effectiveness of mitigation measures, and socio-environmental correlations.

Disclaimer: Scientific analysis of the data

As a Coordination and Support Action (CSA), this project did not have the mandate, scientific staff, or research budget to produce formal scientific results beyond the gathering of scientific data through citizen science. The primary aim of the CSA was to engage citizens in standardised data collection, ensure data quality, and enable open access to harmonised datasets for future scientific reuse, which supports the European policy objectives like the Water Framework Directive, the EU Single-Use Plastics Directive or the Marine Strategy Framework Directive. Nevertheless, the project has already generated valuable scientific insights through its extensive and standardised data collection activities. The data are now publicly available and offer a solid foundation for further research and policy-relevant analysis.

Emerging practices for data interpretation

Several national representatives have initiated exploratory approaches, including:

- Geographic and temporal pattern analysis to identify pollution hotspots
- Source analysis based on participant-reported suspected litter origins
- River zone differentiation (foreshore, backshore, crown)
- SUP prevalence and composition analysis

These summaries support cross-national comparison and provide a first analytical layer for hypothesis generation.

Geographic and temporal patterns of plastic pollution

The dataset enables country-by-country comparisons and regional analysis of plastic waste accumulation. Notably, countries like Portugal and Spain recorded both high total plastic waste and high average plastic weight per sampling, indicating consistent pollution hotspots. Germany, in contrast, recorded low average values despite high sampling numbers, suggesting a broader distribution of cleaner sites or different waste management practices.

The diversity in floating litter counts, particularly microlitter, shows potential for further research into hydrological factors influencing plastic dispersion. Temporal comparisons between sampling campaigns (autumn 2022, spring/autumn 2023, spring 2024) will enable future trend analysis.

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Potential questions for further research include:

- What spatial patterns can be identified across Europe in terms of plastic accumulation?
- Are there seasonal fluctuations in plastic load (e.g. comparing spring and autumn campaigns)?
- How does the pollution intensity differ between upstream and downstream river sections?

Plastic composition and dominance of single-use items

The prevalence of single-use plastics (SUPs) is a central theme in the dataset. In countries such as Spain, Hungary, and Bulgaria, SUPs accounted for over 90% of all plastic items collected. This strongly aligns with the objectives of the EU Single-Use Plastics Directive and opens opportunities for analysing its national-level implementation and local impact.

The dataset allows exploration of the composition of plastic waste and its distribution by riverbank zone or sampling location type (e.g. urban vs. rural). The high share of plastics among all waste types in countries like Hungary and Greece further emphasises the need for plastic-specific policy measures.

Potential questions for further research include:

- Which SUP categories dominate (e.g. bottles, wrappers, cutlery)?
- Are SUPs more prevalent in recreational or urban areas compared to remote or natural sites?
- Can changes over time be linked to awareness campaigns or policy enforcement?

Source attribution and socio-environmental context

An important feature of the dataset is the inclusion of perceived waste sources by the sampling groups. The most commonly reported sources across all countries were visitors, residents, and fly tipping, suggesting a strong link to individual behaviour and local infrastructure. Less frequent mentions of shipping, fishing, agriculture, and industry indicate a more context-specific influence of sectoral pollution.

While these attributions are based on perception and not forensic analysis, they provide a valuable qualitative dataset for understanding social drivers of plastic pollution and for co-developing place-based interventions with communities.

Potential questions for further research include:

- How do perceived sources correlate with observed pollution levels?
- Are certain sources more dominant in particular river types or regions?
- How do local land use and proximity to urban infrastructure influence source attribution?

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Relationships to environmental characteristics

The dataset includes metadata on riverbank zone, location coordinates, and sampling context. Combined with external geospatial data—such as vegetation maps, hydrological data, or land use—it is possible to explore how environmental characteristics affect litter accumulation.

Potential questions include:

- Which riverbank zones accumulate the most plastic, and does this vary by country?
- Does the presence of vegetation act as a natural filter or trap for plastic litter?
- How do local slope, infrastructure, or flow dynamics influence litter deposition?

These insights could inform riverbank restoration measures that aim to naturally reduce litter accumulation or support more effective clean-up efforts.

Opportunities for advanced modelling

Given the dataset's volume and structure, it is suitable for advanced modelling approaches, including:

- Regression analysis to identify predictors of high litter accumulation
- Multivariate analysis to cluster rivers or regions by pollution profile
- Machine learning to simulate future scenarios or predict emerging hotspots
- Scenario-based modelling to assess the expected impact of specific mitigation measures

Such analysis could ultimately feed into EU-wide monitoring frameworks or local action plans, particularly under the Zero Pollution Action Plan, the Water Framework Directive, and the upcoming Riverine Litter Database.

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5. Conclusion

The data processing, verification, and consolidation efforts undertaken within the "Plastic Pirates – Go Europe!" project have led to the creation of one of the most comprehensive and standardised datasets on riverine plastic pollution collected by citizens across Europe. Spanning 13 countries and covering more than 360 unique rivers, the dataset reflects an unprecedented mobilisation of young people, educators, and scientists to jointly address a complex environmental challenge.

Although the project was implemented as a Coordination and Support Action (CSA) under Horizon Europe – with no explicit mandate or dedicated capacity to conduct scientific research beyond the level of gathering data – it successfully demonstrated the feasibility and reliability of large-scale citizen science for data generation in support of European environmental and research policies. The resulting data has not only met high standards of quality and consistency through rigorous verification and FAIR-aligned consolidation procedures, but also holds substantial potential for reuse in academic, policy, and civic contexts.

By publishing the harmonised datasets on Zenodo under open licences and linking them to structured metadata via IMIS, MDA, and potentially EMODnet, the project has ensured that the data is both technically interoperable and accessible to a broad community. These efforts contribute to the European Research Area's goals of open science, evidence-based policymaking, and societal engagement with research.

The data already allows for initial interpretation of key patterns in plastic pollution across geographic, temporal, and behavioural dimensions. It highlights, for instance, the dominant presence of single-use plastics, the significance of local human activity as a source of litter, and the varying degrees of pollution found across European rivers. These findings, while preliminary, pave the way for deeper scientific exploration and may inform local, national, and EU-level strategies under the Zero Pollution Action Plan, Water Framework Directive, and European Green Deal.

Looking ahead, the Plastic Pirates dataset provides a robust platform for further interdisciplinary research. From advanced statistical modelling to impact assessments of mitigation measures, the data can support a wide range of studies addressing environmental, social, and policy-relevant questions. Moreover, the dataset offers a critical reference for developing future monitoring protocols and methodologies, including those envisioned for the Riverine Litter Database and European Digital Twin of the Ocean.

Finally, the project's inclusive and educational approach—engaging thousands of young people in structured scientific inquiry—highlights the dual role of citizen science: not only does it generate valuable data, but it also serves as a powerful tool for science education and public engagement. By involving citizens directly in the research process, initiatives like Plastic Pirates foster environmental awareness, scientific literacy, and public trust in science. While data collected through citizen science need a rigorous verification process for ensuring high quality data in accordance with scientific principles, such efforts nonetheless provide meaningful insights and promote a broader understanding of scientific work. The Plastic Pirates initiative thus stands as a model for participatory, data-driven science that combines research and education across Europe and beyond.