WP2 - Educators' Hub-Task 2.1

State-of-the-art in the field of microplastics and synthetic microfibres release from fashion products to water

UNIVERSITAT POLITÈCNICA DE VALÈNCIA · Politechnika Łódzka · idec · ktu

Applicant Organisation: Universitat Politècnica de València (UPV) - Spain

Partners:

- Politechnika Lodzka (YTV) - Poland
- Aintek Symvouloi Epicheiriseon Efarmoges Ypsilis Technologias Ekpaidefsi Anonymi Etaireia (IDEC) - Greece
- Kauno Technologijos Universitetas (KTU) - Lithuania
- Panepistimio Dytikis Attikis (UNIWA) - Greece

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Project acronym:	MicroWeave-TEX
Project full title:	Sustainable solutions in the textile industry to reduce the release of microplastics/synthetic fibres
Grant agreement no.:	2025-1-ES01-KA220-HED-000356411
Responsible partner for deliverable:	UNIWA
Contributing partners:	UNIWA, KTU, LUT, UPV
Author(s):	Kyriaki Kiskira (UNIWA), Nikitas Gerolimos (UNIWA)
Distribution level:	Public
Total number of pages:	142
Version:	Draft
Language	English
Reviewed by:	ALL
Status:	COMPLETED
Delivery date:	28/ 01 /2026

Version control

Number	Date	Description
V0.1	15/01/2026	1st draft
V1.1	20/01/2026	FINAL for review
V2.0	28/02/2026	FINAL

Contents

1. Introduction

This report has been prepared within Work Package 2 (WP2) - 'Educators' Hub' of the Erasmus+ Higher Education project MicroWeave-TEX - Sustainable solutions in the textile industry to reduce the release of microplastics/synthetic fibres (Project No. 2025-1-ES01-KA220-HED-000356411).

WP2 aims to transform consolidated scientific knowledge into structured and pedagogically sound educational resources for Higher Education. These include multilingual learning materials, an interpretive dictionary, podcasts, innovative teaching tools, and educator training activities. Within this framework, Task 2.1 (T2.1) - 'Research and State-of-the-Art on Microplastics', led by University of West Attica (UNIWA), establishes the scientific foundation upon which all WP2 outputs are built.

The present deliverable provides a consolidated and comparative State-of-the-Art report on the release of microplastics and, more specifically, synthetic microfibres from textile products into aquatic and other environmental systems. In line with project terminology, the term fibre (and its derivatives, such as microfibre) is used consistently throughout the document.

1.1. Microplastics and the Textile Sector

Plastics are synthetic polymeric materials characterised by durability, light weight and versatility. Their exponential growth in production and use has led to their widespread presence in natural environments (Geyer et al., 2017). Microplastics are commonly defined as plastic particles smaller than 5 mm (Arthur et al., 2009; Frias & Nash, 2019), and may originate either as primary particles intentionally manufactured at microscopic scale or as secondary fragments generated through degradation processes (Andrady, 2011).

Among the various forms of microplastics, fibrous particles represent a particularly significant subgroup due to their elongated morphology and high aspect ratio. These characteristics influence transport behaviour, filtration dynamics, and biological interactions, distinguishing fibres from spherical or irregular particles (Cole et al., 2011; Andrady, 2017a; Burns & Boxall, 2018a).

The textile sector is recognised as one of the major sources of synthetic microfibres released into the environment. Microfibre emissions occur throughout the textile life cycle, including fibre production, fabric manufacturing, garment use, domestic and industrial washing, and end-of-life handling. Domestic laundering has been widely identified as a key pathway, with studies reporting releases ranging from approximately 10^5 to 10^6 fibres per wash depending on textile characteristics and washing conditions (Napper & Thompson, 2016; De Falco et al., 2019; Cesa et al., 2020).

Wastewater treatment plants can retain a substantial proportion of released fibres, with reported removal efficiencies between 70% and 98%; however, retained microfibres often accumulate in sewage sludge, potentially re-entering terrestrial systems through land application (Murphy et al., 2017; Suaria et al., 2020). Rivers act as major conduits connecting inland sources to marine environments, and microfibres have been detected from coastal waters to deep-sea sediments and remote regions (Eriksen et al., 2013; Woodall et al., 2014; Bergmann et al., 2019).

Beyond aquatic environments, microfibres have also been documented in atmospheric and terrestrial compartments. Indoor air studies report measurable fibre concentrations, highlighting inhalation as a relevant exposure pathway (Dris et al., 2017a; Gasperi et al., 2018a; Prata, 2018a). Agricultural soils receiving sludge may contain thousands of particles per kilogram, demonstrating the cross-media nature of microfibre pollution (de Souza Machado et al., 2018; Sajjad et al., 2022).

1.2. Environmental and Human Health Considerations

Microfibres may exert both physical and chemical effects. Physically, their geometry may influence ingestion, retention, and inflammatory responses in organisms (Wright & Kelly, 2017a). Chemically, fibres may contain additives or adsorb hydrophobic contaminants, acting as vectors for associated substances (Halden, 2010; Caruso, 2019).

Recent analytical advances have detected microplastics in various human biological samples, including stool, blood, placenta, lung tissue, and reproductive fluids (Schwabl et al., 2019a; Ragusa et al., 2021; Jenner et al., 2022; Leslie et al., 2022). While these findings demonstrate exposure, quantitative risk assessment remains constrained by methodological variability, limited standardisation, and uncertainties regarding environmentally realistic exposure levels (Hermsen et al., 2018; Wright & Kelly, 2017b).

Accordingly, current scientific consensus emphasises caution: environmental distribution of microfibres is well documented, biological interactions are plausible, yet definitive conclusions regarding long-term human health risks require further research.

1.3. Objective, Scope and Methodology of This Report

The purpose of this report is to:

- Present a structured and evidence-based overview of the current scientific knowledge on microplastic and synthetic microfibre release from textiles;
- Analyse environmental pathways, measurement approaches, technological mitigation strategies, and policy developments;
- Synthesize and compare national contexts (Greece, Lithuania, Poland, and Spain);
- Provide a consolidated foundation for the development of WP2 educational materials.

In contrast to the individual national reports, which follow a common template, this document does not replicate country analyses sequentially. Instead, it adopts a comparative and integrative structure, in which each thematic section synthesises findings across countries. This approach strengthens analytical coherence and avoids duplication of content.

The methodology underpinning this report includes:

1. A structured review of peer-reviewed scientific literature and technical reports;
2. Compilation of national reports developed under a shared template;
3. Comparative analysis of industrial structures, environmental evidence, research capacity, regulatory frameworks, and educational needs;
4. Internal peer review to ensure scientific rigour and pedagogical relevance.

1.4. Added Value for WP2 and Educational Integration

By consolidating scientific evidence with national contextual analysis, this report establishes the knowledge baseline required for WP2 outputs. The comparative insights generated here inform:

- Curriculum development in sustainable textile systems;
- Educator training modules;
- The interpretive dictionary of key terms;
- Innovative pedagogical tools such as sustainability-oriented escape rooms;
- Multilingual educational materials.

Importantly, the report does not anticipate conclusions in advance of the comparative analysis, nor does it duplicate country-level findings. Instead, it frames the issue conceptually and methodologically, while reserving synthesis and strategic conclusions for the final section of the document.

Through this structure, the deliverable aligns with the objectives of MicroWeave-TEX and contributes to advancing scientifically grounded, pedagogically robust approaches to reducing microplastic and synthetic microfibre pollution from the textile sector.

2. National textile industry overview

This chapter summarises how the textile and clothing sector is structured across Greece, Lithuania, Poland and Spain. The focus is on sector size, structure, territorial organisation, recent developments, and trade/competitiveness, because these parameters shape where and how synthetic microfibre release is likely to occur across the textile lifecycle (production, use, and end-of-life).

2.1. Sector definition and boundaries

Across the four national reports, the textile and clothing sector is consistently framed as a value chain that includes upstream fibre/yarn activities, fabric formation (weaving/knitting), finishing, and downstream apparel and made-up textile products, although each country's report emphasises different segments depending on national industrial specialisation.

- Spain explicitly defines the sector using CNAE-2009, including: preparation and spinning of fibres, manufacture and finishing of fabrics, manufacture of other textile items, and manufacture of clothing (Instituto Nacional de Estadística, 2023).
- Lithuania defines the sector through National Classification of Economic Activities (EVRK 13), detailing categories such as preparation/spinning, weaving, knitting, made-up textile articles, carpets, ropes/nets, finishing, nonwovens, and sewing, with a quantified structure table (number of companies per activity).
- Poland uses the national classification Polish Classification of Activities (PKD), presenting the industrial structure through tables for textile manufacturing (e.g., spinning, weaving, finishing, nonwovens, technical textiles) and apparel production categories.
- Greece frames the sector historically and structurally (SMEs + vertically integrated firms + specialised producers), highlighting cotton processing, yarn manufacturing, technical textiles, and niche fashion products as core elements.

Although the sector boundaries are broadly comparable across the four national reports, the emphasis and framing differ significantly. Spain places stronger weight on formal classification frameworks and on the long-term restructuring trajectory of the national textile and clothing sector within a context of international competition and industrial adjustment. In contrast, Lithuania and Poland provide a more granular and structured mapping of subsectors, using detailed EVRK/PKD tables to describe the composition of textile manufacturing and apparel activities and the distribution of economic entities across categories. Greece, meanwhile, adopts a more lifecycle-oriented narrative, explicitly connecting fibre use (cotton versus rising synthetics), geographical clustering of production and finishing, and downstream environmental pathways, particularly wastewater infrastructure and coastal pressures, thereby linking industrial structure more directly to microfibre release relevance.

2.2. Sector size, employment and industrial weight

The Greek textile and clothing industry is described as one of the oldest manufacturing sectors, historically significant for employment and exports. After a post-2000s decline due to competition from low-cost production countries, it remains a 'mid-sized but robust' national sector. The report cites over 1,200 enterprises, more than 25,000 workers, and annual exports exceeding €2 billion, mainly to EU markets (SEPEE, 2023; Eurostat, 2023).

Spain's sector remains economically and socially significant despite losing relative weight within manufacturing. According to CITYC data, in 2024 turnover was €5.996 billion (-2.7% vs. previous year), with 3,426 active companies (-2.3%) and 45,429 workers (-1.1% vs. 2023), indicating a post-pandemic adjustment phase (CITYC, 2025).

Poland is positioned as a major EU producer: it ranks third in the EU in number of textile companies and in employment (after Italy/France for number of companies, and after Italy/Germany for employment). The report also estimates production value of textile production sold in 2025 at ~€4.8 billion. Structurally, the sector is highly fragmented: ~97% of clothing companies are micro-enterprises. Dun & Bradstreet estimates just over 9,500 companies in the sector at end-February 2024.

Lithuania reports ~800 companies in the textile and clothing sector, mostly SMEs, and employment of ~26,000 people at end of 2025, with a consistent decline compared to historical employment levels (>30,000). The report also notes workforce structure: women are the majority of employees, and engineering/technical personnel represent ~5-8%, with demand rising as the sector shifts toward high-tech textiles.

In this group, Spain shows the largest employment and clearly quantified turnover (CITYC, 2025). Poland combines a very large number of entities and strong EU standing with deep micro-enterprise fragmentation. Greece and Lithuania are smaller in absolute scale but remain structurally important and export-relevant.

2.3. Industrial structure, specialisation and recent trends

Greece: cotton backbone with rising synthetic and blended fibres

Greece historically relied heavily on cotton, and the report states Greece is the largest cotton-producing country in the EU. Cotton textiles and yarns remain central, but synthetic fibres and blends (polyester, polyamide, acrylic) have become increasingly dominant due to affordability and durability. The report explicitly links this shift to microfibre relevance (synthetic garments shed fibres during washing, wear, and production) and notes alignment with polymers detected in Greek aquatic environments (e.g., PE and PP; example given for Thermaic Gulf findings, Kermenidou et al., 2023).

Spain: long-term restructuring under trade liberalisation

Spain's report situates structural change in the context of international trade liberalisation and WTO integration (Agreement on Textiles and Clothing, fully integrated in 2005), which intensified competition (especially from Asia). This drove productive restructuring, partial relocation, and strategies based on differentiation (quality, design, rapid market response) (Moral, 2004; European Commission, 2004). Recent performance shows consolidation and adjustment after post-pandemic growth, with declines in companies and employment but continued relevance in higher value-added segments (fabrics, technical textiles, home textiles)

Poland: transformation toward niche/high-value while firms decline

Poland's report describes transformation from mass production based on low labour costs toward niche, specialised, higher value-added solutions, shaped by systemic transformation and global market changes. It also notes recent contraction signals: the number of textile companies has been declining over the past three years; in 2023 the decrease was nearly 1.6% compared to 2022, and nearly 500 companies suspended operations in 2023. Despite this, textile activity remains regionally strong in some areas.

Lithuania: stability with upgrading toward high-tech and export-focused production

Lithuania reports a sector that is stable but under export-order pressure at end of 2025, with slightly declining expectations/production volumes. Structurally, the report emphasises that most industry is focused on final products (fabrics and garments), while primary preparation/spinning is a small part of the chain. Production of synthetic/chemical fibres and yarns is among the smallest segments due to high technological requirements; one historically important company in this domain is AB 'Dirbtinis pluoštas'. The report describes a shift from mass production/'cheap tailoring" toward high-tech textiles (medical, transportation, protective textiles) and highlights the role of KTU and FTMC in supporting innovation (smart/protective textiles).

2.4. Territorial concentration and business fabric

Territorial patterns matter for microfibre relevance because they indicate where textile activities, especially wet processing and finishing, concentrate wastewater pressures and monitoring needs.

Greece: textile manufacturing is concentrated in Northern Greece, especially Central Macedonia (Thessaloniki region), Eastern Macedonia and Thrace, and Thessaly, where spinning, weaving/knitting, dye houses, finishing plants and apparel manufacturers are clustered. The report links this clustering to potential pressures on wastewater networks and notes vulnerability where industrial effluents discharge into rivers or municipal WWTPs (example referenced via Kifissos River research, Koutsikos et al., 2023).

Spain: production is highly concentrated geographically; Cataluña and Comunitat Valenciana are highlighted for spinning, weaving and finishing, while clothing manufacturing is more widely distributed (Andalucia, Galicia, Madrid, Castilla-La Mancha) (Instituto Nacional de Estadística, 2023).

Lithuania: the report identifies Kaunas, Šiauliai and Utena as historical textile centres for knitting/hosiery; it also notes that nonwovens companies concentrate in major industrial centres and regions with textile traditions.

Poland: the report notes that, despite sector contraction, there remain regions where the textile industry is thriving (Producenci tekstyliów, 2025). It supports this with structured PKD tables showing entity counts across multiple textile and apparel categories.

Spain explicitly highlights that >50% of companies have fewer than five employees, and a significant proportion have no employees, underscoring a highly fragmented production model with limited investment capacity (Moral, 2004). Poland mirrors fragmentation in the apparel segment, where micro-enterprises dominate. Lithuania reports SME dominance (only ~0.2% large firms) in sewing/apparel and a strong contract-manufacturing model ('lohn production') for EU brands. Greece similarly describes SME prevalence and highlights cost barriers for microfibre filtration adoption.

2.5. Production, trade, competitiveness and market dynamics

Spain: widening trade deficit under competitive pressure

Spain's textile exports reached €4.72 billion (2024; +1.6% vs. 2023), while imports were €5.107 billion (+6.3%), producing a trade deficit of €387 million (CITYC, 2025). Export destinations include Morocco, France, Italy, Portugal and Germany; imports are led by China, Turkey, Italy and Pakistan (CITYC, 2025). The report frames competitiveness around differentiation, flexibility and control of the value chain, especially in higher value-added segments.

Poland: declining synthetic production but strong import signals and a large consumer market

Poland's report provides a microfibre-relevant insight: production of synthetic yarns and fabrics has systematically decreased since 2020, with synthetic yarn production falling threefold and reaching levels comparable to cotton yarn production (as interpreted in the report's figures and narrative). However, the report also notes import dynamics: the value of synthetic fibre imports is almost three times cotton import value, and imports of man-made staple fibres have increased since 2022, described as an unfavourable trend for reducing microplastics from the textile industry. Additionally, import value of apparel is tenfold higher than imports of fibres/yarns/knitted fabrics and increased significantly in 2024. The report also provides market estimates (e.g., PIOT estimate of Polish clothing market worth PLN 66.9 bn in 2024, with PLN 10 bn from domestic production).

Lithuania: export-led model with gradual domestic-market strengthening

Lithuania reports that about 75-80% of production is exported, while domestic sales have increased (over 20% of production sold domestically compared with 8% a few decades ago). The report forecasts sector market size reaching EUR 579.5 million in 2026, noting recovery at end of 2025 (annual growth 2.6-3.5%) but continued competition from lower-cost countries and the strategic need to move toward higher value-added production.

Greece: export-oriented mid-sized sector and innovation constraints

Greece's report emphasises strong exports (>€2 bn annually, mainly to EU markets) and ongoing modernisation toward sustainability and cleaner production (SEPEE, 2023; Eurostat, 2023). It also stresses that although some companies adopt water recycling and improved filtration in finishing/dyeing, dedicated microfibre filtration remains limited—especially among SMEs due to cost barriers and lack of national guidelines. The report cites EU-funded initiatives such as CLAIM as evidence that high-retention filtration technologies (up to 95%) are technically feasible in wastewater settings (Gkanasos et al., 2021).

2.6. Comparative implications for microfibre relevance

Taken together, the four national industry profiles point to a shared European reality, fragmented production structures and intense competitive pressure, but with distinct national 'microfibre-relevant' configurations:

- Production-side relevance (industrial shedding / wet-processing wastewater): Strong where clusters of finishing/dyeing exist and where industrial effluents interact with municipal wastewater systems. Greece explicitly highlights these pathways in Northern Greece and links industrial clustering to wastewater vulnerability (Koutsikos et al., 2023). Lithuania describes a modernising finishing sector (bleaching, dyeing, printing, coating) supporting export-oriented manufacturers, implying concentrated wet-processing activities relevant for microfibre capture measures. Spain and Poland also document strong weaving/finishing structures within regional clusters.
- Use-phase relevance (domestic washing of synthetic and blended textiles): Greece explicitly links increased synthetic fibre use and the presence of fibres in Greek marine environments (e.g., urban-influenced gulfs such as Saronikos; Adamopoulou et al., 2021). Poland's very large apparel import volumes relative to upstream imports suggest strong consumption-driven laundering impacts (even as domestic synthetic production declines). Spain's trade deficit and high import flows reinforce a similar consumption-laundering relevance.

- Capacity to adopt mitigation technologies: SME dominance appears across all four countries, with Spain and Poland providing strong evidence of micro-entity structures (Moral, 2004; ~97% micro-enterprises in clothing in Poland). This implies that mitigation measures may require policy support, standardised guidance, and incentives, since firm size constrains investment capacity. Greece explicitly mentions cost barriers and limited adoption of dedicated microfibre filtration among SMEs.

Overall, the national reports indicate that microfibre release mitigation must be designed with awareness of national sector structure:

- where production is clustered and finishing is prominent, wastewater-focused measures become highly relevant;
- where imports and clothing consumption dominate, use-phase measures (washing practices, filtration at household/industrial laundering) become central;
- and in all cases, SME prevalence suggests the importance of accessible technologies, guidance, and supportive policy frameworks.

.

3. Relevance of microplastics/microfibres in the national contexts

Although all four national reports recognise microplastics and synthetic microfibres as environmentally significant, the way in which their national relevance is framed differs according to environmental exposure, industrial structure, regulatory maturity and research emphasis.

In Greece, the issue is strongly contextualised within a marine and coastal vulnerability perspective, reflecting the country's extensive coastline and tourism-based economy. The report highlights that fibre-shaped particles dominate microplastic profiles in Greek marine and freshwater environments and links these findings to wastewater pathways and infrastructure limitations. Seasonal tourism pressures and insufficient tertiary treatment coverage in certain areas are presented as amplifying factors. Research evidence from coastal and riverine systems reinforces the relevance of textile-related fibres in national environmental monitoring (Adamopoulou et al., 2021; Koutsikos et al., 2023). Consequently, microfibre pollution in Greece is framed not only as an industrial issue but also as a marine ecosystem and socio-economic concern, with implications for fisheries, biodiversity and coastal tourism.

In Lithuania, the relevance of microfibres is framed primarily through a circular economy and sustainability transition lens. The national report positions microfibre release as part of the broader environmental transformation of the Lithuanian textile and clothing sector, aligning with EU sustainability commitments and national policy strategies. Rather than focusing predominantly on contamination evidence in natural systems, Lithuania emphasises structured assessment, policy alignment and coordinated action among public authorities, industry and research institutions. The issue is therefore embedded within an industrial modernisation narrative, where environmental performance and technological upgrading are central to maintaining export competitiveness.

In Poland, the relevance of microplastics is articulated through the scale, structure and market dynamics of the national textile and clothing industry. The report stresses the need to understand the size and economic position of the sector in order to assess its contribution to domestic water pollution. Particular attention is given to production trends, the role of synthetic fibre imports and the scale of apparel consumption. This framing connects microfibre release to both upstream industrial activity and downstream consumer use patterns. The Polish approach therefore combines industrial analysis with mitigation-oriented considerations, highlighting the importance of sector-specific strategies to reduce environmental impacts.

In Spain, the relevance of microplastics and microfibres is situated within a broader context of industrial restructuring, regulatory adaptation and competitiveness under international trade pressures. The Spanish report links environmental challenges to long-term sectoral transformation following trade liberalisation and global competition (Moral, 2004; European Commission, 2004). Microfibre concerns are integrated into wider discussions of sustainability, innovation and technological upgrading as strategic tools for maintaining competitiveness in higher value-added textile segments. In this context, environmental performance becomes both a compliance issue and a market differentiator.

While the environmental phenomenon of microfibre pollution is common across all four countries, its national articulation differs:

- Greece emphasises marine exposure, wastewater limitations and tourism-related pressures.
- Lithuania highlights policy alignment and sustainable industrial transition.
- Poland stresses industrial scale, trade flows and consumption-driven impacts.
- Spain focuses on restructuring, regulatory adaptation and sustainability-driven competitiveness.

These differences demonstrate that the relevance of microfibre pollution is shaped not only by environmental evidence but also by industrial configuration, trade patterns and policy context. A coherent European response therefore requires contextualised mitigation strategies that reflect national structural conditions while maintaining a shared scientific basis.

4. Sources of Microfibre Release in the Textile Sector

This chapter provides a comparative synthesis of the main sources and pathways of synthetic microfibre release identified in the national reports of Greece, Lithuania, Poland and Spain. Following a lifecycle perspective, sources are analysed across three main stages: (1) production and industrial processing, (2) use phase (domestic and commercial laundering), and (3) end-of-life handling and waste management. While the overall pathways are structurally similar across countries, their relative importance differs depending on industrial configuration, wastewater infrastructure, consumption patterns and policy maturity.

4.1. Production stage

Across all four countries, textile manufacturing processes are recognised as potential sources of microfibre release, particularly where mechanical abrasion and wet processing are involved.

The Greek report explicitly identifies spinning, weaving/knitting, brushing, cutting, dyeing, washing and finishing operations as industrial shedding points. Northern Greece, particularly Central Macedonia, Eastern Macedonia and Thrace, and Thessaly, hosts concentrated clusters of textile processing facilities, including dye houses and finishing plants. These clusters generate localised pressures on wastewater networks, especially where industrial effluents discharge into rivers or municipal wastewater treatment plants (WWTPs). Evidence from the CLAIM project demonstrates that microplastics, including fibre-shaped particles, are present in effluents and that advanced filtration technologies can achieve removal efficiencies of up to 95% under pilot conditions (Gkanasos et al., 2021). The Greek report further links synthetic fibre use (polyester, polyamide, acrylic blends) to polymer types detected in aquatic environments, reinforcing the production-environment connection (Kermenidou et al., 2023).

Lithuania provides a detailed structural breakdown of production activities under EVRK 13, including spinning, weaving, knitting, finishing, nonwovens and sewing. Although the production of synthetic and chemical fibres is limited in number of companies, finishing processes, bleaching, dyeing, printing, coating and impregnation, are widely present. The report notes that many companies integrate finishing departments and are rapidly modernising toward environmentally friendly technologies that reduce water and chemical use. Given Lithuania's strong export orientation (75-80% of production exported), industrial shedding relevance is closely linked to compliance with EU sustainability requirements and technological upgrading.

The Polish report provides extensive data on production categories under PKD classification, including spinning, weaving, finishing, nonwovens and technical textiles. Importantly, production of synthetic yarns and woven fabrics has decreased systematically since 2020, with synthetic yarn production declining threefold and approaching cotton yarn levels. However, imports of synthetic fibres remain significant and increasing in certain categories. This indicates that although domestic synthetic production may be decreasing, upstream industrial and trade-related pathways for microfibre introduction remain relevant.

Spain's report emphasises productive specialisation in fabrics, technical textiles and home textiles, with geographically concentrated spinning, weaving and finishing in regions such as Cataluña and Comunitat Valenciana. Although not framed exclusively in microfibre terms, the presence of finishing-intensive clusters implies similar wet-processing shedding pathways as identified in other countries. Spain's sectoral restructuring under global trade pressures (Moral, 2004; European Commission, 2004) has reinforced competitiveness in higher value-added segments, where synthetic performance textiles are common and potentially associated with fibre shedding during production and finishing.

All four countries identify industrial processing, particularly mechanical agitation and wet finishing, as potential microfibre release points. Greece provides the most explicit link between production clusters and wastewater escape pathways, while Lithuania and Poland offer detailed structural mappings of subsectors. Spain situates industrial processes within a broader restructuring narrative but shares similar technological profiles.

4.2. Use phase

Across all four national contexts, the use phase, particularly washing of synthetic garments, is identified as a major source of microfibre release.

The Greek report emphasises that the majority of microfibre emissions originate from domestic laundering, as synthetic garments dominate the national textile market. Nearly all households use conventional washing machines without fibre filters, allowing released fibres to enter wastewater systems directly. Fibre dominance in marine samples (e.g., Aegean, Ionian, Saronikos) supports the link between laundering and environmental loads (Adamopoulou et al., 2021). Seasonal tourism increases washing frequency in coastal areas, amplifying wastewater pressures.

Poland's report links use-phase relevance to high levels of apparel imports and domestic consumption. The value of clothing imports significantly exceeds fibre/yarn imports, suggesting that laundering of imported synthetic garments may represent a substantial source of domestic microfibre emissions.

Although less focused on environmental monitoring data, Lithuania's strong export orientation and production of synthetic and blended textiles imply use-phase shedding relevance both domestically and in destination markets. The sector's transition toward high-performance and technical textiles may influence fibre durability and shedding characteristics.

Spain's large apparel market and trade deficit indicate strong consumption-driven flows. Although the Spanish report emphasises competitiveness and restructuring, the widespread use of synthetic textiles in higher value-added and fashion segments reinforces the significance of laundering as a release pathway.

Across all countries, the use phase emerges as structurally important. Greece provides the strongest environmental evidence linking laundering to marine fibre prevalence. Poland highlights consumption and import-driven relevance. Lithuania and Spain underscore sectoral structures that indirectly reinforce laundering-related emissions through synthetic fibre prevalence.

4.3. End-of-life handling

End-of-life management represents an indirect but significant source of microfibre release. The Greek report notes that textiles are often disposed of in mixed municipal waste, exported as second-hand clothing, or informally collected. Landfilling remains dominant, allowing gradual fragmentation and microfibre leakage through leachate and soil diffusion. Although EPR schemes for textiles are being introduced, no dedicated microfibre strategy currently exists. Poland reports increasing imports of used clothing and second-hand textile products. While extended product life may reduce production-related emissions, improper disposal and fragmentation still pose potential release risks. Lithuania aligns textile waste management with EU circular economy policies. The report emphasises structured strategies for sustainability and environmentally responsible production, although detailed microfibre-specific end-of-life measures remain limited. Spain situates textile waste within broader sustainability and industrial policy discussions. As in other countries, fragmentation during disposal and insufficient separate collection systems may contribute to environmental fibre leakage.

5. Scientific and Technical Research on Microfibre Release

This chapter synthesises the scientific and technical research capacity described in the national reports of Greece, Lithuania, Poland and Spain. It focuses on institutional research structures, microfibre-related studies, technological innovation and participation in EU-funded initiatives.

5.1. Research Landscape and Institutional Capacity

The Greek national report highlights strong academic engagement in microplastic and microfibre research, particularly in marine and freshwater environments. Studies conducted in the Aegean Sea, Saronikos Gulf and river systems (e.g., Kifissos River) demonstrate fibre dominance among identified microplastic particles (Adamopoulou et al., 2021; Koutsikos et al., 2023). Furthermore, Greek institutions participated in the EU-funded CLAIM project, which piloted microplastic filtration technologies in wastewater treatment systems and reported removal efficiencies of up to 95% (Gkanasos et al., 2021). However, the report also notes that although research capacity is strong, translation of scientific results into industrial-scale microfibre mitigation remains limited, especially among SMEs.

The Lithuanian report describes a structured research-industry interface supported by Kaunas University of Technology (KTU) and the Textile Institute of the Centre for Physical and Technological Sciences (FTMC). These institutions conduct research on smart textiles, protective materials and sustainable finishing technologies. The report emphasises innovation in environmentally friendly finishing processes, digital textile printing and advanced materials engineering, aligned with export-oriented sector upgrading. Although the Lithuanian report contains less environmental monitoring evidence than the Greek report, it situates research within the broader sustainability and circular economy transition of the textile sector.

The Polish report provides extensive structural and statistical data on textile production and trade, supported by sectoral reports, national statistics and industry analyses. While microplastic-specific environmental monitoring is less emphasised compared to Greece, the Polish report highlights production trends, import dynamics and sector restructuring as critical elements for assessing microfibre relevance. The research focus therefore appears more strongly oriented toward industrial performance, market structure and economic analysis than toward environmental microfibre quantification.

The Spanish report frames research and technological development within the long-term restructuring of the textile sector under global trade pressures (Moral, 2004; European Commission, 2004). The report emphasises innovation, digitalisation and sustainability as strategic tools for maintaining competitiveness, particularly in higher value-added textile segments such as technical textiles and specialised fabrics. Although detailed microplastic monitoring data are not central to the Spanish report, environmental compliance and technological upgrading are presented as necessary responses to evolving EU regulatory frameworks.

5.2. Industry Research and Technological Innovation

Across the four countries, industrial research activities focus on:

- Water and chemical reduction in finishing processes
- Sustainable production methods
- High-performance and technical textiles
- Compliance with EU sustainability standards

In Greece, cleaner production practices such as water recycling and advanced filtration are mentioned, though microfibre-specific technologies are not yet widely implemented in the industrial sector. Lithuania highlights rapid modernisation of finishing technologies and the role of research institutions in supporting industrial innovation. Poland documents structural transformation toward niche and higher value-added production. Spain integrates sustainability-driven innovation into its competitiveness strategy

5.3. EU Project Participation and Cross-Border Collaboration

Participation in EU-funded research projects appears as a key driver of knowledge exchange and technological development.

- Greece demonstrates active engagement in projects directly addressing microplastic filtration and wastewater monitoring (CLAIM)
- Lithuania integrates EU sustainability frameworks into sectoral modernisation strategies
- Poland and Spain situate EU integration within broader industrial and trade restructuring processes.

5.4. Comparative Interpretation

Three distinct research orientations emerge:

- Environmental monitoring and pilot mitigation technologies (Greece)
- Technological upgrading and smart textile innovation (Lithuania)
- Industrial and market-driven restructuring analysis (Poland and Spain)

While research engagement exists in all four countries, microfibre-specific mitigation remains uneven in industrial implementation. Strengthening the link between environmental monitoring, technological innovation and SME uptake emerges as a common cross-country challenge.

6. Case Studies: Good Practices and Intervention Examples

This chapter presents selected case studies from Greece, Lithuania, Poland and Spain illustrating technological, institutional and policy-based interventions addressing microplastic and synthetic microfibre release within the textile lifecycle.

6.1. Greece

6.1.1. Case Study 1: CLAIM Project - Advanced Wastewater Microplastic Filtration

Context: EU-funded CLAIM project involving Greek research institutions.

Problem Identified: Wastewater treatment plants (WWTPs) act as key pathways for microfibre transport into marine ecosystems.

Intervention Implemented: Pilot-scale advanced filtration technologies were installed and tested in wastewater environments.

Quantitative Results: Removal efficiencies of up to 95% were achieved under pilot conditions (Gkanasos et al., 2021)

Lessons Learned: Technological solutions are feasible but require policy support and scaling mechanisms.

6.1.2. Case Study 2: Microplastic Monitoring in the Saronikos Gulf - Fibre Dominance Assessment

Context: Marine monitoring studies conducted in Greek coastal environments.

Problem Identified: Increasing detection of microplastics in marine ecosystems, particularly fibre-shaped particles.

Findings: Fibres represent a significant fraction of identified microplastics in marine samples, especially in urban-influenced areas such as the Saronikos Gulf (Adamopoulou et al., 2021).

Lessons Learned: Environmental monitoring confirms that laundering and wastewater discharge pathways contribute to marine microfibre loads.

6.2. Lithuania

6.2.1. Case Study 3: Sustainable Textile Finishing Modernisation - Water and Chemical Reduction

Context: Lithuanian textile finishing companies upgrading production technologies.

Problem Identified: Dyeing, bleaching and finishing processes generate wastewater potentially containing microfibres and chemical residues.

Intervention Implemented: Adoption of environmentally friendly finishing technologies, digital printing and water-reduction systems.

Results: Documented reductions in water and chemical use; improved compliance with EU environmental standards.

6.2.2. Case Study 4: Technical Textile Innovation - Smart and Protective Textiles

Context: Research and industry collaboration supported by Kaunas University of Technology (KTU) and FTMC.

Problem Identified: Need to move beyond low-cost mass production toward high-value sustainable textiles.

Intervention Implemented: Development of smart textiles, medical and protective fabrics, and innovation in advanced materials.

Lessons Learned: Technological upgrading supports sustainability but requires continuous R&D investment.

6.3. Poland

6.3.1. Case Study 5: Reduction in Domestic Synthetic Yarn Production (2020-2024)

Context: National production statistics analysis.

Problem Identified: Synthetic fibre production contributes to potential microfibre generation.

Findings: Production of synthetic yarns decreased threefold between 2020 and 2024, reaching levels comparable to cotton yarn production.

Implication: Potential reduction in domestic production-related microfibre generation, although import dynamics remain relevant.

6.3.2. Case Study 6: Apparel Import Dynamics and Consumption-Driven Microfibre Risk

Context: Analysis of trade statistics and textile imports.

Problem Identified: High import volumes of apparel and synthetic fibres.

Findings: Apparel import values significantly exceed fibre and yarn imports; synthetic fibre import value is almost three times that of cotton.

Lessons Learned: Use-phase laundering of imported garments may represent a major microfibre release pathway.

6.4. Spain

6.4.1. Case Study 7: Sectoral Restructuring and Sustainable Competitiveness

Context: Spanish textile restructuring following trade liberalisation.

Problem Identified: Increased competition from low-cost countries under WTO integration (Moral, 2004; European Commission, 2004).

Intervention Implemented: Strategic shift toward higher value-added segments, digitalisation and sustainability.

Results: 2024 turnover of €5.996 billion despite structural adjustment (CITYC, 2025).

6.4.2. Case Study 8: Regional Textile Clusters - Innovation and Process Specialisation

Context: Concentration of spinning, weaving and finishing in Cataluña and Comunitat Valenciana.

Problem Identified: Need for competitiveness through technological and process upgrading.

Intervention Implemented: Process innovation, specialisation in technical textiles and home textiles.

Lessons Learned: Industrial clustering supports innovation but requires environmental compliance alignment.

6.5. Comparative Insights from Case Studies

Across the eight case studies, three dominant intervention patterns emerge:

1. Wastewater filtration and environmental monitoring (Greece)
2. Process modernisation and R&D-driven upgrading (Lithuania)
3. Structural and trade-driven transformation (Poland and Spain)

Greece provides the strongest microfibre-specific environmental quantification evidence. Lithuania highlights innovation-led sustainability transition. Poland and Spain emphasise industrial restructuring and market-driven transformation. These case studies demonstrate that mitigation strategies vary across national contexts but converge around technological upgrading, regulatory alignment and lifecycle awareness.

7. Main Challenges and Barriers to Reducing Microfibre Release

This chapter synthesises the principal structural, technological, economic and regulatory challenges identified in the national reports of Greece, Lithuania, Poland and Spain regarding the reduction of synthetic microfibre release from the textile sector. While the lifecycle pathways of microfibre emissions are similar across countries, the obstacles to mitigation differ according to industrial structure, wastewater infrastructure, policy development and market dynamics.

7.1. Technological and Infrastructure Limitations

A common challenge across all four countries concerns the limited implementation of dedicated microfibre filtration technologies, particularly at industrial and household levels. In Greece, although pilot-scale filtration solutions demonstrated high removal efficiencies under EU-funded projects such as CLAIM, their large-scale adoption remains limited, especially among SMEs due to financial and regulatory constraints. Furthermore, variability in wastewater treatment infrastructure, including uneven tertiary treatment coverage, increases the risk of microfibre discharge into aquatic systems. Lithuania highlights ongoing modernisation of finishing technologies but acknowledges that microfibre-specific capture systems are not yet systematically implemented. The sector's strong export orientation places pressure on environmental compliance, yet investment capacity varies across enterprises. In Poland, despite declining domestic production of synthetic yarns, high import volumes and extensive apparel consumption maintain use-phase microfibre relevance. However, the sector's fragmentation and prevalence of micro-enterprises create barriers to technological investment. Spain faces similar constraints, where high business fragmentation and restructuring pressures limit investment capacity in advanced environmental technologies (Moral, 2004).

7.2. Economic and Structural Constraints

All four countries report SME dominance and sector fragmentation, which restrict economies of scale and limit financial capacity for environmental upgrading. In Poland, approximately 97% of clothing enterprises are micro-enterprises. Spain reports that more than half of companies have fewer than five employees. Lithuania identifies SME dominance in sewing and apparel production, with only around 0.2% classified as large enterprises. Greece similarly highlights SME prevalence and cost-related barriers to implementing advanced microfibre filtration technologies. Additionally, international competition and trade pressures reduce profit margins and prioritise short-term competitiveness over environmental investment, particularly in Spain and Poland.

7.3. Regulatory and Policy Gaps

While EU-level environmental and circular economy policies provide a common framework, national-level implementation remains uneven. Greece notes the absence of specific national guidelines targeting microfibre release from textiles, despite active research engagement. Lithuania emphasises alignment with EU sustainability policies but acknowledges that structured microfibre-specific regulation is still developing. Poland and Spain both situate environmental performance within broader industrial and trade policy contexts rather than within targeted microfibre regulation. A cross-country barrier therefore lies in the lack of harmonised microfibre-specific standards for textile production, laundering equipment or wastewater discharge, despite increasing scientific evidence.

7.4. Data and Monitoring Limitations

Another shared challenge concerns limited standardisation of monitoring methodologies and insufficient systematic data collection on microfibre release. Greece provides strong marine monitoring evidence, but continuous nationwide textile-source attribution remains limited. Lithuania and Poland rely more heavily on industrial statistics and production data than on environmental microfibre quantification. Spain integrates microplastic concerns into broader sustainability reporting but does not present extensive microfibre-specific datasets. This lack of harmonised and comparable microfibre monitoring systems complicates evidence-based policy development across countries.

7.5. Awareness and Behavioural Barriers

Use-phase emissions depend heavily on consumer laundering practices. However, none of the national reports indicate widespread deployment of household microfibre filtration devices. Greece highlights the dominance of conventional washing machines without fibre filters. Poland’s large apparel consumption market suggests similar exposure pathways. Public awareness, eco-design principles and product labelling mechanisms remain underdeveloped in all four contexts.

7.6. Comparative Interpretation

Across Greece, Lithuania, Poland and Spain, six common cross-cutting barriers emerge:

- Limited industrial-scale microfibre filtration implementation
- SME-dominated sector structure
- Investment constraints under international competition
- Lack of microfibre-specific regulatory frameworks
- Insufficient harmonised monitoring systems
- Limited consumer-level mitigation measures

While Greece demonstrates strong environmental research evidence, Lithuania shows structured industrial upgrading, and Poland and Spain emphasise industrial restructuring and trade pressures, all four countries face similar structural constraints in translating research into systemic microfibre reduction.

8. National success stories and best practices in reducing microfiber release

This chapter synthesises successful initiatives, innovative practices and emerging good practices identified in the national reports of Greece, Lithuania, Poland and Spain. While the degree of direct microfibre-specific implementation varies, all four countries present examples of technological upgrading, sustainability-oriented production, research integration and sectoral modernisation that contribute, directly or indirectly, to reducing synthetic microfibre release.

The best practices identified fall into four main categories:

1. Technological innovation in wastewater treatment and finishing
2. Sustainable production and eco-design integration
3. Research-industry collaboration models
4. Policy alignment and competitiveness through sustainability

8.1. Technological Innovation and Wastewater Solutions

Greece: Advanced Microplastic Filtration Demonstration

One of the most explicit microfibre-related success examples comes from Greece through participation in the EU-funded CLAIM project. Pilot wastewater filtration systems achieved microplastic removal efficiencies of up to 95%, demonstrating technical feasibility for capturing fibre-shaped particles before discharge into marine environments (Gkanasos et al., 2021). Although large-scale industrial implementation remains limited, the project represents a proof-of-concept success story demonstrating that high retention rates are technically achievable under operational conditions.

Lithuania: Modern Sustainable Finishing Technologies

Lithuanian textile companies have modernised finishing processes to reduce water and chemical use, integrating environmentally friendly technologies and digital textile printing systems. This upgrading reduces overall environmental footprint and indirectly limits microfibre discharge by improving process control and wastewater management. The rapid adoption of sustainable finishing technologies, particularly among export-oriented firms, reflects alignment with EU environmental standards.

8.2. Industry Transformation Toward Higher Value-Added and Technical Textiles

Poland: Structural Shift and Synthetic Production Reduction

Poland reports a significant decrease in domestic synthetic yarn production between 2020 and 2024, reaching levels comparable to cotton yarn production. Although import dynamics complicate the overall picture, this reduction in domestic synthetic output represents a potential structural contribution to lowering industrial microfibre generation. Additionally, sector repositioning toward technical and higher value-added textiles indicates a strategic shift away from mass low-cost production.

Spain: Competitive Upgrading Through Sustainability and Specialisation

Spain's textile sector has responded to global trade pressures by specialising in higher value-added segments such as technical textiles, advanced fabrics and home textiles. Innovation, digitalisation and sustainability are positioned as competitiveness drivers in the Spanish report, reflecting a long-term restructuring process (Moral, 2004; European Commission, 2004). By moving toward specialised and quality-focused production, Spanish firms strengthen environmental compliance capacity and reduce reliance on low-cost, high-volume synthetic mass production models.

8.3. Research-Industry Collaboration as a Good Practice

Lithuania presents a structured collaboration model between industry and research institutions, particularly Kaunas University of Technology (KTU) and the Textile Institute (FTMC), supporting innovation in smart textiles, protective materials and sustainable processes. Similarly, Greece demonstrates active engagement of academic institutions in environmental monitoring and EU research projects addressing microplastics. These collaborative ecosystems represent best practices because they facilitate knowledge transfer from environmental research into industrial application.

8.4. Alignment with EU Sustainability and Circular Economy Objectives

All four national contexts demonstrate increasing alignment with EU-level sustainability frameworks. Greece emphasises cleaner production and wastewater innovation. Lithuania integrates circular economy principles and export-oriented environmental compliance. Poland situates sectoral transformation within broader industrial restructuring dynamics. Spain frames sustainability as a competitiveness strategy under global trade integration. While microfibre-specific regulation remains limited, sustainability-driven modernisation across countries constitutes an enabling framework for future microfibre mitigation.

8.5. Comparative Interpretation

Across the four countries, success stories share common characteristics:

- Demonstration of technological feasibility (Greece)
- Modernisation of finishing processes and R&D integration (Lithuania)
- Structural production shifts and industrial repositioning (Poland)
- Sustainability-driven competitiveness strategies (Spain)

However, a critical observation emerges: most best practices indirectly reduce microfibre release through sustainability improvements, rather than directly targeting fibre shedding as a standalone environmental parameter.

Future best practices would benefit from integrating:

- Standardised microfibre measurement protocols
- Dedicated filtration systems at industrial and household levels
- Eco-design criteria addressing fibre shedding durability

9. National policies and regulatory framework

This chapter synthesises the regulatory and policy frameworks relevant to microplastics and synthetic microfibre release in Greece, Lithuania, Poland and Spain. Although all four countries operate within the overarching EU legislative environment, national implementation, enforcement intensity and sectoral integration differ. The analysis focuses on:

1. National legislation relevant to microplastics and textile sustainability
2. Alignment with EU directives and circular economy policies
3. Strategic plans and incentive schemes
4. Standardisation and monitoring activities

9.1. National Legislative Context

Across all four countries, there is no standalone national legislation specifically targeting microfibre release from textiles. Instead, regulation is embedded within broader environmental, waste and water management frameworks.

The Greek report indicates that environmental protection is primarily governed through national transposition of EU directives on water quality, marine protection and waste management. While microplastics are increasingly recognised as a marine pollution concern, there are currently no textile-specific microfibre emission standards. Wastewater discharge is regulated through national water legislation aligned with EU frameworks, but microfibre quantification is not yet a formal compliance parameter.

Lithuania aligns its environmental governance strongly with EU sustainability and circular economy strategies. The report emphasises structured alignment with EU environmental performance standards in textile production and finishing, particularly for export-oriented firms. However, as in Greece, no specific microfibre discharge thresholds are defined in national law.

Poland regulates textile production and wastewater management under general environmental protection, water law and waste legislation. The report situates textile-related microplastic concerns within broader industrial and trade policy frameworks rather than under dedicated environmental regulation.

Spain’s textile regulatory environment reflects EU integration and WTO-related trade restructuring (Moral, 2004; European Commission, 2004). Environmental compliance obligations apply through national implementation of EU water and waste directives. Sustainability increasingly functions as a competitiveness requirement, but microfibre-specific regulation remains indirect.

9.2. Alignment with EU legislation

All four countries operate within EU-level frameworks including:

- Water Framework Directive
- Marine Strategy Framework Directive
- Urban Wastewater Treatment Directive
- Circular Economy Action Plan

The national reports consistently indicate strong EU alignment.

- Greece emphasises marine monitoring and wastewater treatment obligations
- Lithuania integrates circular economy principles into textile sector development
- Poland positions textile transformation within EU industrial and trade integration contexts
- Spain links sustainability compliance to EU competitiveness and restructuring strategies

However, EU-level regulation on microplastics is still evolving, and explicit microfibre release standards for textiles or washing machines are not yet fully harmonised at national level.

9.3. Strategic plans, incentives and programmes

Greece highlights participation in EU-funded research initiatives (e.g., CLAIM) addressing microplastic filtration technologies. However, structured national incentive schemes specifically targeting microfibre reduction in textile manufacturing are limited.

Lithuania integrates sustainability upgrading into sectoral development strategies, particularly through innovation support, R&D collaboration and environmentally friendly production processes. Export-driven compliance acts as an indirect regulatory driver.

Poland's report highlights structural transformation and adaptation toward higher value-added segments, influenced by market pressures and EU integration. However, targeted microfibre mitigation incentives are not yet prominently documented.

Spain situates sustainability and innovation within industrial competitiveness policy. The sector's adaptation to global competition reinforces environmental upgrading as a strategic necessity, although microfibre-specific instruments remain indirect.

9.4. Standardisation and Monitoring Activities

Monitoring of microplastics varies across countries.

- Greece provides documented environmental monitoring data in marine and freshwater systems

- Lithuania focuses more on industrial performance and technological upgrading than on environmental fibre quantification
- Poland relies heavily on industrial and trade statistics
- Spain integrates sustainability reporting but does not present detailed microfibre monitoring frameworks

A key cross-country gap is the absence of harmonised national standards for measuring microfibre release during production or laundering.

10. Training needs and educational proposals

This chapter synthesises the training needs and educational recommendations identified in the national reports of Greece, Lithuania, Poland and Spain. The analysis aims to identify common gaps and cross-cutting priorities that inform the development of WP2 outputs within MicroWeave-TEX (Project No. 2025-1-ES01-KA220-HED-000356411).

Although the four countries differ in industrial structure and research emphasis, they converge on the need for structured, interdisciplinary and sustainability-oriented educational responses addressing synthetic microfibre release across the textile lifecycle.

10.1. Training Needs and Education Proposals

Limited Systematic Integration in Higher Education

All four national reports indicate that although research and policy awareness are increasing, microfibre-specific content is not yet systematically embedded in higher education programmes.

- Greece demonstrates strong research activity in marine and wastewater monitoring, yet structured curricular integration remains limited.
- Lithuania highlights the growing need for engineering competences as the sector shifts toward high-value technical textiles.
- Poland emphasises sector structure and production trends, but microfibre mitigation training is not consistently formalised in education pathways.
- Spain integrates sustainability within competitiveness strategies, yet dedicated microfibre modules are not clearly institutionalised

This indicates a common gap between scientific knowledge and educational delivery.

Need for Interdisciplinary Competences

Microfibre release intersects multiple domains:

- Textile engineering
- Polymer science
- Wastewater engineering
- Environmental monitoring
- Circular economy
- Industrial sustainability management

Lithuania explicitly notes increasing demand for technical and engineering professionals, while Greece provides strong environmental monitoring expertise that could be more deeply integrated into engineering curricula. Educational programmes must therefore bridge environmental science and textile production systems.

Practical Monitoring and Measurement Skills

Although Greece provides documented marine and freshwater monitoring data, systematic laboratory training in microfibre detection and quantification is not consistently institutionalised across the four countries. Lithuania and Poland focus more on industrial statistics and production structures than on fibre-specific analytical methodologies

There is a shared need for training in:

- Fibre sampling methodologies
- Laboratory identification techniques
- Lifecycle emission assessment
- Evaluation of filtration technologies

SME-Oriented Sustainability Education

The textile sectors in all four countries are dominated by SMEs:

- Poland: approximately 97% micro-enterprises in clothing
- Spain: majority of firms with fewer than five employees
- Lithuania: only around 0.2% large enterprises
- Greece: strong SME prevalence with cost-related implementation barriers

This structure requires practice-oriented, accessible and scalable training tools that can support small and medium-sized enterprises in implementing microfibre mitigation strategies.

10.2. Recommendations for curriculum integration and professional training

Based on the comparative analysis, the following priorities are proposed:

1. Lifecycle-Based Modules: Integration of modules covering fibre production, industrial shedding, wastewater pathways, laundering emissions and end-of-life fragmentation.
2. Applied Laboratory Components: Hands-on training in fibre detection, wastewater analysis and evaluation of mitigation technologies.
3. Eco-Design and Sustainable Materials Education: Incorporation of durability, material selection and circular economy principles, reflecting Lithuania's upgrading trajectory and Spain's sustainability-driven competitiveness approach
4. Policy and Regulatory Literacy: Training on EU environmental directives and sustainability frameworks applicable across all four countries
5. Innovative Pedagogical Tools (WP2 Context)

a. Multilingual learning materials
b. Interpretive dictionary
c. Podcasts linking research and industry
d. Simulation-based learning
e. Sustainability-oriented ‘escape room’ methodologies

These tools directly support the objectives of WP2 within MicroWeave-TEX.

Across Greece, Lithuania, Poland and Spain, the primary educational gap lies not in the absence of research, but in the insufficient integration of microfibre knowledge into structured, interdisciplinary and practice-oriented higher education programmes. Addressing these training needs is essential for building long-term capacity to reduce synthetic microfibre release across the textile lifecycle.

11. Conclusions

This report, developed under Task 2.1 of WP2 within MicroWeave-TEX (Project No. 2025-1-ES01-KA220-HED-000356411), provides a consolidated and comparative State-of-the-Art analysis of microplastic and synthetic microfibre release from the textile sector in Greece, Lithuania, Poland and Spain. Rather than replicating national reports, the document synthesises structural, environmental, technological and educational findings across countries to identify common patterns and context-specific differences.

11.1. Microfibre Release as a Lifecycle and Systemic Issue

Across all four national contexts, microfibre release is confirmed as a lifecycle-based phenomenon, occurring at multiple stages:

- Industrial production and finishing
- Domestic and commercial laundering
- End-of-life disposal and fragmentation

While the relative weight of each stage varies by country, the structure of the problem is shared. Greece provides the most explicit environmental monitoring evidence, demonstrating fibre dominance in marine and freshwater systems and linking wastewater pathways to marine exposure. Poland highlights the influence of production and import dynamics, showing declining domestic synthetic yarn production but significant apparel imports. Lithuania frames fibre release within industrial upgrading and sustainable finishing modernisation, while Spain integrates the issue into broader sector restructuring and competitiveness strategies.These differences demonstrate that although microfibre pollution is scientifically recognised across contexts, its national articulation depends on industrial structure, trade flows and environmental exposure.

11.2. Structural Constraints and Shared Barriers

Despite variations in sector size and specialisation, the four countries share several structural constraints:

- Strong SME dominance limiting investment capacity
- Absence of microfibre-specific discharge standards
- Limited harmonised monitoring methodologies
- Dependence on general water and waste legislation rather than targeted textile emission regulation

Poland and Spain report high business fragmentation. Lithuania and Greece also highlight SME prevalence and cost barriers to environmental technology adoption. While EU environmental frameworks provide a common regulatory foundation, national implementation of microfibre-specific measures remains limited.

11.3. Technological and Research Capacity

Research and innovation capacity exists in all four countries but is unevenly translated into industrial-scale mitigation.

- Greece demonstrates strong environmental research and pilot filtration technologies (e.g., CLAIM project).
- Lithuania shows structured research-industry collaboration supporting sustainable finishing and smart textiles.
- Poland provides detailed industrial and trade analysis relevant for assessing emission drivers.
- Spain links technological upgrading with long-term competitiveness and sustainability strategies.

However, widespread deployment of microfibre-specific filtration technologies or eco-design standards remains limited.

11.4. Educational and Capacity-Building Imperatives

A central conclusion of this report is that reducing synthetic microfibre release requires not only technological and regulatory measures, but also systematic educational intervention.

Across the four national reports, gaps are identified in:

- Integration of microfibre topics into textile and engineering curricula
- Interdisciplinary training linking environmental science and textile production
- Practical laboratory competences in fibre detection and monitoring
- SME-oriented sustainability education

These findings directly justify the development of structured, multilingual and interdisciplinary educational outputs within WP2 of MicroWeave-TEX.

11.5. Towards a Coordinated European Response

The comparative analysis demonstrates that microfibre pollution cannot be addressed through isolated interventions. Effective mitigation requires:

1. Lifecycle-based approaches covering production, use and end-of-life stages.
2. Harmonised monitoring and measurement methodologies.
3. SME-accessible technological solutions.
4. Integration of sustainability within industrial competitiveness strategies.
5. Structured higher education and professional training programmes.

While Greece's marine monitoring evidence, Lithuania's industrial upgrading, Poland's production and trade insights, and Spain's restructuring trajectory highlight different dimensions of the issue, they collectively illustrate the need for coordinated action at European level.

11.6. Final Reflection

Microfibre release from the textile sector represents a complex environmental challenge embedded in industrial systems, consumer behaviour, global trade and regulatory evolution. The comparative evidence gathered in this report confirms that:

- The scientific basis for concern is well established.
- Structural industrial characteristics strongly influence emission patterns.
- Regulatory frameworks are evolving but remain incomplete regarding textile-specific microfibre control.
- Education and capacity-building are essential enabling mechanisms for long-term mitigation.

Through its Educators' Hub and structured knowledge translation, MicroWeave-TEX contributes to bridging the gap between research, industry and higher education, strengthening the foundations for more sustainable textile systems in Europe.

12. References

Adamopoulou, A., Zeri, C., Garaventa, F., Gambardella, C., Ioakeimidis, C., & Pitta, E. (2021). Distribution patterns of floating microplastics in open and coastal waters of the Eastern Mediterranean Sea (Ionian, Aegean, and Levantine Seas). Frontiers in Marine Science, 8, 699000. https://doi.org/10.3389/fmars.2021.699000

Andrady, A. L. (2011). Microplastics in the marine environment. Marine Pollution Bulletin, 62(8), 1596-1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

Andrady, A. L. (2017a). The plastic in microplastics: A review. Marine Pollution Bulletin, 119, 12-22. https://doi.org/10.1016/j.marpolbul.2017.01.082

Arthur, C., Baker, J., & Bamford, H. (Eds.). (2009). Proceedings of the international research workshop on the occurrence, effects, and fate of microplastic marine debris. NOAA Technical Memorandum NOS-OR&R-30.

Bergmann, M., Mützel, S., Primpke, S., et al. (2019). White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. Science Advances, 5. https://doi.org/10.1126/sciadv.aax1157

Burns, E. E., & Boxall, A. B. A. (2018a). Microplastics in the aquatic environment: Evidence for or against adverse impacts and major knowledge gaps. Environmental Toxicology and Chemistry, 37, 2776-2796. https://doi.org/10.1002/etc.4268

Caruso, G. (2019). Microplastics as vectors of contaminants. Marine Pollution Bulletin, 146, 921-924. https://doi.org/10.1016/j.marpolbul.2019.07.052

Centro de Información Textil y de la Confección-CITYC. (2025). Datos Generales Industria Textil Española.

Cesa, F. S., Turra, A., Checon, H. H., et al. (2020). Laundering and textile parameters influence fibers release in household washings. Environmental Pollution, 257, 113553. https://doi.org/10.1016/j.envpol.2019.113553

Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin, 62, 2588-2597. https://doi.org/10.1016/j.marpolbul.2011.09.025

De Falco, F., Di Pace, E., Cocca, M., & Avella, M. (2019). The contribution of washing processes of synthetic clothes to microplastic pollution. Scientific Reports, 9, 6633. https://doi.org/10.1038/s41598-019-43023-x

de Souza Machado, A. A., Kloas, W., Zarfl, C., et al. (2018). Microplastics as an emerging threat to terrestrial ecosystems. Global Change Biology, 24, 1405-1416. https://doi.org/10.1111/gcb.14020

Dris, R., Gasperi, J., Mirande, C., et al. (2017a). A first overview of textile fibers, including microplastics, in indoor and outdoor environments. Environmental Pollution, 221, 453-458. https://doi.org/10.1016/j.envpol.2016.12.013

Eriksen, M., Mason, S., Wilson, S., et al. (2013). Microplastic pollution in the surface waters of the Laurentian Great Lakes. Marine Pollution Bulletin, 77, 177-182. https://doi.org/10.1016/j.marpolbul.2013.10.007

European Commission. (2004). Study on the implications of the 2005 trade liberalization in the textile and clothing sector.

Eurostat. (2023). Manufacturing industry statistics - Textiles and wearing apparel (NACE C13-C14). https://ec.europa.eu/eurostat/

Frias, J. P. G. L., & Nash, R. (2019). Microplastics: Finding a consensus on the definition. Marine Pollution Bulletin, 138, 145-147. https://doi.org/10.1016/j.marpolbul.2018.11.022

Gasperi, J., Wright, S. L., Dris, R., et al. (2018a). Microplastics in air: Are we breathing it in? Current Opinion in Environmental Science & Health, 1, 1-5. https://doi.org/10.1016/j.coesh.2017.10.002

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7), e1700782. https://doi.org/10.1126/sciadv.1700782

Gkanasos, A., Tsiaras, K., Triantaphyllidis, G., Panagopoulos, A., Pantazakos, G., Owens, T., Karametsis, C., Pollani, A., Nikoli, E., Katsafados, N., & Triantafyllou, G. (2021). Stopping macroplastic and microplastic pollution at source by installing novel technologies in river estuaries and wastewater treatment plants: The CLAIM project. Frontiers in Marine Science, 8, 738876. https://doi.org/10.3389/fmars.2021.738876

Halden, R. U. (2010). Plastics and health risks. Annual Review of Public Health, 31, 179-194. https://doi.org/10.1146/annurev.publhealth.012809.103714

Hermsen, E., Mintenig, S. M., Besseling, E., & Koelmans, A. A. (2018). Quality criteria for the analysis of microplastic in biota samples: A critical review. Environmental Science & Technology, 52, 10230-10240. https://doi.org/10.1021/acs.est.8b01611

Instituto Nacional de Estadística. (2023). Estadística estructural de empresas: Sector industrial. https://www.ine.es/dyngs/Prensa/EEESI2023.htm

Jenner, L. C., Rotchell, J. M., Bennett, R. T., et al. (2022). Detection of microplastics in human lung tissue using μFTIR spectroscopy. Science of the Total Environment, 831, 154907. https://doi.org/10.1016/j.scitotenv.2022.154907

Kermenidou, M., Frydas, I. S., Moschoula, E., Kousis, D., Christofilos, D., Karakitsios, S., & Sarigiannis, D. (2023). Quantification and characterization of microplastics in the Thermaic Gulf, in the North Aegean Sea. Science of the Total Environment, 892, 164299. https://doi.org/10.1016/j.scitotenv.2023.164299

Koutsikos, N., Koi, A. M., Zeri, C., Tsangaris, C., Dimitriou, E., & Kalantzi, O.-I. (2023). Exploring microplastic pollution in a Mediterranean river: The role of introduced species as bioindicators. Heliyon, 9(4), e15069. https://doi.org/10.1016/j.heliyon.2023.e15069

Leslie, H. A., et al. (2022). Discovery and quantification of plastic particle pollution in human blood. Environment International, 163, 107199.

Moral, M. J. , & P. C. (2004). El sector textil y confección en España ante un futuro incierto.

Murphy, F., Russell, M., Ewins, C., & Quinn, B. (2017). The uptake of macroplastic & microplastic by demersal & pelagic fish in the Northeast Atlantic around Scotland. Marine Pollution Bulletin, 122, 353-359. https://doi.org/10.1016/j.marpolbul.2017.06.073

Napper, I. E., & Thompson, R. C. (2016). Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions. Marine Pollution Bulletin, 112, 39-45. https://doi.org/10.1016/j.marpolbul.2016.09.025

Od potęgi do niszy dla wytrwałych. Co czeka branżę włókienniczą? 2024; https://media.big.pl/informacje-prasowe/832884/od-potegi-do-niszy-dla-wytrwalych-co-czeka-branze-wlokiennicza

Polska branża odzieżowa na tle światowych rynków, https://www.trade.gov.pl/wiedza/polska-branza-odziezowa-na-tle-swiatow, 25.11.2025; KO BP, Departament Analiz Ekonomicznych, „Rynki międzynarodowe: odzież. Sytuacja bieżąca i prognozy do 2029", sierpień 2025

Producenci tekstyliów 24-11-2025; https://www.coig.com.pl/wykaz_lista_producentow-tekstyliow.php

Ragusa, A., Svelato, A., Santacroce, C., et al. (2021). Plasticenta: First evidence of microplastics in human placenta. Environment International, 146, 106274. https://doi.org/10.1016/j.envint.2020.106274

Rosalio. Blog. 2025. Polska jest 6. w Europie w wydatkach na modę, ale 78% nadal kupuje stacjonarnie. Co się zmieni? https://rosalio.pl/blog/polska-rynek-mody-digitalizacja-2025-prognozy/?srsltid=AfmBOoob_Z-Ee1RcJgoWtDdwVfWktDVhfug5EtEjB8HtazUs8wZsNues#badanie-cyfrowa-przepasc

Sajjad, M., Huang, Q., Khan, S., et al. (2022). Microplastics in the soil environment: A critical review. Environmental Technology & Innovation, 27, 102408. https://doi.org/10.1016/j.eti.2022.102408

Schwabl, P., Koppel, S., Königshofer, P., et al. (2019a). Detection of various microplastics in human stool: A prospective case series. Annals of Internal Medicine, 171, 453-457. https://doi.org/10.7326/M19-0618

SEPEE - Hellenic Fashion Industry Association. (2023). Annual report of the Greek textile and clothing sector 2023.

Suaria, G., Achtypi, A., Perold, V., et al. (2020). Microfibers in oceanic surface waters: A global characterization. Science Advances, 6, eaay8493. https://doi.org/10.1126/sciadv.aay8493

Walkowska-Macias K. Produkcja wyrobów przemysłowych w latach 2020-2024, GUS, Warszawa 2025.

Woodall, L. C., Sanchez-Vidal, A., Canals, M., et al. (2014). The deep sea is a major sink for microplastic debris. Royal Society Open Science, 1, 140317. https://doi.org/10.1098/rsos.140317

Wright, S. L., & Kelly, F. J. (2017a). Plastic and human health: A micro issue? Environmental Science & Technology, 51, 6634-6647. https://doi.org/10.1021/acs.est.7b00423

Yearbook of Foreign Trade Statistics of Poland 2022, 2023, 2024.

13. Annexes

Annex I: National Report – Greece

13.1. Introduction

Microplastics and microfibres have emerged as critical environmental contaminants across global marine and freshwater systems, with growing scientific attention directed at their prevalence, fate, and impacts. In Europe and particularly in the Mediterranean region, the issue is amplified due to high population density, intense coastal activity, seasonal tourism, and semi-enclosed basins that promote accumulation of plastic particles. Greece, located at the heart of the Eastern Mediterranean, exhibits similar patterns, with multiple studies documenting the presence of microplastics in surface waters, sediments, marine organisms, rivers, and coastal environments. These findings underscore the need for a systematic analysis of national data and sectoral dynamics, especially regarding textile-derived microfibres, a key but under-studied source of microplastic pollution (Adamopoulou et al., 2021).

Microplastics in the Greek marine environment have been recorded in a variety of marine compartments, including the open Aegean and Ionian Seas, gulfs near metropolitan areas, and remote islands. Recent studies highlight significant spatial variability, shaped by oceanographic features such as surface slicks, local currents, and proximity to urban centres. For example, floating microplastics in the Aegean and Ionian Seas show concentrations comparable to global hotspots, with polyethylene (PE), polypropylene (PP), and polystyrene (PS) dominating the polymer composition, patterns strongly linked to packaging and textile fragmentation (Kalogerakis et al., 2017; Adamopoulou et al., 2021). This context frames microfibres as a central topic for Greece, given the high consumption of synthetic textiles, widespread washing-machine usage, and ageing wastewater treatment infrastructure.

Moreover, biomonitoring studies in Greek seas reveal clear evidence of microplastic ingestion across multiple species. Research in Zakynthos showed that Paracentrotus lividus sea urchins ingest microplastics present in sediments, with oxidative-stress biomarkers indicating physiological responses to exposure (Gigka et al., 2023). Similarly, the Mediterranean monk seal (Monachus monachus), a critically endangered species sampled non-invasively through faeces, was found to ingest microplastics and associated chemical additives such as phthalates, demonstrating the bioavailability and trophic transfer of these particles in Greek waters (Hernandez-Milian et al., 2023). These findings reinforce the ecological relevance of microplastic pollution in the national context.

Greek freshwater systems also act as key transport pathways of microplastics from terrestrial activities to coastal zones. A recent study on the Kifissos River, flowing through the Athens metropolitan area, identified microplastics in both the water column and the gastrointestinal tracts of freshwater fish, indicating a moderate but continuous flux of urban-derived microplastics toward coastal ecosystems. Polyethylene, polypropylene and polyvinyl alcohol dominated polymer types, reflecting typical sources such as packaging materials and textile fibres (Koutsikos et al., 2023). This evidence is particularly relevant for microfibre pollution, since synthetic fibres from garment washing represent one of the major pathways through wastewater systems into rivers and coastal waters.

On a national level, Greek research institutions, including the Hellenic Centre for Marine Research (HCMR), major universities, and environmental organisations, have produced an expanding body of work that documents the occurrence, distribution, and ecological implications of microplastics. Reports from HCMR and citizen-science surveys (e.g., Aegean Rebreath collaboration) demonstrate substantial loads of microplastics in Greek beaches, with fibre-like particles being one of the most frequent categories, consistent with textile sources (HCMR, 2022). These findings highlight the importance of microfibres in the national scenario and the need for improved monitoring, mitigation and regulation.

The European Marine Strategy Framework Directive (MSFD) provides the policy framework for assessing and addressing marine litter in Greece, including microplastics and microfibres (EC, 2017). However, despite progress in monitoring macroplastics, systematic national data on microfibres, especially those released during textile production, washing and end-of-life disposal, remain limited. This national report aims to fill that gap by providing an integrated overview of the Greek textile sector, evaluating microfibre occurrence and sources, assessing national scientific contributions, and identifying barriers and opportunities for mitigation and training.

13.1.1. Purpose of the National Report

The purpose of this national report is to present a comprehensive overview of the status of microplastics and microfibres in Greece, with emphasis on their relevance to the textile lifecycle and the associated environmental impacts. This includes synthesising scientific findings, assessing national sectoral characteristics, and identifying country-specific challenges and opportunities. The report follows the common structure defined in Task T2.1: State-of-the-art in the field of microplastics and synthetic microfibres release from fashion products to water of the Erasmus+ project number: 2025-1-ES01-KA220-HED-000356411, Sustainable solutions in the textile industry to reduce the release of microplastics/synthetic fibres, MicroWeave-TEX, to ensure comparability between participating countries and to contribute to the European-level State-of-the-Art Report (D2.1).

Scope and Structure

This report covers:

- an introduction to the issue of microplastics in the Greek context;
- an overview of the national textile industry;
- an assessment of the relevance of microplastics/microfibres in Greece;
- identification of national sources of microfibre release across the textile lifecycle; and
- documentation of scientific and technical studies produced by Greek organisations.

The following chapters provide detailed analyses based on peer-reviewed publications, national reports, uploaded scientific documents, and supplementary web-sourced data for policy and industry context.

13.2. National textile industry overview

The Greek textile and clothing industry is one of the oldest manufacturing sectors in the country and has historically played a significant role in national employment and exports. Although the sector experienced a decline after the early 2000s due to increased competition from low-cost production countries, it remains a notable part of Greece's manufacturing landscape. Today, the industry is characterised by a mix of small- and medium-sized enterprises (SMEs), vertically integrated companies, and specialised producers focusing on high-quality fabrics, cotton processing, yarn manufacturing, technical textiles, and niche fashion products. According to recent data from the Hellenic Fashion Industry Association (SEPEE), Greece hosts over 1,200 textile and clothing enterprises, employing more than 25,000 workers, with annual exports exceeding €2 billion, primarily to EU member states (SEPEE, 20230. These structural features establish Greece as a mid-sized but robust European player, with modernisation efforts increasingly directed toward sustainability and cleaner production (Eurostat, 2023).

In terms of fibre production and use, the Greek textile industry historically relied heavily on cotton, as Greece is the largest cotton-producing country in the European Union. Cotton textiles and yarns remain a core part of the sector's output, but synthetic fibres, particularly polyester, polyamide, acrylics, and blended fabrics, have become increasingly dominant due to affordability, durability and adaptability to fashion markets. The rise in synthetic fibre use is directly relevant to microfibre pollution, as polyester and polyamide garments shed fibres during washing, wear, and production processes. This trend aligns with the polymer types identified in Greek aquatic environments, where polyethylene (PE) and polypropylene (PP), often associated with packaging and synthetic textiles, dominate microplastic loads. For example, studies in the Thermaic Gulf revealed that PE and PP were the most common microplastic polymers in surface waters, sediments, and commercial fish-reflecting both consumer textile use and industrial sources (Kermenidou et al, 2023).

Geographically, textile manufacturing in Greece is concentrated in Northern Greece-particularly in Central Macedonia (Thessaloniki region), Eastern Macedonia and Thrace, and Thessaly. These regions host spinning mills, weaving and knitting units, dye houses, finishing plants, and apparel manufacturers. The clustering of textile operations creates localised pressures on wastewater networks, especially in areas where industrial effluents are discharged into rivers or municipal wastewater treatment plants (WWTPs). Such pathways have been associated with microplastic releases in Greek waters. For instance, recent research in the Kifissos River (Athens), though not exclusively linked to textile plants, shows that urban and industrial effluents significantly contribute to microplastic loads in freshwater ecosystems, highlighting vulnerabilities where similar textile-intensive regions may also pose risks (Koutsikos et al., 2023).

Industrial innovation in Greece increasingly focuses on environmental performance, driven both by EU regulations and market demand. Several Greek companies have adopted cleaner production methods such as water recycling, advanced filtration systems, and reduced chemical consumption in dyeing and finishing. However, the adoption of dedicated microfibre filtration technologies remains limited, particularly among SMEs due to cost barriers and lack of national-level guidelines. EU-funded initiatives, such as the CLAIM project, in which Greek institutions were heavily involved, have demonstrated technological solutions that could be adapted by the textile sector. The project piloted microplastic filtration technologies in wastewater treatment settings and showed high retention rates (up to 95 %), illustrating the potential of such systems for industrial textile effluents (Gkanasos et al., 2021).

From a market perspective, the Greek sector is increasingly orienting itself toward high-value segments such as technical textiles, sportswear, eco-friendly fabrics, and small-batch fashion production. These shifts may influence microfibre profiles, given the increased global use of high-performance synthetic textiles that shed fibres during production and household laundering. The prevalence of synthetic blends also aligns with the morphological characteristics of microplastics found in Greek marine samples, where fibres represent a significant fraction of identified particles-especially in urban-influenced gulfs such as Saronikos (Adamopoulou et al., 2021).

Overall, the Greek textile industry, while not as large as in earlier decades, remains an important national sector with notable environmental intersections. Its reliance on synthetic fibres, combined with ageing wastewater infrastructure and a large consumer market, positions it as a relevant contributor to microfibre emissions. Understanding these industrial characteristics is essential for identifying strategic intervention points across the textile lifecycle, from raw material selection to production, use, and end-of-life handling.

13.3. Relevance of microplastics/microfibres in the national context

Microplastics and microfibres have become an increasingly important environmental issue in Greece, due to the country's high coastal population density, intense tourism, and reliance on synthetic textiles. The Mediterranean Sea is recognised as one of the world's major microplastic accumulation basins, and studies show that the Eastern Mediterranean and Greek seas host concentrations comparable to global hotspots. Greek research has demonstrated that microplastics, especially fibres, are found across surface waters, sediments, beaches, and marine organisms, indicating their pervasive presence and continuous input from both land-based and maritime sources (Adamopoulou et al., 2021).

Within Greece, microfibres hold specific relevance because they are strongly linked to textile use and washing behaviours. The national market has increasingly shifted toward synthetic fibre-based garments (polyester, nylon, acrylic), mirroring global fast-fashion trends. This is reflected in the types of polymers found in Greek marine environments, where PE and PP, common in textile blends, dominate microplastic profiles. Research in the Thermaic Gulf, one of Greece's most industrialised coastal zones, revealed extremely high microplastic abundances in seawater and sediments, with PE and PP as the primary polymers, many of them fibre-shaped, suggesting a connection to textile use and fragmentation (Kermenidou et al., 2023).

Tourism significantly enhances microplastic relevance in the Greek context. Greece receives more than 30 million visitors annually, with peak summer activities concentrated along coastlines. Seasonal load increases of microplastics and macroplastics have been documented in numerous national monitoring efforts, including HCMR's 2022 national report on Greek beaches, where synthetic fibres constituted one of the most common microplastic categories. The report highlights that tourism-driven waste generation, laundering of tourist accommodation linens, and increased use of recreational textiles contribute to microplastic pollution pressures (HCMR, 2022).

At the ecological level, Greek studies consistently demonstrate that microplastics, including fibres, are ingested by marine organisms across trophic levels, including key species in national ecosystems. Sea urchins (Paracentrotus lividus) collected in the Ionian Sea were found to ingest microplastics present in sediments, some of which exhibited oxidative stress biomarkers linked to exposure (Digka et al., 2023).

Moreover, fibre-shaped particles are regularly detected in the digestive tracts of commercially important fish species in the Thermaic Gulf and other areas, indicating potential routes for trophic transfer toward humans, given Greece's high seafood consumption (Kermenidou et al., 2023).

Microplastic relevance is also linked to Greece's endangered flagship species. A study using non-invasive sampling of Mediterranean monk seal (Monachus monachus) faeces in Zakynthos found substantial microplastic ingestion, primarily of small (<3 mm) particles, along with phthalate additives. Fibres constituted a major proportion of ingested items, illustrating how textile-derived microfibres permeate even remote or protected marine habitats (Hernandez-Milian et al., 2023).

Freshwater systems further elevate the national relevance of microfibres, since rivers act as major transport pathways from urban areas to coastal seas. Research on the Kifissos River, a heavily urbanised river crossing Athens, found that microplastics, including fibres, were abundant in both the water and in fish gastrointestinal tracts. The polymer types identified (PE, PP, PVA) match common textile and packaging materials, suggesting household laundering, road runoff, and industrial discharges as contributing factors (Koutsikos et al., 2023). This is particularly relevant given that many Greek wastewater treatment plants are not equipped with advanced filtration capable of capturing microfibres.

Overall, microplastics and microfibres hold significant environmental, societal, and economic relevance for Greece, due to the country's textile consumption patterns, coastal geographical characteristics, and ecological sensitivities. The consistent presence of textile-derived fibres across environmental compartments indicates the need for targeted mitigation strategies adapted to national habits and infrastructure.

13.3.1. National Awareness and Policy Attention

In Greece, awareness of microplastic pollution has grown substantially over the past decade, supported by scientific publications, NGO campaigns, and EU-driven policy obligations. National media regularly highlight microplastic findings in Greek seas, especially around popular tourist destinations such as Zakynthos, Crete, and the Aegean islands. Public awareness initiatives by environmental organisations, including Aegean Rebreath, WWF Greece, and HCMR, have contributed to mobilising citizens through beach clean-ups, citizen-science sampling campaigns, and educational workshops. Evidence from the national HCMR–Aegean Rebreath 2022 survey points to strong societal recognition of microplastic issues, particularly regarding beach litter and fibre fragments (HCMR, 2022).

At the policy level, Greece implements the MSFD through national monitoring programmes that include microplastic indicators. However, microfibres specifically are not yet independently quantified under national legislation, despite their recognized environmental relevance. The CLAIM project, with strong Greek participation, demonstrated that wastewater systems can be engineered to remove microplastics, but national policy has not yet mandated fibre-capture technologies in household appliances or industrial facilities (Gkanasos et al., 2021).

Additionally, Greece has transposed EU directives banning certain single-use plastics, but these actions primarily target macroplastics rather than microfibres, underscoring a policy gap. The increasing presence of microplastics in commercially important seafood species, as documented in the Thermaic Gulf and other regions, has raised concern among public health authorities and consumers, motivating further research and long-term monitoring (Kermenidou et al., 2023).

Industry and Societal Relevance

Microfibres hold particular relevance for the Greek textile and fashion sector, household consumption patterns, and wastewater infrastructure. Increased reliance on synthetic textiles in Greece, driven by affordability and fast-fashion trends, leads to greater microfibre shedding during washing. With nearly all households using conventional washing machines lacking microfibre filters, large quantities of fibres are transported into wastewater systems daily. The lack of advanced tertiary filtration in many Greek WWTPs increases the likelihood of microfibres entering rivers and ultimately the sea.

The industrial relevance is equally significant: textile production clusters in Northern Greece include numerous dyeing, printing, and finishing operations, which are known globally to generate microfibre-rich effluents. Although Greek industries increasingly adopt environmentally friendly practices, fibre-capture solutions remain largely absent. Findings from the CLAIM project highlight how industrial and municipal wastewater systems can unintentionally release fibres, reinforcing the relevance of microfibres at the production stage (Gkanasos et al., 2021).

Societally, microfibre pollution intersects with Greece's identity as a tourism-based, coastal nation. Clean beaches are integral to the country's tourism economy, and rising public awareness of microfibres, often visible as lint-like fragments in sand, creates pressure for action from local authorities and businesses. The widespread detection of fibres in Greek marine species, including endangered monk seals and commonly consumed fish, further elevates the perceived urgency among citizens and stakeholders (Hernandez-Milian et al., 2023).

13.4. National sources of microfibre release

Microfibre emissions in Greece occur throughout the textile lifecycle, from industrial production to consumer use and final disposal, reflecting both structural characteristics of the Greek textile sector and national consumption patterns. Evidence from marine and freshwater studies in Greece consistently shows high proportions of fibre-shaped microplastics in environmental samples, highlighting the importance of understanding their origin and pathways.

13.4.1. Production stage

Industrial Shedding Sources

Microfibre releases during textile manufacturing in Greece primarily originate from spinning, weaving/knitting, brushing, cutting, dyeing, washing, and finishing operations. Northern Greece hosts the majority of textile finishing, dye houses, and processing facilities, many of which use synthetic fibres such as polyester, polyamide, and acrylic blends, materials known to shed fibres during mechanical abrasion and wet-processing. Although no dedicated Greek industrial microfibre quantification studies exist, international research demonstrates that pre-consumer textile finishing can shed millions of fibres per kilogram of fabric, particularly during brushing and mechanical finishing.

This aligns with the polymer types found in Greek marine samples, mainly PE and PP,indicating that industrial fragments contribute to environmental loads (Kermenidou et al., 2023).

Process Steps Contributing Most

Processes involving mechanical agitation (brushing, shearing, raising) and wet processing (dyeing, scouring, enzyme washing) are recognised globally as major microfibre emission points. In the Greek context, industrial clusters discharging wastewater into rivers or municipal networks amplify the risk of microfibres bypassing insufficient filtration systems. Evidence from the CLAIM project in Greek wastewater treatment settings confirms that microplastics, including fibre-shaped particles, are present in effluents and that advanced filtration can remove up to 95 % of them. This demonstrates both the presence of microplastics in industrial/urban wastewater and the potential for mitigation technology (Gkanasos et al., 2021).

13.4.2. Use phase

Consumer Use Stage

The majority of microfibre emissions in Greece originate from domestic laundering, as synthetic garments dominate the national textile market. Every wash cycle releases thousands to millions of microfibres depending on fabric type, detergent, and water conditions. Given that nearly all Greek households use conventional washing machines without fibre filters, released fibres enter wastewater systems unhindered.

Fibres are the most frequent microplastic morphology documented in Greek marine environments such as the Aegean, Ionian, Thermaic, and Saronikos Gulfs, confirming that domestic washing contributes significantly to environmental fibre loads (Adamopoulou et al., 2021).

Laundry Habits Specific to Greece

Greek households typically wash clothes at temperatures between 30-40°C, with frequent use of quick-wash programmes and high spin speeds, conditions known to increase fibre shedding. Additionally:

- Many households dry clothes outdoors, where sunlight and abrasion increase long-term fibre fragmentation.
- Laundry frequency is slightly higher in tourist regions during summer due to short-term accommodation turnover.
- Coastal tourism hotspots (Cyclades, Crete, Ionian Islands) experience seasonal increases in washing loads from hotels and rental units, adding pressure to local wastewater systems.

Findings in Zakynthos, an island with high seasonal tourism, reveal increased microplastic presence in sediments and marine organisms, supporting correlations between tourism activity and microplastic inputs (Digka et al., 2023).

Local Detergent Markets

Greek consumers rely heavily on powdered detergents and fragrance-enhanced softeners. Powder detergents, abrasive by nature, can increase fibre shedding during mechanical action. The widespread use of fabric softeners may reduce static but does not significantly reduce microfibre release.

Water Hardness Impacts

Much of Greece, especially Athens, Thessaly, Crete, and the Dodecanese, has hard to very hard water. Hard water increases mechanical stress on fabrics, leading to:

- greater fibre loss per wash,
- increased detergent use,
- higher washing temperatures, and
- faster degradation of synthetic garments.

These factors are indirectly reflected in studies showing high fibre loads in urban-influenced aquatic systems such as the Kifissos River and Saronikos Gulf (Koutsikos et al., 2023).

13.4.3. End-of-life handling

Disposal Practices

Textile end-of-life management in Greece remains limited, with the majority of used garments either:

- disposed of in mixed municipal waste,
- exported as second-hand clothing, or
- informally collected by charities.

Landfilling remains the dominant waste disposal method, and textiles undergo slow fragmentation in landfills, gradually generating microfibres that can leach into leachate or diffuse into surrounding soils.

Fibre-like particles found in Greek coastal and beach samples support the hypothesis that diffuse terrestrial leakage contributes to microplastic loads (HCMR, 2022).

National Textile Waste Strategies

Greece has begun aligning with EU Circular Economy requirements by introducing Extended Producer Responsibility (EPR) schemes for textiles, expected to become fully operational by 2025-2026. However:

- No dedicated national microfibre strategy currently exists.
- Collection rates for textiles remain low.
- Municipalities rarely sort textiles separately.

Consequently, microfibres continue to escape into the environment through improper disposal and fragmentation of unmanaged textile waste.

National Wastewater Treatment Systems

Greece operates more than 400 WWTPs, yet many smaller islands and rural areas lack tertiary treatment. Existing WWTPs remove a portion of microplastics through sedimentation, but microfibres are too small and buoyant, allowing them to pass through.

Evidence from Greek studies shows:

- Fibres dominate microplastic profiles in coastal waters near Athens and Thessaloniki, indicating WWTP escape routes (Adamopoulou et al., 2021).

- Fibres are present in river systems such as the Kifissos, confirming incomplete capture upstream (Koutsikos et al., 2023).
- CLAIM project trials in Greece showed that microplastics persist even after conventional treatment, highlighting the need for advanced filtration technologies (membrane bioreactors, dynamic sand filters, electro-coagulation) (Gkanasos et al., 2021).

Insufficient wastewater infrastructure on small islands, coupled with intense tourism, makes microfibre leakage particularly acute during peak months.

13.5. National scientific and technical studies

Greece has developed a strong and rapidly expanding research base on microplastics and, increasingly, on microfibres, spanning marine, freshwater and biota compartments. National studies document microplastics in open-sea waters, coastal zones, rivers, sediments, commercial fish, invertebrates and protected marine mammals, often with a focus on the Eastern Mediterranean. Together, they provide a robust scientific foundation for understanding sources, pathways and impacts of microplastics that can be directly leveraged for textile-related microfibre research.

13.5.1. Active research institutions

The Hellenic Centre for Marine Research (HCMR) is the leading national institution on microplastics, with multiple institutes and laboratories engaged in monitoring, experimental work and method development. The Institute of Oceanography has produced key studies on floating microplastics in the Ionian, Aegean and Levantine Seas, characterising concentrations, shapes and polymer types in relation to circulation patterns and proximity to urban sources (Adamopoulou et al., 2021).

The Institute of Marine Biological Resources and Inland Waters (IMBRIW) contributes to inland and coastal studies and maintains advanced facilities for microplastic extraction and analysis, as documented in its institutional evaluation, which highlights monitoring of aquatic pollution and biological indicators (IMBRIW, 2022).

Several Greek universities host active microplastic research groups. The University of the Aegean (Department of Marine Sciences and Department of Environment) collaborates closely with HCMR on field and biomonitoring studies in marine and freshwater environments, including microplastic ingestion in sea urchins and riverine fish. The Aristotle University of Thessaloniki (AUTH), particularly through the Environmental Engineering Laboratory and affiliated research centres (e.g. HERACLES Research Centre), leads work on microplastics in the Thermaic Gulf, integrating environmental monitoring with exposure and human health assessments.

Non-governmental research organisations also play a key role. Archipelagos - Institute of Marine Conservation collaborates with HCMR and Italian partners in monk seal research, implementing non-invasive methods to detect microplastics and plastic additives in faeces (Hernandez – Milian et al., 2023). These institutions rely on a range of laboratory infrastructures, including FT-IR and µFT-IR spectroscopy, Raman spectroscopy, stereomicroscopy and biochemical/biomarker labs, to characterise particles and assess biological effects, as detailed across national case studies.

13.5.2. University research projects

Greek universities have led or co-led multiple microplastic and microfibre-oriented research projects, often in collaboration with HCMR. In the Eastern Mediterranean open sea and coastal waters, Adamopoulou et al. (2021) quantified floating microplastics and explored distribution patterns in relation to sources and surface slicks, revealing high variability and dominance of PE, PP and PS in Greek waters, polymers strongly associated with packaging and textiles. In the Thermaic Gulf, Kermenidou et al. (2023) carried out one of the first integrated studies of microplastics in surface water, beach sediments and commercial fish, documenting extremely high abundances (up to millions of items per km^2) and highlighting PE and PP as the predominant polymers.

University-HCMR collaborations have also focused on biological effects and bioindicators. Digka et al. investigated microplastic ingestion in wild Paracentrotus lividus sea urchins in Zakynthos and related it to biomarkers of oxidative stress, neurotoxicity and genotoxicity, demonstrating subtle physiological responses even at relatively low environmental concentrations (Digka et al., 2023). Hernandez-Milian et al. (2023) developed a non-invasive method using Mediterranean monk seal faeces to assess microplastic ingestion and plastic additives, demonstrating the presence of 166 microplastic particles and several phthalates in samples from Zakynthos marine caves.

Freshwater-focused projects extend this work inland. Koutsikos et al. (2023) examined microplastics in the Kifissos River, an urban river flowing through the Athens metropolitan area, using an introduced fish species as a bioindicator. The study demonstrated moderate microplastic contamination in fish gastrointestinal tracts and river water, with PE, PVA and PP as dominant polymers, linking the findings to urban runoff and wastewater discharges. Complementary work on rivers and wastewater effluents entering the Aegean Sea has been conducted by Greek teams, providing first records of microplastic amounts and types in riverine and WWTP effluents and confirming their role as pathways to the sea (Zeri et al., 2021).

Historical pollution and biomarker expertise developed in Greece also underpins current microplastic research capacity. Early studies on biochemical markers of pollution in mussels (Mytilus galloprovincialis) from Saronikos Gulf established protocols for biomonitoring and contaminant-response assessment that have since been adapted to the context of microplastic and additive exposure (Tsangaris et al., 2004).

13.5.3. Industry Research and National R&D Activities

Industry-linked research on microplastics in Greece is particularly visible in the Horizon 2020 CLAIM project, where Greek SMEs and engineering companies collaborated with HCMR to develop and test technological solutions that directly target plastic and microplastic releases. Gkanasos et al. (2021) describe the design and deployment of the CLEAN TRASH system at the Kifissos River estuary and a microplastic filtration system installed at the Megara wastewater treatment plant, demonstrating ~90 % retention for macroplastics and ~95 % retention for microplastics at lab scale.

The Greek SME New Naval led the development and field testing of the riverine litter collection system within CLAIM, focusing on macro- and mesoplastic interception at river mouths feeding into Saronikos Gulf (New Naval, 2024). These pilots, although not textile-specific, are directly relevant for future microfibre mitigation, as similar technologies could be adapted to textile industrial effluents or urban catchments with high fibre loads. Furthermore, Greek companies active in wastewater treatment and environmental technologies (e.g. Waste & Water SARL, also involved in CLAIM) have built testing infrastructure for filtration, pre-treatment and advanced oxidation systems that can be applied to microplastic and microfibre removal.

National and regional activities on marine litter more broadly, often involving chambers of commerce, port authorities and local industries, have provided data, pilots and awareness relevant to microplastics. For example, collaborations between HCMR and local stakeholders in the Saronikos and Thermaic Gulfs have combined monitoring of microplastics in biota and sediments with discussions on port waste management, shipping practices and urban runoff, laying the groundwork for future textile-specific R&D.

13.5.4. EU Project Participation

Greek institutions have been highly active in EU-funded projects related to marine litter and microplastics, which provide essential knowledge and infrastructure for microfibre-focused work.

- Horizon 2020 – CLAIM (Cleaning Litter by developing and Applying Innovative Methods in European Seas): Coordinated by HCMR, CLAIM brought together 19 institutions (including six SMEs) to develop new strategies to prevent marine plastic litter, focusing on riverine barriers, WWTP microplastic filtration, and modelling. Greek partners led technological development, field trials and modelling for the Eastern Mediterranean.
- Interreg MED – Plastic Busters MPAs: This project, with Greek participation, tackled the full management cycle of marine litter in Mediterranean Marine Protected Areas-from monitoring and assessment to prevention and mitigation. The project harmonised methods for microplastic monitoring and generated policy recommendations for MPAs across several countries, including Greek sites.
- Interreg & related initiatives – ACT4LITTER and Plastic Busters family of projects: Greek institutions and experts have been involved in successive Interreg projects focusing on marine plastic litter management and policy roadmaps in the Mediterranean, which integrate microplastic concerns into broader circular-economy and marine protection frameworks.
- Erasmus+ – Sea4All and related educational projects: Greek partners (e.g. Regional Directorate of Primary and Secondary Education of Crete, Archipelagos, universities) have participated in Erasmus+ projects such as Sea4All, which develop educational materials and digital tools to raise awareness about marine pollution, including plastics and microplastics, among teachers and students.

These EU projects have significantly strengthened Greek capacity in sampling, analysis, modelling, mitigation technology and education on microplastics. They also provide a direct bridge between national scientific findings and European-level policy processes, making them highly relevant for the integration of textile microfibre issues into future curricula, training materials and stakeholder engagement under WP2.

13.6. Case studies

In Greece, the majority of measures to address microplastic pollution have focused on three key areas: marine ecosystems, wastewater management and activities related to this field, and the coastal zone. This reflects Greece's long coastline and the importance of water-related infrastructure and maritime activities. Despite the restricted scope of applied actions that explicitly target textile-derived microplastics, several empirical studies and pilot initiatives have contributed relevant evidence on mitigation pathways, particularly in the scope of wastewater treatment systems and fishing-related technical textiles. The subsequent case studies illustrate representative Greek cases with demonstrated relevance to textile-related microplastic pollution (Adamopoulou et al., 2021; HCMR, 2022; WWF, 2025).

13.6.1. CLAIM - Mitigation of microplastics at wastewater treatment plant level

Context

The CLAIM project (Clean Litter by Developing and Applied Innovative Methods in European seas) is a Horizon 2020 research initiative involving Greek research organizations, including the Hellenic Centre for Marine Research (HCMR). The initiative focuses on the development and testing of new methods to reduce marine litter. In the context of Greece, CLAIM has examined river inputs and wastewater treatment plants (WWTPs) as critical pathways for microplastics entering marine environments. This is particularly relevant in urban catchments discharging into the Saronikos Gulf (Gkanasos et al., 2021, Tsangaris et al., 2004; HCMR, 2022).

Problem identified

Conventional WWTPs are not specifically designed to capture microplastics and microfibres. Although a significant proportion of particles is retained during treatment, residual microplastics may be released with treated effluents, while a considerable fraction is transferred to the sludge line. This creates ongoing environmental pressures through both aquatic discharges and sludge management practices. Textile-derived microfibres, generated mainly during domestic washing, are recognized as part of this input stream.

Intervention implemented

Within the CLAIM framework, integrated technological solutions were developed and tested to intercept microplastics before they reach marine environments. The approach combined in-river capture systems with retention technologies applied at WWTP inlets and outlets. These solutions were designed to operate as complementary modules within existing treatment infrastructures, without interfering with standard processes. Pilot testing addressed a broad range of particle sizes and morphologies, including fibrous microplastics consistent with textile abrasion (Gkanasos et al., 2021).

Quantitative results (kg/year reduction, %, etc.)

Pilot-scale and laboratory tests demonstrated microplastic removal efficiencies of up to 95 %, depending on particle characteristics and operational conditions. Modelling scenarios adapted to Greek urban settings suggested that the application of such systems could result in an estimated reduction of approximately 87 % of microplastic loads entering marine environments over a two-year period. The retained particle spectrum included fibrous microplastics, although results were not exclusively attributed to textile sources (Gkanasos et al., 2021).

Stakeholder engagement

The implementation of CLAIM entailed collaboration between research institutions, municipal water authorities and European project partners. Greek stakeholders played an important role by providing operational data and site-specific information, thus facilitating the adaptation of the proposed solutions to real infrastructure conditions. The project results were disseminated through scientific publications and stakeholder-oriented communication activities, achieving the dual objectives of facilitating knowledge transfer and encouraging future replication.

Lessons learned

The CLAIM case study corroborates the assertion that wastewater treatment facilities constitute a pivotal intervention point for mitigating microplastic emissions, encompassing textile-related microfibres. The case study indicates that the integration of technological add-ons upstream of marine discharge points can substantially improve retention efficiency. However, the long-term potency of these measures is strongly contingent upon the implementation of systematic monitoring programmes, meticulous maintenance schedules, and seamless integration with comprehensive source-reduction strategies.

13.6.2. Fishing gear and technical textiles as marine-based sources of microplastics

Context

The case study examines small-scale coastal fisheries along the Greek coastline and the extent to which synthetic fishing gear, such as nets and lines manufactured from polyamide (nylon) and polyethylene fibres, is utilized in these fisheries. These materials are 'technical textiles' engineered to last in challenging marine environments. It is evident that the commercial fishing sector represents a particularly salient topic in the context of national affairs, given the intensity of fishing activities and the prolonged exposure of fishing gear to the marine environment (Adamopoulou et al., 2021; Kermenidou et al., 2023).

Problem identified

Fishing nets and lines are instruments of daily use and remain in the sea for notable periods of time. Over time, normal use leads to material deterioration, resulting in the release of minute particles into the water. In the event of the loss or abandonment of fishing gear, this process continues unchecked, thereby adding to the overall presence of plastic in marine environments. Further research is needed to clarify the extent to which fishing-related polymers contribute to microplastic pollution (Adamopoulou et al., 2021; Kermenidou et al., 2023).

Intervention implemented

At the national level, there is an absence of a designated programme that is focused on addressing microplastic contamination from fishing equipment. Nevertheless, a number of monitoring and remediation programmes, supported by scientific analysis, have indirectly addressed this issue. A systematic and comprehensive classification of plastic debris by morphology and polymer type has been achieved through national-scale beach and marine monitoring activities that have been coordinated by research institutions. This endeavor has paved the way for the identification of fibrous materials that bear a remarkable resemblance to fishing-related textiles, thereby facilitating effective management and remediation strategies in the context of marine pollution. These activities provide a scientific basis for the development of targeted preventive measures, such as enhanced gear management and retrieval schemes (HCMR, 2022; Koutsikos et al., 2023).

Quantitative results (kg/year reduction, %, etc.)

Monitoring data indicate that fibrous plastic particles occur at low but persistent levels in coastal and marine environments, primarily within larger size fractions. Polymer analyses have identified materials consistent with fishing gear composition. While specific annual reduction figures are not available, the evidence points to a continuous contribution from marine-based technical textiles rather than short-term or episodic inputs (Adamopoulou et al., 2021; Digka et al., 2023).

Stakeholder engagement

Stakeholder participation has encompassed research organizations, environmental non-governmental organizations (NGOs), local fishers and volunteer networks engaged in marine litter monitoring and removal activities. Although structured, industry-led mitigation schemes retain a limited scope, these interactions have enhanced awareness of fishing gear as a source of plastic debris and microplastic pollution and facilitated the exchange of professional knowledge between scientific and local actors (WWF, 2025).

Lessons learned

This case study highlights fishing-related technical textiles as a distinct and under-addressed pathway for microplastic generation in Greece. Unlike land-based textile sources, these materials release particles directly into marine environments, bypassing wastewater treatment systems. Addressing this pathway requires sector-specific approaches combining prevention, monitoring and targeted training for fisheries stakeholders.

13.7. Main challenges and barriers

13.7.1. Limited attribution of microplastics to textile-related sources

Challenges in linking observed microplastics to textiles

In the specific context of Greece, a considerable challenge exists pertaining to the complexity involved in associating microplastics that are detected with specific sources, notably those that are associated with textile-related activities. The majority of national studies have concentrated on the documentation of the presence, spatial distribution and ecological effects of microplastics in marine and freshwater environments. The question of the origin of microplastics has been less often investigated. Consequently, the contribution of textiles is typically inferred indirectly, based on parameters such as particle shape or polymer type. In contradistinction, explicit source attribution is generally not employed.

Research undertaken in open and coastal waters has repeatedly reported the presence of fibrous particles; nevertheless, these particles tend to constitute a smaller proportion of the sample when compared to fragments or foams, which limits their usefulness for quantitative source attribution

(Adamopoulou et al., 2021). In a similar vein, large-scale beach monitoring programmes coordinated by the Hellenic Centre for Marine Research (HCMR) have indicated that fibres are not the dominant particle type in beach sediments. This finding suggests that this environmental compartment is not well suited for identifying textile-derived microplastics (HCMR, 2022).

13.7.2. Emphasis on marine environments over upstream sources

Gaps in monitoring wastewater and riverine pathways

It is important to note that another significant barrier is presented by the substantial emphasis that is placed on marine and coastal environments within the context of national monitoring initiatives. While these studies provide essential information on environmental exposure and ecological impacts, they are less effective in quantifying emissions linked to textile use, which are more likely to occur further upstream.

Research conducted in the context of study of rivers and wastewater analysis has indicated the presence of microplastic particles, that is to say, particles measuring less than 5 mm, including fibrous components, prior to their entry into the marine environment (Gkanasos et al., 2021; Koutsikos et al., 2023). This observation highlights the potential of urban ecosystems, such as rivers and wastewater treatment facilities, as conduits for distributing these particles into the marine ecosystem. A paucity of systematic monitored data exists for these compartments in Greece. This raises concerns relating to the capacity to establish effective mitigation strategies that address textile-related emissions at or in close proximity to their point of origin.

13.7.3. Insufficient quantitative evidence on mitigation performance

Lack of long-term and site-specific reduction data

Despite the testing of pilot interventions and technological solutions under controlled or semi-operational conditions, there remains a paucity of long-term quantitative data describing their effectiveness in real-world settings. The CLAIM project has demonstrated that high removal efficiencies can be achieved under specific conditions, with modelling suggesting substantial reductions in microplastic loads entering marine environments (Gkanasos et al., 2021). However, these results are not yet supported by consistent, facility-level data expressed in annual reduction metrics.

This limitation is particularly evident in the context of marine-based textile sources, such as fishing gear. Whilst there are several monitoring studies which have confirmed the presence of fibrous particles which are compatible with fishing-related polymers, these studies have not provided any quantified estimates of reduction associated with specific management or recovery measures (Adamopoulou et al., 2021; Kermenidou et al., 2023).

13.7.4. Policy and regulatory limitations

Absence of textile-specific approaches

Policy-wise, text-derived microplastics are not explicitly addressed in current provisions. National regulatory and sectoral strategic frameworks in Greece primarily address the issue of debris in the marine environment in broad terms, without a granular approach that would distinguish between different material types or product categories. Consequently, textiles are rarely treated as an independent source requiring customized monitoring or mitigation measures.

Policy-oriented analyses have been undertaken which have indicated that this generalized approach has the effect of diminishing the effectiveness of prevention strategies and reducing the uptake of solutions which are specific to individual sectors. This is particularly the case in relation to technical textiles which are utilized in marine activities (WWF, 2025).

13.7.5. Methodological and capacity-related gaps

Need for harmonization and targeted expertise

A synthesis of the reviewed studies ultimately reveals methodological differences in terms of sampling, analysis and reporting. These discrepancies render comparison and synthesis across datasets a complex endeavor. In numerous instances, constraints pertaining to fiber-specific identification and characterization have been observed to impede the interpretation of results. This phenomenon is especially salient when assessing the potential contributions of textile materials (Digka et al., 2023; Hernandez-Milian et al., 2023).

These gaps highlight a necessity for methodologies and capacity-building initiatives to be harmonized. It is considered imperative to enhance the technical proficiency of researchers, wastewater professionals and stakeholders engaged in marine operations, in order to optimize the caliber of monitoring and the pertinence of results for policy formulation (WWF, 2025).

13.8. National success stories and best practices

In Greece, successful practices related to microplastic mitigation are primarily associated with research-driven technological solutions, targeted pilot applications and collaborative initiatives linking scientific institutions with public authorities and civil society. Although large-scale industrial deployment remains limited, several examples demonstrate practical progress and provide transferable insights, particularly in relation to wastewater management, monitoring methodologies and cross-sectoral cooperation.

13.8.1. Innovative technologies

Advanced microplastic interception technologies in wastewater pathways

One of the most notable instances of technological success within the Hellenic context is associated with the development and testing of advanced interception systems for microplastics in riverine and wastewater environments. In the course of the CLAIM project, innovative technologies have been developed for the purpose of capture of microplastics, specifically at critical entry points such as river mouths and inflows to wastewater treatment plants. The objective of this capture process is to prevent the release of microplastics into marine ecosystems.

As evidenced by Gkanasos et al. (2021), these systems have demonstrated high removal efficiencies under pilot-scale conditions. This confirms that targeted technological add-ons have the potential for substantial enhancement of the performance of existing wastewater infrastructure with regard to microplastic retention. Technologies designed to capture microplastics do so effectively, even if they weren't originally developed for this purpose.

The present example illustrates how research-led innovation can be translated into practical solutions that are compatible with extant infrastructure and adaptable to different operational contexts.

13.8.2. Industry or municipal initiatives

Municipal engagement in monitoring and mitigation of microplastic pathways

At municipal level, best practices are chiefly reflected in the growing involvement of local authorities in monitoring and assessment activities related to microplastic pollution. The collaboration between municipalities, wastewater operators and research institutions has facilitated the collection of site-specific data and the testing of mitigation concepts in real operational settings.

Initiatives of this kind, often in conjunction with scientific collaborators, have facilitated enhanced comprehension of microplastic flows within urban catchments and wastewater systems, particularly in densely populated areas with effluent discharge into sensitive marine environments, such as the Saronikos Gulf (HCMR, 2022; Tsangaris et al., 2004). Despite the absence of these measures within formal municipal mitigation programmes at present, they signify a significant advancement in the direction of integrating considerations pertaining to microplastic into local water management practices.

13.8.3. Certifications or voluntary schemes

Voluntary engagement and awareness-driven practices

Contrary to the practices in other European countries, Greece currently lacks certified schemes or voluntary standards that specifically address the issue of textile-related microplastic emissions. Nonetheless, there has been an emergence of voluntary engagement in the form of initiatives driven by awareness, as well as participation in monitoring programmes led by research institutions and environmental organizations.

Despite their informal character, these efforts have enabled data collection, raised public awareness and encouraged stakeholder involvement, notably in the contexts of coastal and marine regions. As indicated by policy-oriented assessments, voluntary actions have a role to play as effective precursors to more structured frameworks, especially in the apparent absence of binding regulatory requirements targeting textile-derived microplastics (WWF, 2025).

13.8.4. Successful partnerships or projects

Research-based partnerships bridging science and policy

In Greece, the development of collaboration between research institutions and public authorities has been primarily driven by applied research initiatives. Collaborative endeavors encompassing research centers, universities, public bodies and non-governmental organizations have facilitated the systematic collection of data pertaining to microplastic pollution. It is evident that, as time has passed, these endeavors have led to the enhancement of analytical methodologies and the fortification of the dependability of the available datasets. Research outputs have also been disseminated beyond academic publications, contributing to their use in environmental management.

Studies by the Hellenic Centre for Marine Research have been central to this process. There is a growing body of research that provides consistent evidence on the occurrence, distribution and effects of microplastics across different environmental compartments (Adamopoulou et al., 2021; Digka et al., 2023; Hernandez-Milian et al., 2023). It is evident that, despite the present limitations on large-scale industrial applications, this experience underscores the efficacy of sustained collaboration between scientific and public institutions in informing policy development.

13.9. National policies and regulatory framework

Greece's regulatory framework on plastics and microplastics is largely driven by the transposition of EU legislation, particularly the Marine Strategy Framework Directive (MSFD), waste and circular economy directives, and the Single-Use Plastics (SUP) Directive. While there is no dedicated law yet on microfibres, microplastics are increasingly recognised in national policy through marine litter monitoring, waste management reforms and circular economy strategies. Descriptor 10 of the MSFD ('properties and quantities of marine litter do not cause harm to the coastal and marine environment') provides the overarching framework for assessing litter, including microplastics, in Greek marine waters (Galgani et a., 2013; EC, 2017; iSea, 2026).

13.9.1. National laws related to microplastics

The primary national law governing plastics and waste in Greece is Law 4819/2021 on waste management and the circular economy, which transposes key EU waste directives and introduces extended producer responsibility (EPR), separate collection targets and landfill reduction objectives. Among other measures, the law strengthens EPR obligations for packaging, prepares the ground for EPR in textiles and encourages separate collection of textile waste by 2025-2026, in line with EU requirements (Hellenic Republic, 2020; 2021).

A second cornerstone is Law 4736/2020, which transposes the EU Single-Use Plastics Directive (EU 2019/904) and introduces bans or restrictions on a range of SUP items, including cutlery, plates, straws, stirrers and expanded polystyrene food containers. The law entered into force in July 2021 and combines product bans with economic instruments, awareness campaigns and green public procurement measures (EC, 2020; Hellenic Republic, 2020; NKUA, 2026). Although its primary focus is macroplastics, the expected reduction in litter and packaging may also indirectly decrease microplastic generation through fragmentation.

In parallel, sectoral legislation and strategies (e.g. national waste prevention plans and marine environment policies) reference marine litter and plastic pollution as priority issues. However, textile-derived microfibres are still not explicitly addressed as a separate category, and there are no binding requirements for microfibre filters in washing machines or industrial facilities at national level (Hellenic Republic, 2021).

13.9.2. Alignment with EU legislation

Greece implements the Marine Strategy Framework Directive (2008/56/EC) through national marine strategies and monitoring programmes coordinated by the Ministry of Environment and Energy and research institutes such as HCMR. Descriptor 10 on marine litter has led to the establishment of monitoring programmes for beach litter, seafloor litter and microplastics in water and biota, using indicators and methodologies aligned with EU guidance and regional conventions (Galgani et al., 2013; EC, 2017). Recent syntheses of marine litter and microplastics in the Aegean Archipelago, led by Greek researchers, provide an integrated evidence base to support these MSFD obligations and highlight knowledge gaps relevant to policy, including the need for more systematic monitoring of microfibres and riverine inputs (Zeri et al., 2022; Anagnostou et al., 2024).

Under EU waste and circular economy legislation, Greece has also developed national strategies that align with targets on separate collection, landfill reduction and EPR, including provisions that will become directly relevant for textile waste streams. Law 4819/2021 foresees separate collection systems for textiles and eco-modulated fees for producers, which could in the future incorporate microplastic-related performance criteria (e.g. eco-design for low-shedding textiles) (Hellenic Republic, 2021).

13.9.3. Strategic plans, incentives and programmes

Greece has adopted a National Waste Prevention Programme and a broader circular economy agenda that emphasise prevention, reuse and recycling of materials, including plastics. These strategies promote separate collection, green public procurement and eco-innovation, with potential to integrate requirements and incentives for low-shedding textiles, microfibre filters and better design of synthetic products (Hellenic Republic, 2012; 2021).

Several national and EU-funded projects act de facto as policy pilots. Projects such as CLAIM and national initiatives like EVMAR (Evaluating Marine Litter in Greece) have generated data and recommendations on marine litter pathways, microplastic monitoring and mitigation technologies, supporting implementation of MSFD Descriptor 10 and informing national priorities (Rigatou et al., 2025; iSea, 2026). Educational and citizen-science projects (e.g. “Schools Against Plastics”) have been used by policymakers and NGOs as examples of good practice for integrating microplastics into environmental education and local action plans (HCMR, 2023; Beyond Plastics Med, 2026; Patsiou et al., 2026).

13.9.4. National standardization activities

Formal standardisation activities in Greece related specifically to microplastics and microfibres remain limited. National laboratories typically follow international or European protocols (e.g. MSFD monitoring guidelines, Plastic Busters MPAs protocols, harmonised intercalibration methods) rather than Greek-specific standards. Harmonisation work led by Greek scientists in interlaboratory comparison exercises and method evaluations, such as studies on extraction protocols and bioindicators, has, however, directly contributed to the development of best practices adopted in MSFD and regional seas conventions (Tsangaris et al., 2004; Scacco et al., 2022 Zeri et al., 2022).

Going forward, there is scope for the Hellenic Organisation for Standardisation (ELOT), research institutes and industry to develop or adopt national technical specifications on microplastic sampling, analytical methods and performance criteria for low-shedding textiles or filtration technologies. This would support consistent monitoring, facilitate compliance checks and create clearer signals for market actors in the textile and wastewater sectors.

13.10. Training needs and educational proposals

13.10.1. Training needs and education proposals

The rapid expansion of Greek research on microplastics and microfibres has not yet been fully translated into systematic training for key professional groups. Several gaps are evident across higher education, vocational education and continuous professional development:

- Textile and fashion engineers require deeper understanding of microfibre shedding mechanisms, eco-design for low-shedding fabrics, life cycle assessment (LCA) and recyclable fibre systems.
- Wastewater and water-utility professionals need training on microplastic monitoring, filtration technologies, sludge management and integration of microfibre considerations into plant operation and design.
- Teachers and educators require accessible, age-appropriate resources to integrate microplastics and microfibres into science, geography and environmental education curricula.
- Policy-makers and municipal staff need training on interpreting microplastic data, evaluating mitigation options, and designing local action plans that include textile-related measures.

Recent educational and citizen-science projects demonstrate both the need and the potential for such training. The 'Schools Against Plastics' initiative engaged Greek primary school students in beach macro- and microplastic monitoring, combining simple sampling protocols with data collection and interpretation; results show improvements in students' environmental awareness and understanding of plastic pollution (HCMR, 2023; Patsiou et al. 2026). Similar Greek work on digital storytelling and environmental literacy has also shown that innovative pedagogical approaches can effectively build students' understanding and attitudes regarding plastic waste (Andriopoulou et al., 2022).

At the same time, cutting-edge research on microplastics in key Greek ecosystems, such as seagrass meadows acting as sinks and vectors (Rigatou et al., 2025), or integrative reviews of marine litter and microplastics in the Aegean Archipelago (Zeri et al., 2022), highlights the need to train scientists, engineers and environmental managers in advanced methods (e.g. modelling, ecotoxicology, bioindicator use) and in translating research into management measures.

13.10.2. Recommendations for curriculum integration and professional training

Building on identified gaps and existing best practices, several concrete training proposals can be made for Greece:

1. Higher Education (Universities)
    - Integrate dedicated modules on microplastics and microfibres into curricula in environmental science, marine science, chemical engineering and textile engineering.
    - Use Greek case studies, e.g. microplastic ingestion in mussels and fish, seagrass meadows as sinks, monk seal monitoring, as teaching material to contextualise global concepts in national reality (Scacco et al., 2022, Zeri et al., 2022; Rigatou et al., 2025).
    - Promote interdisciplinary thesis projects combining textile design, wastewater treatment and environmental monitoring.
2. Vocational and professional training (VET, CPD)

- Develop short courses for WWTP operators, municipal staff and industry technicians on microplastic sampling, basic analytics, interpretation of results and mitigation technologies (e.g. filtration, retrofitting). CLAIM results and Greek WWTP pilots offer ready-made examples for training materials (Rigatou et al., 2025; iSea, 2026).
- Introduce modules on low-shedding textile design, circular business models and EPR obligations for professionals in the textile/fashion sector, linking upcoming EU textile regulations with national circular economy policies (Hellenic Republic, 2021).

3. School education and teacher training
   - Scale up programmes like 'Schools Against Plastics' into a national microplastics education initiative, providing a standardised toolkit for sampling, simple analysis and data sharing, supported by HCMR and the Ministry of Education (HCMR, 2023; Patsiou et al., 2026).
   - Integrate microplastics and microfibres into existing environmental education frameworks, including topics such as sustainable consumption, marine biodiversity and circular economy.
4. Fisheries and coastal stakeholders
   - Provide targeted training for fishers and aquaculture operators on marine litter and microplastics from fishing gear, including best practices for gear maintenance, retrieval schemes and participation in citizen-science monitoring. Recent multi-decadal datasets on marine litter ingestion in sea turtles and fish, involving Greek co-authors, offer powerful material for awareness-raising and professional training (Zeri et al., 2022; Kouvara et al., 2024)

These proposals can directly inform WP2 curricula, podcasts and teaching materials under the MicroWeave-TEX project, ensuring that educational outputs are grounded in up-to-date Greek evidence and address the specific training needs of national stakeholders.

13.11. Conclusions

Greece has developed an impressive and rapidly growing body of research on microplastics and microfibres, with Greek scientists contributing to both national case studies and global syntheses. Studies now span open-sea waters, coastal zones, seagrass meadows, beaches, rivers, wastewater systems and a wide range of organisms, including commercial fish, mussels, sea urchins, sea turtles and endangered monk seals. Recent work on seagrass meadows as microplastic sinks, integrated Aegean Archipelago assessments and citizen-science initiatives such as Schools Against Plastics illustrate the maturity and diversity of the national research landscape.

Despite this progress, significant gaps remain in linking observed microplastics directly to textile-related sources, particularly for microfibres. Most Greek studies identify fibres as an important morphological category and infer textile contributions from polymer types, but robust source apportionment (e.g. distinguishing between domestic washing, industrial processes and fishing gear) is still limited. Upstream compartments such as wastewater treatment plants, industrial discharges and household laundering remain relatively under-monitored compared to marine environments, constraining the design of source-focused mitigation strategies.

On the policy side, Greece has aligned with EU directives on marine litter, waste management and single-use plastics, and is progressively integrating circular economy principles, separate textile collection and EPR into national law. However, microfibres are not yet explicitly regulated, and there are no binding requirements for microfibre filters or low-shedding textile design. Existing initiatives, such as CLAIM pilots, Interreg projects and education programmes, demonstrate technical and social feasibility but have not yet been scaled into mainstream policy or practice.

Operationally, three broad lines of action emerge:

1. Strengthen source-focused monitoring and mitigation
    - Expand systematic monitoring of microfibres in wastewater, industrial effluents and rivers, integrating harmonised methods and interlaboratory protocols.
    - Pilot and scale up microplastic interception technologies at WWTPs and river mouths, building on CLAIM experience and targeting textile-dense catchments.
2. Integrate microfibres into policy and standardisation
    - Embed microfibre considerations into national implementation of EU textile, waste and circular economy policies, including EPR schemes and eco-design criteria.
    - Develop technical guidelines or standards for low-shedding textiles, washing machine filtration and microplastic sampling and analysis, in collaboration with ELOT, industry and research labs.
3. Invest in education, training and stakeholder engagement
    - Use national research and case studies to design structured training for textile engineers, wastewater professionals, teachers and coastal stakeholders.
    - Scale up citizen-science and school initiatives, which have proven effective in building environmental awareness and generating useful data for researchers and policymakers.

For higher education, industry and public managers, the key message is that Greece already possesses much of the scientific and technical capacity required to address textile-related microplastics. The challenge now lies in consolidating this knowledge into coherent policies, operational standards and training programmes that reduce microfibre emissions across the textile life cycle, from design and production to use and end-of-life, while supporting a just and innovative transition for the national textile sector.

13.12. References

Adamopoulou, A., Zeri, C., Garaventa, F., Gambardella, C., Ioakeimidis, C., & Pitta, E. (2021). Distribution patterns of floating microplastics in open and coastal waters of the Eastern Mediterranean Sea (Ionian, Aegean, and Levantine Seas). *Frontiers in Marine Science, 8*, 699000. https://doi.org/10.3389/fmars.2021.699000

Anagnostou, C., Kostianoy, A., Mariolakos, I., Panayotidis, P., Soilemezidou, M., & Tsaltas, G. (2024). Aegean Archipelagos: A significant place of human presence and civilization in the broader area – Human–nature interaction. In *The Aegean Sea Environment* (pp. 3–14). Springer Nature Switzerland. https://doi.org/10.1007/698_2024_1164

Archipelagos Institute of Marine Conservation. (2023). Marine mammal microplastic monitoring programme (Mediterranean monk seal), in collaboration with HCMR and international partners. (Documented via Hernandez-Milian et al., 2023.)

Aristotle University of Thessaloniki (AUTH) – Environmental Engineering Laboratory. (2023). Research infrastructure and expertise in microplastic environmental monitoring, as documented through projects in the Thermaic Gulf. (Referenced through peer-reviewed outputs.)

Beyond Plastic Med. (n.d.). *Schools Against Plastics*. Retrieved January 8, 2026, from https://www.beyondplasticmed.org/en/projects/assemble-allies-mobilize/schools-against-plastics/

Bray, L., Digka, N., Tsangaris, C., Camedda, A., Gambaiani, D., de Lucia, G. A., … Kaberi, H. (2019). *Determining suitable fish to monitor plastic ingestion trends in the Mediterranean Sea. Environmental Pollution, 247*, 1071–1077. https://doi.org/10.1016/j.envpol.2019.01.100

Cadiou, J.-F., Gerigny, O., Koren, Š., Zeri, C., Kaberi, H., Alomar, C., Panti, C., Fossi, M. C., Adamopoulou, A., Digka, N., Deudero, S., Concato, M., Carbonnel, A., Baini, M., Galli, M., & Galgani, F. (2020). *Lessons learned from an intercalibration exercise on the quantification and characterisation of microplastic particles in sediment and water samples. Marine Pollution Bulletin, 154*, 111097. https://doi.org/10.1016/j.marpolbul.2020.111097

Digka, N., Patsiou, D., Kaberi, H., Krasakopoulou, E., & Tsangaris, C. (2023). Microplastic ingestion and its effects on sea urchin *Paracentrotus lividus*: A field study in a coastal East Mediterranean environment. *Marine Pollution Bulletin, 196*, 115613. https://doi.org/10.1016/j.marpolbul.2023.115613

ELSTAT – Hellenic Statistical Authority. (2023). *Industrial production statistics of Greece.* https://www.statistics.gr

Erasmus+ Programme. (2020-2023). Sea4All: Educational tools and training for marine pollution awareness. European Union.

European Commission. (n.d.) (2017). *EU Marine Strategy Framework Directive*. European Union. Retrieved January 2, 2026, from https://research-and-innovation.ec.europa.eu/research-area/environment/oceans-and-seas/eu-marine-strategy-framework-directive_en research-and-innovation.ec.europa.eu

European Commission. (2020). Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment (Single-Use Plastics Directive). Official Journal of the European Union.

European Commission. (2017-2022). CLAIM – Cleaning Litter by developing and Applying Innovative Methods in European Seas. Horizon 2020 Project. Grant No. 774586.

Eurostat. (2023). *Manufacturing industry statistics – Textiles and wearing apparel (NACE C13-C14).* https://ec.europa.eu/eurostat/

Galgani, F., Hanke, G., Werner, S., & De Vrees, L. (2013). Marine litter within the European Marine Strategy Framework Directive. *ICES Journal of Marine Science, 70*(6), 1055–1064. https://doi.org/10.1093/icesjms/fst122

Galgani, F., Tsapakis, M., Pitta, P., Tsiola, A., Tzempelikou, E., Kalantzi, I., … Loiselle, S. A. (2019). Microplastics increase the marine production of particulate forms of organic matter. Environmental Research Letters, 14, 124085. https://doi.org/10.1088/1748-9326/ab59ca

Gkanasos, A., Tsiaras, K., Triantaphyllidis, G., Panagopoulos, A., Pantazakos, G., Owens, T., Karametsis, C., Pollani, A., Nikoli, E., Katsafados, N., & Triantafyllou, G. (2021). *Stopping macroplastic and microplastic pollution at source by installing novel technologies in river estuaries and wastewater treatment plants: The CLAIM project.* Frontiers in Marine Science, 8, 738876. https://doi.org/10.3389/fmars.2021.738876

Hellenic Centre for Marine Research (HCMR). (2022). Microplastics on the beaches of Greece: Results report. Aegean Rebreath.

Hellenic Centre for Marine Research (HCMR), Institute of Marine Biological Resources and Inland Waters (IMBRIW). (2022). Institute report 2018-2021. https://imbriw.hcmr.gr/wp-content/uploads/2024/10/imbriw_evaluation_report_final_17-21.pdf

Hellenic Centre for Marine Research (HCMR) & BeMed. (2023). *Schools against plastics* [Poster]. EurOCEAN 2023.

Hellenic Republic. (2012). Law 4042/2012: Protection of the environment through criminal law-Framework for waste management and harmonization with Directive 2008/98/EC. Government Gazette A’ 24/13-02-2012.

Hellenic Republic. (2020). Law 4736/2020. (2020). *Reduction of the impact of certain plastic products on the environment – Transposition of Directive (EU) 2019/904.* Government Gazette of Greece.

Hellenic Republic. (2021). Law 4819/2021. (2021). *Integrated waste management – Transposition of Circular Economy Package.* Government Gazette of Greece.

Hernandez-Milian, G., Tsangaris, C., Anestis, A., Fossi, M. C., Baini, M., Caliani, I., Panti, C., Bundone, L., & Panou, A. (2023). Monk seal faeces as a non-invasive technique to monitor the incidence of ingested microplastics and potential presence of plastic additives. *Marine Pollution Bulletin, 193*, 115227. https://doi.org/10.1016/j.marpolbul.2023.115227

iSea – Institute for Sustainability (n.d.). *Evaluating Marine Litter in Greece (EVMAR Project)*. Retrieved January 7, 2026, from https://isea.com.gr/evaluating-marine-litter-in-greece-evmar-project-eng/?lang=en

Interreg MED Programme. (2018-2022).Plastic Busters MPAs: Monitoring, preventing and mitigating marine litter in Mediterranean Marine Protected Areas. Interreg MED reference documentation.

Kalogerakis, N., Karkanorachaki, K., Kalogerakis, G. C., Triantafyllidi, E. I., Gotsis, A. D., Partsinevelos, P., & Fava, F. (2017). Microplastics generation: Onset of fragmentation of polyethylene films in marine environment mesocosms. *Frontiers in Marine Science, 4*, 84. https://doi.org/10.3389/fmars.2017.00084

Kermenidou, M., Frydas, I. S., Moschoula, E., Kousis, D., Christofilos, D., Karakitsios, S., & Sarigiannis, D. (2023). *Quantification and characterization of microplastics in the Thermaic Gulf, in the North Aegean Sea.* Science of the Total Environment, 892, 164299. https://doi.org/10.1016/j.scitotenv.2023.164299

Koutsikos, N., Koi, A. M., Zeri, C., Tsangaris, C., Dimitriou, E., & Kalantzi, O.-I. (2023). Exploring microplastic pollution in a Mediterranean river: The role of introduced species as bioindicators. *Heliyon, 9*(4), e15069. https://doi.org/10.1016/j.heliyon.2023.e15069

Kouvara, K., Kosmopoulou, A., Fakiris, E., Christodoulou, D., Filippides, A., Katsanevakis, S., Ioakeimidis, C., Geraga, M., Xirotagarou, P., Galgani, F., & Papatheodorou, G. (2024). Assessing marine litter in a highly polluted area in the Mediterranean: A multi-perspective approach in the Saronikos Gulf, Greece. *Marine Pollution Bulletin, 203*, 116497. https://doi.org/10.1016/j.marpolbul.2024.116497

New Naval Ltd. (2024). *EU Horizon 2020 CLAIM program: River trash & marine litter collection system*. Retrieved January 7, 2026, from https://www.oilspillresponse.gr/project/eu-horizon-2020-claim-program-river-trash-marine-litter-collection-system/

National and Kapodistrian University of Athens (NKUA), Faculty of Law. (n.d.). *Athens Public International Law Group*. Retrieved January 8, 2026, from https://www.athenspil.law.uoa.gr/

Patsiou, D., Digka, N., Galli, M., Baini, M., & Tsangaris, C. (2024). *Assessment of the impact of microplastic ingestion in striped red mullets from an Eastern Mediterranean coastal area (Zakynthos Island). Marine Environmental Research*, 106438. https://doi.org/10.1016/j.marenvres.2024.106438

Patsiou, D., Adamopoulou, A., Digka, N., Kaberi, H., Zeri, C., & Tsangaris, C. (2026). Schools against plastics: Schooling environmentally conscious students and supporting research on marine litter and microplastics. *Marine Pollution Bulletin, 225*, 119224. https://doi.org/10.1016/j.marpolbul.2026.119224

Rigatou, D., Gerakaris, V., Digka, N., Adamopoulou, A., Patsiou, D., Hatzonikolakis, Y., Tsiaras, K., Tsangaris, C., Zeri, C., Kaberi, H., & Raitsos, D. E. (2025). *The role of seagrass meadows (Posidonia oceanica) as microplastics sink and vector to benthic food webs. Marine Pollution Bulletin, 211*, 117420. https://doi.org/10.1016/j.marpolbul.2024.117420

Scacco, U., Mancini, E., Tiralongo, F., & Marcucci, F. (2022). Microplastics in the deep: Comparing dietary and plastic ingestion data between two Mediterranean bathyal opportunistic feeder species, *Galeus melastomus* (Rafinesque, 1810) and *Coelorinchus caelorhincus* (Risso, 1810), through stomach content analysis. *Journal of Marine Science and Engineering, 10*(5), 624. https://doi.org/10.3390/jmse10050624

SEPEE – Hellenic Fashion Industry Association. (2023). *Annual report of the Greek textile and clothing sector 2023.*

Tsangaris, C., Strogyloudi, E., & Papathanassiou, E. (2004). *Measurements of biochemical markers of pollution in mussels Mytilus galloprovincialis from coastal areas of the Saronikos Gulf (Greece).* Mediterranean Marine Science, 5(1), 175–186. https://doi.org/10.12681/mms.223

Tsiaras, K., Costa, E., Morgana, S., Gambardella, C., Piazza, V., Faimali, M., Minetti, R., Zeri, C., Thyssen, M., Ben Ismail, S., Hatzonikolakis, Y., Kalaroni, S., & Garaventa, F. (2022). *Microplastics in the Mediterranean: Variability from observations and model analysis. Frontiers in Marine Science, 9*, 784937. https://doi.org/10.3389/fmars.2022.784937

University of the Aegean - Department of Environment & Department of Marine Sciences. (Various years).Internal research reports and laboratory protocols for microplastic extraction, microscopy and FT-IR analysis. (Unpublished institutional materials referenced through affiliated publications.)

WWF. (2025). *Plastics, health, and one planet: An evidence-based call for global rules.* WWF Germany.

Zeri, C., Adamopoulou, A., Koi, A., Koutsikos, N., Lytras, E., & Dimitriou, E. (2021). Rivers and wastewater-treatment plants as microplastic pathways to Eastern Mediterranean waters: First records for the Aegean Sea, Greece. *Sustainability, 13*(10), 5328. https://doi.org/10.3390/su13105328

Zeri, C., Tsangaris, C., & Kaberi, H. (2022). *Marine litter, plastics and microplastics in the Aegean Archipelago: Current knowledge and priorities for the future.* In *The Aegean Sea Environment: Anthropogenic Presence and Impact* (pp. 1-34). Springer. https://doi.org/10.1007/698_2022_906

Annex II: National Report – Lithuania

13.13. Introduction

Microplastics and synthetic microfibre pollution has become a major threat to the environment and human health. It often causes illness and death in humans and aquatic animals. To combat microplastic pollution, we need to identify and identify the main sources of microplastics and the pathways through which they enter nature. Urbanization and industrialization have led to a deterioration in the water quality of rivers, lakes and oceans. The big problem is that these pollutants cannot be collected by conventional wastewater treatment plants. The textile industry, household washing of textile products and textile waste entering the environment contribute significantly to water pollution with microplastics. Synthetic fibres are non-biodegradable, so they do not decompose for a long time in nature, and in the form of microfibres enter the ecosystem of water bodies and seas.

Synthetic microfibres are short synthetic fiber elements with a diameter of about 10 micrometers or less and a length of about 0.5–2 cm. Commonly used synthetic fibres in clothing include mainly polyester, polyamide, acrylic, and polypropylene (Gago et al., 2018). Larger particles of synthetic fibres released into the environment become the main sources of microfibres. Recently increase in the use of plastics and synthetic fibres has been a major factor in the high pollution of microplastics and synthetic microfibres. According to research (Tanaka, 2022), by 2015, the plastic industry generated up to 6,300 million tons of plastic waste, of which about 80 % is still undecomposed in landfills around the world. It is predicted that by 2050, this amount of plastic waste will double to reach 12 billion tons (Greyer et al., 2017).

In the textile and clothing industry, polyester fibre is the dominant synthetic fibre, with other synthetic raw materials also making up a significant portion. Recently, the use of synthetic fibres in the textile industry has become a prominent trend. The industry of synthetic clothing and other textile products has outcompeted natural fibre products due to their durability and relative cheapness, that is, economic feasibility. The production of textile fibres worldwide can be divided into three categories: synthetic fibres, fibres of natural origin, and various blends of these fibres. Synthetic fibres account for about 60 % of the total production, while natural (mainly cotton) and blended fibres account for the remaining 40 % (Geyer et al., 2017). When synthetic or blended fibre clothing is washed after use, synthetic fibres and their parts are released from the clothing and enter the wastewater system, and from there enter water bodies and oceans, which affects the health of wildlife.

The washing process is responsible for approximately 90 % of garment damage during the consumption phase (Rathinamoorthy & Balasaraswathi, 2020). Physical aging of garments also has a significant impact on the release of microfibres during washing. Polyester and other synthetic textiles generally have a higher transition temperature than ambient room temperature. Prolonged storage at room temperature can lead to physical aging, which causes changes at the molecular level of the polymer unit, including modifications in its free volume, enthalpy, and molecular mobility (Rathinamoorthy & Balasaraswathi, 2020). Thus, the microfibres in these synthetic products weaken over time, become brittle, and are removed during washing.

In Lithuania, the textile and clothing industry constitutes a significant part of the industrial sector, where textile products are manufactured and sold not only in Lithuania, but also in other EU and non-EU countries. Lithuania is striving for a rapid industrial transition to the implementation of the principles of a circular economy and sets very high environmental requirements for both production and products and their collection at the end of their life cycle. This national report on synthetic microfibres in the Lithuanian textile and clothing sector has been prepared to provide a structured and up-to-date overview of the issue of textile microfibres release in the environment in a national context. The aim of the national report is to provide the latest scientific and technological knowledge, identify the main sources of synthetic microfibres, their release pathways throughout the whole life cycle of textile products, review the applicable national regulatory framework and existing research, technological innovation and cooperation initiatives, and highlight good practices and applied technological solutions implemented by the Lithuanian industry in cooperation with other stakeholders.

This national report also aims to be a decision-making support tool for public administrative bodies, enterprises, technology centers and other stakeholders, in order to facilitate the implementation of strategies and measures to reduce the release of microplastics and synthetic microfibres, in line with European policies and national commitments on sustainability, circular economy and environmental protection. The aim of this document is to contribute to coordinated and evidence-based actions that would promote the transition of the textile and clothing sector in Lithuania and other EU countries towards the development of more sustainable and environmentally responsible production models.

13.14. National textile industry overview

13.14.1. Introduction and definition of the sector

The textile and clothing sector is an important part of the Lithuanian economy, which has a significant impact on employment, exports and the country's GDP. There are about 800 companies operating in Lithuania that can be classified as companies belonging to the textile and clothing sector; most of them are small and medium-sized enterprises.

The Lithuanian textile and clothing sector employs approximately 26 thousand people at the end of 2025. Although historically this sector employed over 30 thousand people, a consistent decrease in the number of employees has been observed recently.

According to the National Classification of Economic Activities (EVRK 13), the textile and clothing sector includes the preparation and spinning of fibres, the production and finishing of fabrics, knitwear, carpets, ropes, non-woven materials, etc., textile products, clothing production, etc. (see in Table 1).

Table 1: Structure of the Lithuanian textile sector

Production type	This production type includes	Number of companies
Preparation and spinning of fibres	• cocooning and washing, • wool degreasing, carbonization and dyeing, • carding and combing of various animal, vegetable and man-made fibres, • spinning and manufacturing of yarns or threads for weaving, knitting or sewing, • flax carding, • manufacture of synthetic and man-made filament yarns, including reinforced yarns • texturing, twisting, folding, twisting and impregnating of chemical filament yarns.	12
Weaving	▪ manufacture of broad fabrics of cotton, flax, hemp, jute, wool, worsted wool and silk yarns, including mixed, man-made and synthetic yarns, ▪ manufacture of pile and chenille fabrics, terry fabrics, etc., ▪ manufacture of fabrics of glass, carbon fibres and aramid fibres and yarns, • manufacture of artificial fur by weaving.	21
Knitting	• manufacture of weft and warp knitted, plain, pile and terry fabrics, • manufacture of hosiery, glows, etc. • manufacture of regular and seamless knitted garments, • manufacture of artificial fur by knitting, • manufacture of curtains and other home textiles.	55

Manufacture of made-up textile articles, except apparel	• manufacture of blankets, including travel rugs, bed, table or kitchen linen, cloths, • manufacture of quilted and eiderdown blankets, bedspreads, furniture upholstery, cushions, pillows, sleeping bags, etc., • manufacture of tarpaulins, tents, tourist (camping) equipment, sails, sun blinds, life jackets, parachutes, etc., • manufacture of textile parts for electric blankets, • manufacture of other technical textile products.	49
Carpet manufacturing	• manufacture of woven floor coverings: carpets, rugs, etc. • manufacture of felt floor coverings	4
Production of ropes, cables and nets	• manufacture of ropes, cables and cordage of textile fibres or strips, etc., whether or not impregnated with rubber or plastics, whether or not coated, sheathed or covered, • manufacture of nets of twine, cordage or rope, • manufacture of fishing nets, etc.	12
Textile finishing	• bleaching, dyeing and printing of textile fibres, yarns, products and textile articles, including clothing, • dressing, drying, steaming, sanforizing, mercerizing, etc. of textile products and textile articles, including clothing • pleating, combing, etc. of textile products • impregnation, coating, gumming or impregnation of finished garments • screen printing on textile products and clothing.	13
Nonwoven fabrics	This class includes all activities involving a large number of technological processes and a large number of manufactured items.	11
Sewing	Sewing of clothing and workwear.	420
Preparation for trade and sale of textile products		up to 200

The textile sector in Lithuania remains stable, but production volumes and company expectations recorded a slight decline at the end of 2025 due to declining export orders.

13.14.2. Recent developments and business structure

The majority of the Lithuanian textile industry is focused on the production of final products – fabrics and garments (EVRK 13), while primary preparation and spinning constitute only a small part of this chain. The production of synthetic and chemical fibres and yarns in Lithuania is one of the smallest industries in terms of the number of companies, as this activity requires extremely high technological capabilities. Historically and economically, the most important company in this sector in Lithuania is AB “Dirbtinis pluoštas” operating in Kaunas. Most other spinning companies are not engaged in the production of the fibre itself, but in its processing.

According to data from EVRK and Statistics Lithuania, there were 51 business entities engaged in textile weaving in Lithuania. The size of the weaving industry market in Lithuania in 2025 reached EUR 42.2 million. Although the number of companies has grown by an average of 4.0 % annually over the last five years (until 2025), the total market size has decreased by an average of 4.5 % over the same period, indicating increasing competition or optimization of operations. Many Lithuanian weaving companies specialize in niche products, such as linen, silk or other specific woven fabrics. Many weaving companies also have their own finishing and sewing departments. For example, UAB "A Grupė" is a company with weaving, finishing and sewing departments, weaving linen, semi-linen and terry fabrics.

In Lithuania, the knitting and hosiery production sector is one of the most numerous parts of the textile industry. Most knitting companies are concentrated in the Kaunas, Šiauliai and Utena regions, which are historically considered the textile centres of Lithuania. While the total number of industrial companies remains stable, there is a noticeable shift from mass production to higher value-added – custom-made brands and sustainable fashion for Western markets.

The number of carpet and rug manufacturing companies operating in Lithuania is very small. The size of the carpet manufacturing market in Lithuania in 2025 was approximately EUR 1.6 million, indicating that this is a small but stable industry segment. One of the main companies in this sector is UAB "Pluošto linija", whose brand *Ecolinum* specializes in the production of linen carpets. *Ecolinum* is the only company in Lithuania that produces linen carpets, and exports most of its production. Another related company is UAB "Litspin", which produces woollen yarns for carpet production, but not the carpets themselves.

The field of technical and specialized textiles requires specific innovations and high value-added technologies. The sector is strongly supported by Kaunas University of Technology (KTU) and the Textile Institute of the Physical and Technological Sciences Centre (FTMC), which conducts scientific research into the development of smart and protective textiles. Companies operating in this field produce not only specialized clothing, but also fabrics for medicine, the automotive industry, construction (geotextiles), and personal protective equipment. This textile segment is considered one of the most promising due to its lower dependence on mass production competition and its orientation towards exports and innovation.

The production of ropes, cables and nets is a small but technologically specialized branch of the textile industry. Companies produce products for fishing, construction, agriculture and industry. Lithuania produces nets for fishing, sports, safety nets for construction, and various types of synthetic and natural fibre ropes. The sector is strongly export-oriented (especially to Scandinavian countries for the fishing industry) and remained stable in 2025 due to growing demand for technical textiles in global markets.

After several years of decline, the Lithuanian nonwovens market began to grow again in 2024–2025 and reached a value of about EUR 55 million. Most of these companies are concentrated in major industrial centres or regions with strong textile traditions.

Textile finishing companies perform essential processes - bleaching, dyeing, finishing, printing and specialized coating of fabrics and knitwear to give fabrics certain properties (e.g., fire resistance, water resistance). In Lithuania, there are both large textile companies with their own finishing departments and specialized finishing service providers such as UAB "Tributum". The most significant textile companies with their own finishing departments are: UAB "Utenos trikotažas", UAB "Garlita", UAB

“Liningas”, TŪB “Klasikinė tekstilė” and others. In addition to traditional dyeing and bleaching, companies also offer more complex services, such as digital printing on fabrics, which allows them to respond more flexibly to changes in the fashion market. Most finishing companies serve other Lithuanian textile manufacturers focused on export markets. The sector is rapidly modernizing, implementing sustainable and environmentally friendly finishing technologies that reduce the use of water and chemicals, which is important for EU customers.

The largest segment of the Lithuanian textile industry in terms of the number of economic entities is sewing and apparel production. The sector is dominated by small and medium-sized enterprises (SMEs). Only about 0.2 % of all companies in the sector are considered large (with over 250 employees). Over 80 % of products made in Lithuania are exported to EU countries, and a large part of companies work on a contract basis ("*lohn-production*") for strong European fashion brands.

According to data from the end of 2025, the production volumes of the textile, clothing and finishing industries in Lithuania were under pressure due to energy costs and fluctuating demand in EU markets, therefore no new players emerged in this specific production niche segment. Compared to the period 2021–2023, the number of operating sewing companies has slightly decreased. This was due to increased production costs and decreasing consumption.

The Lithuanian textile and clothing sector employs approximately 26 thousand people at the end of 2025. Although historically this sector employed over 30 thousand people, a consistent decrease in the number of employees has been observed recently. The majority of those employed work in the clothing industry, while the rest work in textile manufacturing and finishing companies. Despite the decline, this industry remains one of the largest employers in Lithuanian manufacturing. The majority of employees are women. The share of engineering and technical personnel (production engineers, technologists, equipment maintenance specialists, quality engineers) accounts for approximately 5–8 % of all employees in the sector. As the sector moves away from "cheap tailoring" and towards high-tech textiles (medical, transportation, protective textiles), the need for engineering professionals is growing proportionately.

13.14.3. Production, international trade, and competitiveness

The European clothing and textile manufacturing industry is largely driven by the production of luxury brands and high-value-added products. Apparel manufacturers around the world have faced challenges caused by the COVID-19 pandemic, high inflation, disrupted supply chains and foreign competition. Despite these challenges, technological innovations, the digital revolution have inspired new growth opportunities for the sector.

Lithuanian textiles industry is highly-developed market with many domestic players and some foreign investors, mainly Scandinavians. With one of the fastest growth in the EU, Lithuania’s textile is now becoming recognized in the North Europe and CIS markets. The market size of the textile and clothing manufacturing industry in Lithuania has grown at an annual growth rate of 2.6 % over the past five years (according to data from IBISWorld). Over the next five years, the industry in Lithuania is expected to grow as well. The Lithuanian textile and clothing sector is one of the most important manufacturing industries, employing about a quarter of the total industrial workforce. The sector's market size is forecast to reach EUR 579.5 million in 2026. After a slight decline in previous years, a recovery in production was recorded at the end of 2025 (annual growth of 2.6-3.5 %). The sector is still affected by the consequences of past crises and increasing competition from lower-cost countries, so the aim is to move from a cheap labor model to higher value-added production. The level of competition in the textile and clothing manufacturing industry in Lithuania is average and stable.

There is a noticeable increase in the popularity of Lithuanian products within the country – over 20 % of production is now sold on the domestic market (compared to 8 % a few decades ago). However, the sector is highly oriented towards foreign markets – about 75 – 80 % of all production is exported.

Lithuanian companies are valued for their flexibility, creativity and ability to quickly adapt to modern lifestyle trends. Lithuania is actively presenting its capabilities in specialized areas, for example, in the production of textiles for NATO forces. The sector's survival in the global market depends on modernization and investment in productivity. Digitalization and sustainable innovation play an important role.

13.15. Relevance of microplastics/microfibres in the national context

Textiles scored highest in water impact, waste generation, climate change, energy consumption, material efficiency and life cycle extension due to the high impact of material sourcing, production, use and disposal, as well as the significant potential for improvement in all these aspects, which is still not fully exploited.

Various regulations impact the European clothing manufacturing industry. Policies across Europe focus on sustainability, fair trade and labelling among others, shaping manufacturing processes and consumer choices.

By 2025, managing microplastic and synthetic microfibre pollution in Lithuania has become not only an ecological priority, but also a strictly regulated business necessity. This directly affects the textile industry, water management, and consumer behavior. In public sectors, textile products are subject to strict environmental protection criteria, limiting the use of chemicals and polluting fibres. Lithuania positions itself as a manufacturer of high-quality, natural fibre products, which provides a competitive advantage in a market where synthetic microfibres (polyester, nylon) are seen as a source of pollution.

In 2025, scientific discussions in Lithuania (e.g., KTU) emphasize that micro- and nano plastics enter the human body through the food chain (especially fish), posing a long-term threat to health. Studies show that microplastic particles are consistently detected in samples from Lithuanian rivers and the Curonian Lagoon. The main source is washing machine wastewater, through which synthetic fibre particles enter treatment facilities and then into open waters. Wastewater treatment plants operating in Lithuania retain a large portion of these fibres, but the smallest fibre particles (smaller than 500 µm) still enter open waters.

Under EU Regulation (EU) 2023/2055, new restrictions on the intentional addition of microplastics in products entered into force at the end of 2025. Businesses have an important deadline of 31 May 2026 to adapt to certain bans on synthetic polymer particles. From 2026, stricter requirements will apply to microplastic producers and suppliers regarding annual reporting on the quantities released into the environment.

13.16. National sources of microfibre release

13.16.1. Production stage

Microfibre release during the textile and clothing production phase in Lithuania occurs through several key technological processes. Although the majority of microplastic pollution is associated with the consumption stage (washing), the production stage generates a significant amount of primary microfibre:

- Wet manufacturing processes (wastewater pollution). This is the main route by which microfibres enter the environment from factories. The highest risks are:
    - Fabric finishing and washing: The final washing of products before shipping to customers removes manufacturing residues, but also washes away loose fibres.
    - Dyeing and printing: The mechanical and chemical effects in dye baths weaken the fibre structure, making fiber particles more likely to break and enter the production wastewater.
- Mechanical processing (air and solid waste pollution). During mechanical impact, microfibres are released not only into water, but also into the air:
    - Spinning and winding: The twisting and mechanical stretching of the fibre causes friction, which causes fine particles to separate and become airborne dust.
    - Shearing and sewing: Cutting fabrics opens the ends of the fibre, so the microfibres fall apart directly at the cutting points. In Lithuania, where the sewing sector is very strong, this phase generates a lot of fine waste.
    - Weaving and knitting: The constant movement of yarns through the loom causes mechanical abrasion.
- Specialized manufacturing processes:
    - Production of pile fabrics (e.g., fleece): Mechanical rubbing of the fabric surface to create softness is one of the most intensive sources of microfibre generation.
    - Manufacturing of synthetic fibres: During the production of polyamide (nylon) or polyester (melting, stretching), polymer particles can be formed, which are classified as intentionally added or incidental microplastics.
- Waste management and recycling:
    - Management of production residues: Improperly stored or handled textile waste (offcuts, scraps) can decompose into microfibres under the influence of environmental factors.
    - Recycling processes: With Lithuania investing over 10 million euros in textile recycling in 2025-2026, mechanical shredding of old fabrics is becoming a new source of microfibres, requiring specific filtration solutions.

13.16.2. Use phase

Next to the pesticides use in cotton cultivation, human toxicity impacts are related to microfibres release during laundering which may enter the food chain and affect human health and their health implications on workers, in addition to the impacts of air-borne fibre fragment emissions in factories. Microfibres can also carry toxic substances on their surface or within their materials.

Microfibre release in the consumption and care phase of textiles in Lithuania is a key environmental challenge, as household wastewater remains one of the largest sources of primary microplastics. Main sources and factors of the release:

- Household washing (main source). During a single wash cycle, clothes can release from a few hundred thousand to a few million microfibre particles. This depends on:
    - New products: The most intense release occurs during the first 8 wash cycles, after which emissions stabilize.
    - Fabric type: Synthetic fabrics (polyester, nylon, acrylic) are the main sources of plastic pollution, but studies show that natural fibre products can release even higher total fiber levels during washing.
    - Clothing type: Knitted and fluffy fabrics (e.g., fleece sweaters) release significantly more microfibres than tightly woven fabrics.
- Washing conditions influencing microfibres release:
    - Temperature and duration: High temperatures (above 40°C) and long wash cycles promote fibre breakdown.
    - Water to fabric ratio: Washing a smaller load with a large amount of water increases friction and fibre shedding. A fully loaded drum reduces emissions.
    - Mechanical impact: High spin speeds and strong mechanical impact in the washing machine physically damage fibres.
- Drying: Clothes dryers that vent air to the outside are one of the biggest sources of microfibre air pollution in cities.
- Direct release during wear (Air emission): Although washing is often emphasized, scientific research highlights that similar or even greater amounts of microfibres are released into the air during wear than into water. Movement, friction against other surfaces, and wind constantly seed particles directly into the environment.

13.16.3. End-of-life handling

In 2015, the global textiles and clothing industry was responsible for 92 million tons of waste. It was estimated that 30 % of garments are over-produced and disposed of without being worn even once to preserve the exclusiveness of the brand. All these garments usually are simply (and sometimes illegally) landfilled. With respect to post-consumer waste, discarded textiles equal to 5 million tons textile waste per year in the EU countries, with total reported separate collection in 13 EU countries at around 2 million tons per year (EEA). 87 % of textile waste is landfilled or incinerated after its final use. Increasing fabric resistance to shedding or finding alternative materials that can safely biodegrade if they leak into the environment can be some of the measures to prevent microfibres formation.

From 1 January 2025, the mandatory separate collection of textiles in Lithuania has replaced the following phase:

- Mechanical recycling: When old textiles are shredded to obtain new fibres, the process generates a high concentration of microfibres, which industry standards require strict filtration in 2026.
- Landfill dust: Improperly disposed textiles, exposed to UV rays and wind, break down into micro- and nano-particles that enter groundwater.

Although modern facilities (in Vilnius, Kaunas) retain up to 90–99 % of microplastics, they do not disappear anywhere – they remain in the sludge. In 2026, there is a discussion about limiting the use of such sludge in agriculture so that microfibres do not enter the soil and the food chain.

13.17. National scientific and technical studies

In recent years, Lithuania has paid special attention to addressing sustainability challenges and is conducting an increasing number of scientific and technical research related to reducing microplastics/microfibre pollution. This research is conducted in collaboration with scientific and industrial institutions, contributing to the deepening of knowledge about reducing the number of microplastics/microfibres throughout the entire textile life cycle through ongoing projects.

13.17.1. Active research institutions

Several Lithuanian research institutions are actively conducting investigations into microplastics and microfibres, focusing on environmental monitoring, toxicological impacts, and mitigation through textile sustainability and bioplastics. Lithuanian national research institutions and universities play an important role in implementing sustainability principles at national and international levels, including research into reducing the release of microplastics / microfibres through technological solutions in the textile sector. Institutions coordinating such research are the Research Council of Lithuania (RCL), Central Project Management Agency (CPVA) and others, which has developed several research directions aimed at detecting and collecting microplastics in marine and continental ecosystems and wastewater treatment systems. During such research, high levels of microplastics / microfibres were detected in coastal Lithuanian waters and in sediments from treatment plants (*Every sample is contaminated: new research shows the extent of microplastic pollution in Lithuania* (in Lithuanian), *published on 11-09-204)*. The communication campaign for the closure of the 2014–2021 Norwegian Financial Mechanism "Environment, Energy, Climate Change" programme was initiated by the Central Project Management Agency (CPMA). The aim of the campaign was to reveal the results of the implemented programme, which aims to improve the environmental status of ecosystems in Lithuania and reduce the negative impact of pollution and other human activities. The results of the research revealed that as much as 97 percent of the micro-litter detected was fibre originating from synthetic clothing, nets, or other textiles. These data show how everyday habits affect the state of the environment.

In Lithuania, special attention is paid to the treatment of used water, because Lithuania has an exceptional amount of clean fresh water in Europe and it is understood as a national value (Figure 1).

According to the data, presented in Fig. 1, it is visible that urban waste water in Lithuania almost 100 % meets the strict *Urban Waste Water Treatment Directive* (UWWTD) requirements.

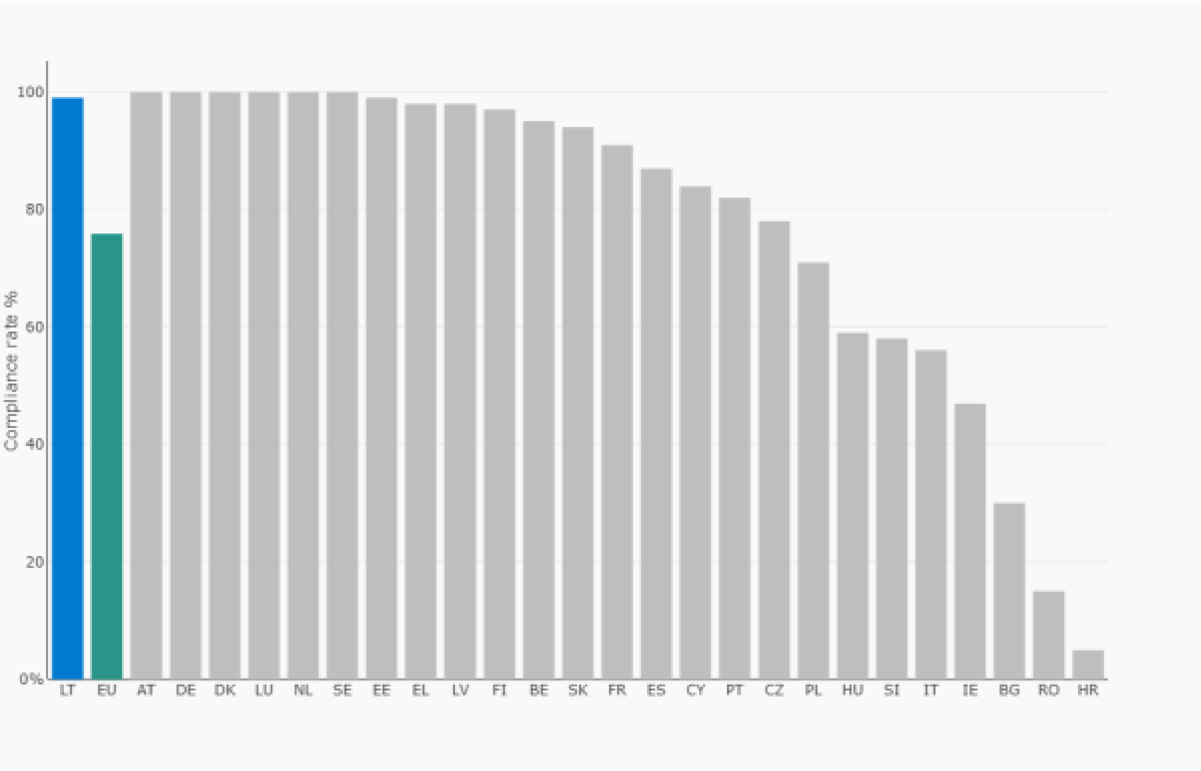

Figure 1: Proportion of urban waste water that meets all requirements of the UWWTD (collection, biological treatment, biological treatment with nitrogen and/or phosphorus removal) in compliant urban areas (according to UWWTD)

Nature Research Centre (NRC) focuses on the ecological and toxicological aspects of microplastic pollution in terrestrial and aquatic environments. In 2025, researchers of NRC have held workshops on analyzing microplastic-induced damage in fish erythrocytes and the broader impacts of microplastics on aquatic biota.

Center for Physical Sciences and Technology (FTMC) has been involved in developing experimental technologies for observing and mitigating submicron aerosol particles and aquatic pollutants, including hosting workshops on microplastic toxicity and air pollution.

Lithuanian Energy Institute (LEI) is currently researching the transport of microplastics in plants using microfluidic systems to understand how these pollutants enter the food chain.

13.17.2. University research projects

Kaunas University of Technology (KTU) is a leader in mitigation and circular economy solutions, particularly regarding synthetic textiles and plastic alternatives. It Develops sustainable solutions and curricula to reduce the release of microplastics and synthetic microfibres in the textile and fashion sectors; conducts macro-environmental analysis on plastic recycling and systemic waste management to prevent microplastic formation.

Klaipėda University (KU) and Marine Research Institute are central to marine monitoring and maritime technology research. They conduct Baltic Sea monitoring, investigates the occurrence and distribution of microplastics in surface waters and wastewater across Lithuania and Latvia, Uses the *Marine Valley* open-access infrastructure for fundamental research on coastal environments and maritime technologies (*A part of Marine Research Institute infrastructure was established after the Lithuanian Government (23 July, 2008, Resolution No. 786) approved The Programme of Integrated Science, Studies and Business Centre (Valley) for the Development of Lithuanian Maritime Sector with a purpose to establish and develop Marine Valley in Klaipėda*).

Life Sciences Centre of Vilnius University (VU) investigates the biological degradation of plastics, exploring microorganisms that could potentially break down plastic polymers in real-world systems, collaborates with the NRC on microplastic identification and geochemical studies of coastal pollutants.

13.17.3. Industry research

Lithuanian industrial research on microplastics and microfibres is primarily concentrated in the textile, waste management, and water technology sectors, often through public-private partnerships:

1. Textile & Fashion Industry. Research in this sector focuses on identifying shedding points and developing "green skills" for sustainable production:

- LTP Group (https://www.ltpgroup.com/): this major Lithuanian textile manufacturer has partnered with global brands (like Vaude) and scientific communities on initiatives such as *TextileMission* to mitigate microfibre release from synthetic apparel.

2. Waste Management & Recycling. Industry leaders are researching systemic improvements to prevent "macro" plastic waste from degrading into microplastics:

- *BALTIPLAST* Project (2024–2026): Companies such as UAB "Nivela", the Kaunas Regional Development Agency, and the Kaunas Regional Waste Management Centre are actively conducting plastic inventories to phase out single-use plastics and optimize industrial waste cycles. The *BALTIPLAST* project, was launched in 2023, bringing together municipalities, researchers, NGOs, and environmental specialists from across the Baltic Sea Region (https://interreg-baltic.eu/project/baltiplast/). An Interreg Baltic Sea Region project equipped municipalities with practical tools to reduce single-use plastics and improve waste management.

3. Water Treatment & Monitoring Technologies - Industrial Laundry Impact: Recent industrial-scale studies in Lithuania (2025) have analyzed the contribution of Industrial Textile Laundry Facilities (ITLF) to microplastic loads in municipal wastewater, finding that a single facility can contribute up to 13 % of the total influx.

- *Detection Sensitivity* (NanoTRAP): The Research Council of Lithuania is currently funding the NanoTRAP project (2025–2026), coordinated by KTU, to develop nano-patterned surfaces for the rapid industrial detection of micro- and nanoplastic traces in production lines.
- *Inobiostar* (Klaipėda): This technology spin-off continues to research the application of advanced aerogels (originally for oil spills) for the filtration of micro-pollutants in industrial water discharge.

- *FanpLESStic-sea* was an EU Interreg project focused on reducing microplastic pollution in the Baltic Sea by mapping pathways, piloting new filtration and sustainable drainage tech, and creating policy recommendations with partners from 8 countries. Its legacy impact includes new models for microplastic flow, innovative removal solutions, enhanced regional cooperation, and policy frameworks for sustainable water management, promoting up-stream solutions and public awareness. The project was implemented by Siauliai Chamber of Comerce, Industry and Crafts (SCCIC), Lithuania, in cooperation with partners from Sweden, Finland, Latvia and Poland. Findings from this project have been integrated into Lithuania's national monitoring programs for the Baltic Sea and Curonian Lagoon.

4. Agricultural Industry:

- PLASTRO Project (2025–2026): In collaboration with the Lithuanian Research Centre for Agriculture and Forestry (LAMMC), research is being conducted on the transport of microplastics through plant systems using microfluidics to help the agricultural sector select crops more resistant to pollution.

13.17.4. EU Project Participation

Lithuanian universities and research institutions are actively participating in projects funded by the European Union and individual EU countries (especially the Nordic and Baltic countries) aimed at addressing the sustainability of the textile sector in general and the release of microplastics into the environment in particular. The initiatives are funded by such programs as LIFE, Horizon 2020, Horizon Europe and Interreg, Nordic countries (like Swedish Institute Program), Baltic Sea region Cooperation Program, etc.

MicroPlastGuard "Mitigating Microplastics Pollution Through Advanced Baltic Cooperation" Project (implemented by KTU in 2024–2026 in cooperation with Borås University, Sweden, and Lodz University of Technology, Poland) focuses on mitigating microplastic pollution from synthetic textiles in the Baltic Sea region by establishing standardized test methods for quantifying fibre release during washing and production.

Bioplastics Development project, implemented by KTU (2024-2026), targets the creation of bioactive and biodegradable bioplastics from sustainable polysaccharides to replace traditional synthetic plastics. Macro-environmental analysis on plastic recycling and systemic waste management has been conducted to prevent microplastic formation.

Project *Modeling microplastic transport in plants using microfluidic systems*, implemented by Lithuanian Energy Institute (LEI) focuses on microplastics and synthetic microfibres accumulation and interaction with plant tissues, on how it affects plant's photosynthetic efficiency and resistance to environmental stress. It is emphasized that microplastic pollution is a global environmental problem. In the European Union countries alone, synthetic textile fibres account for about 35 % of microplastics found in the environment. According to the European Chemicals Agency (ECHA), about 13,000 tons of microplastics enter the environment every year during washing. These particles are found everywhere - in water, soil, atmosphere, and from there they enter the human body. Microplastic pollution changes the properties of the soil, affecting the physiology of the plants growing in it.

Lithuanian Nature Research Centre has implemented INSIGNIA-bee project *Preparatory action for monitoring of environmental pollution using honey bees* (https://www.insignia-bee.eu/), a Horizon Europe-linked initiative, using honey bee colonies as bioindicators to monitor environmental pollutants, including microplastics, across the EU including Lithuania.

The *MicroDrink project* (2024-2026) is an EU-funded initiative focused on harmonizing microplastic monitoring in the Danube region by developing open-access tools, best practices, and training for stakeholders, directly supporting the new EU Drinking Water Directive's requirements for monitoring emerging pollutants like microplastics in tap water across the EU, including in Lithuania, by providing standardized methods and knowledge (https://environment.ec.europa.eu/news/microdrink-removing-microplastics-drinking-water-2025-03-10_en).

13.18. Case studies

In Lithuania, in recent years, applied initiatives and projects have been developed and implemented to reduce and mitigate the amount of microplastics in water and the environment. These case studies reflect the practical implementation of technological, industrial and municipal solutions. The analysis of these cases allows for the identification of concrete measures, quantifiable results and lessons learned, contributing to the transfer of good practices and replication of solutions in other national and European contexts.

13.18.1. Study of the application of medicinal plant extracts to impart antibacterial properties to textile materials intended for sublimation printing (13.1.1-LVPA-K-856-01-005)

Context

The R&D project was implemented by Lithuanian textile company UAB "Textilis" in cooperation with Kaunas University of Technology (KTU). UAB "Textilis", which is located in Kaunas, specializes in textile production, designs development, sublimation and digital printing. The textile fabrics they produce are environmentally friendly, have exceptional functional properties, and distinctive designs. The company's ability to remain competitive in international markets is helped by the constant development and updating of collections, fabric quality control, the introduction of new fabric finishing technologies, and consultations with textile specialists.

Problem identified

One of the product groups produced by UAB Textilis is synthetic fabrics that are printed using sublimation. Since the company is focused on sustainable production, it chose sublimation printing instead of conventional dyeing for fabric printing. Considering that synthetic textile products release microparticles of synthetic fibres into the water during washing, which become dangerous environmental pollution, the company implemented a project that allowed it to reduce the number of washings during consumption.

Intervention implemented

Using natural antibacterial plant extracts, the company has developed a methodology for combining fabric treatment with antibacterial agents and dye-sublimation printing in a single finishing process (creating individual designs and printing only the parts intended for sewing the product, and not the entire width of the fabric - this also reduces dye consumption and reduces additional potential pollution). Importantly, by giving fabrics antibacterial activity, the number of washes can be significantly reduced.

Quantitative results

During the research it was found that the number of washings can be reduced up to 3-4 times, since the anti-bacterially active fabric protects the product from the multiplication of pathogenic bacteria under the influence of sweat. Considering that the majority of synthetic microfibres enter the water precisely during washing, this is a great achievement in reducing microplastic pollution.

Stakeholder engagement

Anti-bacterially active fabrics developed by UAB Textilis have been very well received by consumers, drawing their attention to the environmental damage caused by the textile sector. These research results will be further developed at KTU, as well as at the Life Sciences Centre of Vilnius University (VU).

Lessons learned

The results of the implemented project have proven that the number of washings of textile products during their life cycle can be significantly reduced, which not only contributes to saving resources (water, electricity), but also reduces pollution from microfibres, detergents and fabric softeners used during household washing.

Contact information

Web: https://www.textilis.lt/

13.18.2. Development of technological solutions for the production of sweat-absorbing pads (01.2.1-MITA-T-851-01-0196)

Context

The R&D project was implemented by Lithuanian SME MB “Rūpestingi namai” in collaboration with KTU and Lithuanian University of Health Sciences. MB "Rūpestingi namai" is a young, innovative small company, implementing various initiatives focused on sustainability. The main goal of the implemented project was to create a new, unparalleled model of an underarm sweat-absorbing pad on the market. This product is aimed at consumers with even sensitive skin, and also protects clothes from sweat, absorbing it without leaving marks, and from bad odors caused by the growth of pathogenic bacteria in the sweat medium. Underarm pads are an innovative product due to their minimalist design, sustainable fibre composition and use of active ingredients, in addition, underarm pads are made from cutting waste.

Problem identified

As it is known that the main release of microfibres from textiles occurs during wet procedures and the main source of released microfibres is in washing machine wastewater, through which synthetic fibre particles enter treatment facilities and then into open waters, it is highly important to implement measures that would reduce the number of times textile products need to be washed.

Intervention implemented

Since sustainability issues are currently of particular importance, the aim of the implemented project was to choose sustainable, natural, easily degradable fibres for the production of underarm pads, which, in turn, must ensure the necessary capillarity, static and dynamic moisture absorption. The structure of the pad must be such that it would ensure the thinness of the pad (invisibility), and at the same time a high sorption capacity, rapid absorption of sweat from the body and "locking" in the inner layer, preventing moisture from penetrating to the outside. Since the two-layer underarm pads have a high sorption capacity and protect clothes from sweat and bad odor caused by the growth of pathogenic bacteria in the sweat medium, they help not only to solve the problems of people who sweat more than usual, but also significantly reduce the number of washes. In addition, the underarm pads were treated anti-microbially by natural and eco-friendly antimicrobial substances what has additional influence on decreased number of necessary washings.

Quantitative results (kg/year reduction, %, etc.)

During the research it was found that the number of washings can be reduced up to 5 times, since the underarm pads absorb and “lock” sweat in the inner structure and, additionally, anti-bacterially active treatment of pads protects the product from the multiplication of pathogenic bacteria under the influence of sweat. Considering that the majority of synthetic microfibres enter the water precisely during washing, this is a great achievement in reducing microplastic pollution.

Stakeholder engagement

The newly developed products attracted the attention of consumers and generated great interest. This also attracted the attention of retailers and provided both groups with additional awareness of the sustainability challenges associated with the consumption of textile products. University students were also involved in this work, which contributed to raising their awareness, which is very important for young engineers and future specialists who will work in textile industry companies.

Lessons learned

The results of the implemented project have proven that the number of washings of textile products during their life cycle can be significantly reduced, which not only contributes to saving resources (water, electricity), but also reduces pollution from microfibres, detergents and fabric softeners used during household washing.

13.19. Main challenges and barriers

Lithuania faces several critical challenges and barriers in the mitigation of microfibres and microplastics, ranging from technological limitations in wastewater treatment to economic and regulatory hurdles.

13.19.1. Technological and Infrastructure Barriers

- Insufficient Removal Efficiency: While Lithuania’s wastewater treatment plants (WWTPs) currently remove approximately 57 % of microplastics during primary and secondary stages, a significant portion still enters the environment. Current technologies often struggle to filter smaller particles or those with complex shapes like microfibres.

- Recycling Limitations: High-quality recycling remains a major hurdle. Technologies for recycling composite packaging (often used for aesthetics or shelf-life) are frequently inefficient, both economically and environmentally.
- Infrastructure Gaps: Mitigation at the source, such as mandatory microfibre filters for washing machines, is still in the exploration or early adoption phase and requires integration with existing industrial supply chains.

13.19.2. Economic and Market Challenges

- Low Market Competitiveness: Recycled plastics in Lithuania are often sold at prices 2-3 times lower than virgin plastics. This price gap, exacerbated by an oversupply of cheap virgin plastic from global markets (e.g., China and North America), discourages manufacturers from choosing sustainable alternatives.
- High Operational Costs: Advanced removal technologies for microplastics (e.g., advanced oxidation or membrane filtration) come with high running costs, making widespread implementation financially difficult for many municipalities

13.19.3. Regulatory and Strategic Hurdles

- Outdated and Varying Regulations: Older EU directives allowed member states to implement plastic management in different ways, leading to inconsistent results. While a new 2024 EU regulation aims for uniformity, its full integration into Lithuanian national law and practice is an ongoing 2026 challenge.
- Missed Targets: Lithuania and the EU missed the target of recycling 50 % of plastics by 2025; the new focus is on a 55 % target by 2030.
- Monitoring Gaps: There is a lack of standardized terminology and globally consistent monitoring methodologies to track microplastic abundance accurately in ecosystems like the Curonian Lagoon.

13.19.4. Environmental and Social Barriers

- Public Attitudes and Myths: Public motivation to sort waste is undermined by the persistent myth that sorted waste is eventually incinerated or landfilled. Waste cleanliness also varies significantly by location (e.g., Kaunas apartment blocks vs. private houses), showing that social norms heavily influence sorting quality.
- Primary Source Leakage: Microplastics from non-exhaust traffic emissions (tire and brake wear) and plastic pellets (which are now regulated by EU 2025/2365 as of late 2025) continue to leak into the environment before they can be effectively managed.
- Knowledge Gaps: There is limited research on the environmental fate of airborne microplastics and their interaction with urban green infrastructure in Lithuania.

13.20. National success stories and best practices

Lithuania's success in mitigating microplastics and microfibres is driven by a combination of cross-border academic research, private sector innovation, and a growing cleantech ecosystem. Lithuania’s mitigation of microfibres and microplastics is characterized by advanced academic-industrial partnerships, a maturing "Cleantech" sector, and proactive municipal waste initiatives.

13.20.1. Innovative technologies

MicroPlastGuard

A joint project between KTU, Sweden and Polish partners "MicroPlastGuard: Mitigating Microplastics Pollution through Advanced Baltic Cooperation" is focused on establishing standardized test methods for quantifying microfibre release during washing and raising awareness among fashion brands. The project addresses the issue of microplastic pollution in the Baltic Sea region, particularly focusing on the threat posed by microplastics originating from synthetic textiles. The project responds directly to the prevalent and escalating challenge of microplastic pollution in the Baltic Sea. The project developed test methodologies for quantifying microplastic release and aims to develop innovative coatings and finishes to mitigate the emissions of microplastics from synthetic fabrics. This project also develops innovative coatings and finishes for synthetic fabrics designed to significantly reduce the shedding of microplastics during their lifecycle.

https://midf.ktu.edu/projects/mikroplastiko-tarsos-mazinimas-per-pazangu-baltijos-saliu-bendradarbiavima-microplastguard/

https://si.se/en/projects-granted-funding/microplastguard-mitigating-microplastics-pollution-through-advanced-baltic-cooperation/

Advanced Waste-to-Energy

Lithuanian researchers have pioneered a method to treat microfibres collected from industrial and domestic sources as a resource rather than waste. Scientists from the Kaunas University of Technology (KTU) and the Lithuanian Energy Institute (LEI) developed a pilot pyrolysis plant that converts synthetic lint-microfibres (captured from clothes dryers) into energy products. This thermal decomposition process achieves a 70 % conversion rate, producing oil, gas, and char. It is estimated that lint from 1 million people could produce 14 tons of oil and 21.5 tons of gas annually. This thermal decomposition prevents microfibres trapped in sludge from returning to the environment via agricultural land application.

13.20.2. Industry or municipal initiatives

TextileMission

LTP Group, a major textile manufacturer in Lithuania, has partnered with international brands like Vaude on the international "TextileMission" project, supported by the German Federal Ministry of Education and Research (BMBF). This initiative focuses on developing new fabrics and washing techniques that significantly reduce microfibre shedding. The "TextileMission" takes a multifaceted approach with established measurable objectives. One area of the project focused specifically on optimising production processes and cutting-edge assembling techniques to significantly lower quantities of micro-particles released during this stage. Within the scope of the project, this is where LTP's expertise were required.

https://www.ltpgroup.com/news-trends/searching-for-innovative-solution-approaches-against-microplastics-with-vaude https://tu-dresden.de/bu/umwelt/hydro/ifw/forschung/aktuelle-forschungsprojekte/TextileMission-Microplastics-of-Textile-Origin-Retention-of-Polyester-Particles-in-the-Sewage-Treatment-Plant-and-Environmental-Stability-of-new-Materials

Alytus Waste Model

The city of Alytus has become a national example of successful waste prevention and sorting, demonstrating how local educational initiatives can overcome the myth that sorted waste is not recycled. It is an innovative, data-driven system focused on waste reduction, sorting, and reuse, using smart containers with electronic locks (Pay-As-You-Throw) to encourage residents to sort waste by tracking usage, and implementing reuse systems like "TikoTiks" for items, making it a leader in smart waste management in Lithuania. Innovative and responsible waste collection and processing helps reduce the amount of hazardous waste entering the environment, including textiles or plastic products, from which microplastics enter groundwater through the soil.

https://novian.io/news/alytus-regional-waste-management-system-integrates-data-from-over-100000-users/

13.20.3. Certifications or voluntary schemes

Lithuania mitigates microplastics and microfibres through a combination of mandatory EU reporting, rigorous international textile standards, and voluntary corporate responsibility schemes. Lithuanian textile leaders like Omniteksas and Neaustima utilize international certifications to validate their microfibre and safety standards:

- OEKO-TEX® STANDARD 100: Widely adopted in Lithuania to certify that textiles are tested for harmful substances. Recent updates include stricter limits on synthetic fibre shedding and the use of recycled PET from post-consumer bottles.
- Global Organic Textile Standard (GOTS): Used by Lithuanian producers to ensure at least 70 % organic natural fibre content, which naturally reduces synthetic microfibre release compared to pure synthetics.
- Higg MSI (Materials Sustainability Index): Lithuanian companies use this to quantify and transparently report the environmental impact of their textiles, including fibre fragmentation data.
- Masters of FLAX FIBRE™: Starting in 2026, this new audited standard replaces the "European Flax" charter, guaranteeing sustainable agricultural practices for linen, a major natural fibre industry in Lithuania.

Global testing bodies like SGS, which operate in Lithuania, promote this voluntary initiative to help brands adopt standardized testing methods for fibre fragmentation during washing. Lithuania actively promotes a voluntary-turned-mandatory approach to Extended Producer Responsibility (EPR), particularly for textiles, where brands like H&M's Lithuanian branch have collected over 260 tons of used clothing to prevent improper disposal and subsequent microplastic leakage.

13.20.4. Successful partnerships or projects

FanpLESStic-sea

"FanpLESStic-sea" is a project, focused on preventing and decreasing the pollution of microplastics in water and the Baltic Sea. The project increased knowledge and understanding about dispersal pathways and sources through measurements in different flows in society, as well as cost-effective methods to reduce microplastics. "FanpLESStic-sea" was supported by the EU Interreg program with project partners in Lithuania, Sweden, Denmark, Norway, Finland, Latvia, Poland and Russia. The main Lithuanian partner in the project was Šiauliai Chamber of Commerce, Industry and Crafts. Lithuania participated in this international initiative to map microplastic pathways into the Baltic Sea, leading to the development of new tools for water utilities to stop microplastics before they reach marine ecosystems.

BALTIPLAST Project

A collaboration between the Kaunas Regional Development Agency, UAB "Nivela," and the Kaunas Regional Waste Management Centre to conduct comprehensive plastic inventories and reduce single-use plastic consumption. Its core premise was simple: meaningful plastic prevention requires coordinated action across strategy, daily organisational behaviour, and waste management systems. BALTIPLAST co-developed and tested strategic frameworks focused on prevention, reuse, and recycling. These were complemented by soft solutions targeting plastic consumption at source, most notably the Plastic Inventory Tool, which enabled organisations, schools, businesses, and households to make plastic use visible and act on measurable facts rather than assumptions.

https://interreg-baltic.eu/project/baltiplast/

13.21. National policies and regulatory framework

13.21.1. National laws related to microplastics

In Lithuania's legal framework for microplastics is primarily governed by the direct application of EU regulations, supplemented by national environmental and waste management laws.

1. Restriction on Intentionally Added Microplastics. Lithuania enforces Commission Regulation (EU) 2023/2055, which restricts synthetic polymer microparticles (SPMs) on their own or intentionally added to mixtures:

- Active Prohibitions (as of 2026): The sale of loose plastic glitter and products containing microbeads (used for exfoliation or cleaning) is banned.
- Reporting Obligations (May 2026): By May 31, 2026, Lithuanian manufacturers and industrial downstream users of plastic pellets, flakes, and powders must submit their first annual report to the European Chemicals Agency (ECHA) detailing 2025 data on estimated microplastic releases.
- Labeling and Information: Since October 2025, suppliers of microplastics for industrial use must provide precise instructions for use and disposal on labels or Safety Data Sheets to prevent environmental leakage.

2. Plastic Pellet Loss Prevention. Lithuania is currently implementing the Regulation on Preventing Plastic Pellet Losses (EU 2025/2365), adopted in late 2025.

- Scope: Applies to any Lithuanian economic operator handling five tonnes or more of plastic pellets annually.
- Compliance: Large and medium-sized companies must obtain a certificate of compliance, while smaller enterprises may use a self-declaration of conformity.
- Training Materials: By December 17, 2026, the European Commission, with member state input, will release awareness-raising materials to support this regulation's full implementation.

3. National Waste and Packaging Laws. Lithuania utilizes national legislation to reduce "macro" plastic waste that eventually degrades into secondary microplastics:

- Law on Packaging and Packaging Waste Management: Lithuania has banned the free distribution of both lightweight and very lightweight plastic carrier bags at points of sale.
- Extended Producer Responsibility (EPR): Lithuania emphasizes EPR and its successful deposit return system for PET bottles as key national legal mechanisms for reducing plastic pollution.

4. Future Legislative Deadlines. Lithuanian industry is preparing for upcoming phase-outs under the rolling implementation of EU law:

- October 2027: Ban on rinse-off cosmetics (shampoos, shower gels) containing microplastics.
- October 2028: Ban on detergents, fabric softeners, waxes, and polishes containing microplastics.
- 2031–2035: Mandatory "contains microplastics" labeling for makeup and lip products begins in 2031, followed by a total ban in 2035.

13.21.2. Alignment with EU legislation

In Lithuania, national laws are strictly aligned with EU legislation, prioritizing the reduction of microplastic emissions at the source. This alignment is characterized by the direct application of EU Regulations and the transposition of Directives into national environmental codes.

1. Direct Application of EU REACH Restrictions. Lithuania enforces Commission Regulation (EU) 2023/2055, which targets intentionally added microplastics:

- Active Bans: Products such as loose plastic glitter and cosmetic products containing abrasive microbeads have been prohibited since late 2023.
- Industrial Reporting (New for 2026): By May 31, 2026, Lithuanian manufacturers and industrial users of plastic pellets, flakes, and powders must submit their first annual report to the European Chemicals Agency (ECHA) detailing estimated microplastic releases from the 2025 calendar year.
- Phase-out Schedule: National authorities monitor compliance with the rolling EU timeline, including upcoming bans on rinse-off cosmetics (October 2027) and detergents (October 2028).

2. Prevention of Plastic Pellet Losses. Following the entry into force of Regulation (EU) 2025/2365 in December 2025, Lithuania has integrated new oversight for industrial raw materials:

- Mandatory Risk Management: Lithuanian operators handling 5 tonnes or more of plastic pellets annually are legally required to implement risk management plans to prevent spills.
- Certification Requirements: Large and medium-sized Lithuanian companies (handling >1,500 tonnes/year) must obtain an independent third-party certificate of compliance.
- Labeling and Packaging: New requirements ensure that pellets are accompanied by specific pictograms and warning statements, with further training materials expected from the EU by December 2026 to support local implementation.

3. Transposition of EU Directives. Lithuania aligns its national environmental laws with broader EU strategies to mitigate secondary microplastics:

- Drinking Water Quality: Lithuania has transposed the EU Drinking Water Directive, which includes requirements for monitoring microplastics in the water supply chain as standardized methodologies become available.
- Waste Management Law: The Law on Environmental Protection and the Law on Packaging and Packaging Waste Management align with EU goals to reduce single-use plastics, utilizing an Extended Producer Responsibility (EPR) framework and a successful deposit return system to prevent macro-plastic degradation.
- Washing machine filters: From 2026, requirements for new washing machines to have integrated microfibre filters will be more actively applied.
- Maritime Safety: In alignment with EU maritime transport inclusion in the pellet regulation, Lithuania oversees specific obligations for sea-going vessels to prevent spills in the Baltic Sea, reflecting International Maritime Organization (IMO) recommendations.

13.21.3. Strategic plans, incentives and programmes

Lithuania's strategic landscape for microplastics and microfibres focuses on circular economy integration, targeted R&D funding, and preparing the textile industry for new EU-wide mandates.

1. Strategic National Plans:

- National Environmental Protection Strategy 2030: This high-level document identifies the sustainable use of natural resources and waste management as long-term priorities. In 2026, it serves as the framework for reducing marine litter inputs, including microplastics, into the Baltic Sea ecosystem.
- National Energy and Climate Plan (NECP) 2021–2030: While primarily focused on GHG reductions, the updated plan (2024–2026) integrates "nature-neutral" technologies and climate-neutral innovation, which include funding pathways for advanced waste-to-energy projects that prevent plastic leakage.
- Lithuania 2050 Vision: This long-term strategy includes commitments to "restore, protect, and cultivate natural ecosystems" through responsible consumption and green energy incentives.

2. Targeted R&D Programs and Funding:

- Joint RTO Lithuania Initiative (2025–2026): In 2025, three major innovative environmental projects were selected for funding. A key project involves creating a model to analyze how secondary microplastics from textile fibres migrate through plant vascular systems, led by researchers from LAMMC, LEI, and FTMC.

- Climate Change Programme (2022–2025/2026): Funded by EU Emissions Trading System (ETS) revenues, this program supports investments in biodegradation and green energy development, providing the financial backbone for industrial-scale plastic waste reduction projects.
- Sunrise Tech Park & Cleantech Lithuania: Public investment in the cleantech sector reached €107.4 million by 2025, specifically targeting waste management and the circular economy to boost industrial resilience against microplastic pollution.

13.21.4. National standardization activities

Lithuania's activities in microplastic and microfibre standardization focus on developing unified testing methodologies and aligning national industry practices with new EU mandates.

Lithuania actively participates in development of Research-Driven Methodologies:

- MicroPlastGuard Project (2024–2026): Kaunas University of Technology (KTU), in partnership with Polish and Swedish institutions, is leading efforts to bridge scientific gaps in standardized test methods for quantifying microfibre release during the washing of synthetic textiles.
- Harmonization Initiatives: In 2025 and 2026, Lithuanian researchers have called for internationally harmonized risk assessment frameworks and standardized analytical methodologies to ensure consistent policy across the EU.

Also, Lithuania adopts international standards via the Lithuanian Standards Board (LST), including:

- ISO 24187:2023: General principles for the analysis of microplastics in the environment.
- ISO 4484 Series: Specific standards for microplastics from textile sources, including:
  - Part 1: Determination of material loss from fabrics during washing.
  - Part 3: Measurement of mass released from products during domestic washing.
- Methodological Workshops: Organizations like the Center for Physical Sciences and Technology (FTMC) host training sessions (e.g., EcoBalt 2025) on using standardized μ-FTIR techniques for detecting and characterizing microplastic particles.

13.22. Training needs and educational proposals

13.22.1. Training needs and education proposals

Lithuanian training and education in the field of microplastics and microfibres is focused on developing "green skills" in academia, industry and the public sector, aiming to bridge the gap between scientific knowledge and practical emission reduction. There is a critical push to develop national recommendations for "green skills" training to ensure the Lithuanian labor market can transition to a climate-neutral economy, specifically targeting competencies in circular plastic management. Specific training is being targeted at stakeholders in coastal municipalities, hospitality (campsites, hotels), and waste management companies to map and reduce plastic pathways into the Baltic Sea.

Research in early 2025 indicated that while awareness is rising, only about half of the public actively sorts plastic waste or wears natural fibres to avoid microfibre shedding, highlighting a need for more effective behavior-change education. Lithuania is addressing several identified educational gaps in microplastics and microfibres through targeted higher education (HEI) reforms and specialized vocational training:

- Theory-Practice Disconnect: There is a notable gap between students' recognition of the circular economy's importance and its practical implementation in curricula.
- Systemic Knowledge Deficiency: National research highlights a lack of systematic knowledge regarding the net environmental and economic benefits of a circular economy for Lithuanian businesses, specifically in the textile and clothing sectors.
- Fragmented Curricula: Circularity and sustainability concepts are often missing from lower-tier primary education, leading to a late-stage burden on HEIs to provide foundational environmental literacy.
- Monitoring Inconsistencies: There is an urgent need for standardized monitoring and analysis of circular economy indicators at the national level to guide training programs.

13.22.2. Recommendations for curriculum integration and professional training

Lithuanian Higher Education Institutions (HEIs) and vocational training centers are encouraged to align their curricula with the EU Strategy for Sustainable and Circular Textiles and the Ecodesign for Sustainable Products Regulation (ESPR).

The following recommendations focus on bridging the gap between textile engineering, environmental science, and digital compliance:

- Design for Durability and Low Shedding: Engineering and design programs (such as those at KTU) should introduce mandatory modules on "Fibre Fragmentation Mechanics." This includes teaching students how yarn twist, knit density, and mechanical brushing during finishing affect microfibre release.
- Chemical and Nanomaterial Safety: Integrate specialized courses on sustainable textile finishing. These should cover the development and application of biodegradable coatings and innovative bio-based resins designed to "lock" fibres in place without compromising breathability.
- Digital Product Passport (DPP) Training: As the EU mandates DPPs by 2026/2027, fashion and management students must be trained in traceability technologies (e.g., RFID, blockchain) to track material composition and recycled content, which are critical for microfibre reporting.
- Analytical Chemistry Labs: Establish hands-on lab modules focused on FTIR and Raman spectroscopy for identifying microfibres in wastewater, ensuring students can perform the standardized testing now required by international brands.
- Advanced Maintenance and Laundering: Vocational training for laundry facility managers and industrial technicians should include the installation and maintenance of industrial-grade microfibre filtration systems, which are increasingly becoming an industry standard in 2026.
- Navigating EU Regulations: Incorporate training on the legal landscape, specifically teaching students how to interpret and comply with the Green Claims Directive to ensure "microplastic-free" marketing is backed by verified scientific data.

- Stakeholder Communication: Train future managers in "transparency reporting," enabling them to communicate complex environmental data (like microfibre emissions) to investors and consumers effectively.

13.23. Conclusions

The textile industry sector in Lithuania is an important industrial player, playing a significant role in terms of employment, exports, and GDP. Lithuanian textile companies operate in all areas of production - yarn production, knitwear, woven and non-woven materials, technical and high value-added products, sewing, etc.

An analysis of the current situation in Lithuania has shown that microplastic and textile microfibre pollution is a new but well-known environmental problem of great importance for the textile sector and water environment management. Scientific research confirms that the majority of synthetic microfibres are released during washing and settle in sewage sludge, and then enter the soil and aquatic ecosystems. It has been established that the use phase of textile products, and especially washing at home, is one of the most important sources of microfibre release. However, additional attention should also be paid to the management of textile waste.

Lithuania has a well-developed scientific and technical base of universities, technology centers and public research institutions in the field of textile sustainability and microplastics/microfibres research, supported by national and European research, development and innovation initiatives. These initiatives have led to progress in identifying emission sources, characterizing microfibres and developing technological solutions for both the prevention of microplastics/microfibres release and their collection and removal in water treatment systems.

Lithuania strictly adheres to international environmental requirements and applies strict regulations in the country, aligned with EU documents. In Lithuania, clean freshwater resources are considered a national asset, therefore special attention is paid to their cleanliness and water treatment management.

National and international projects have been and are being implemented in Lithuania aimed at researching and controlling sources of microplastics/microfibres, developing new research methodologies and innovative technologies, educating the public, and training relevant specialists.

The Lithuanian textile industry directly contributes to the generation of released microfibres in various production stages, especially in wet finishing, cutting, etc. stages. The inclusion of eco-design and sustainability criteria, together with the optimization of production and finishing processes, reduces fibre release and the amount of microfibres in industrial wastewater. Also, the use of technological microfibre collection solutions both in the industrial field and in cooperation with other sectors, and participation in collaborative initiatives and pilot projects contribute to the reduction of the related environmental impact. These actions can be integrated into companies' sustainability strategies and extended producer responsibility schemes.

Public administrations also contribute to the prevention and management of microplastic and textile microfibre pollution through the regulatory framework and existing support mechanisms. The development of regulations, appropriate to the European context, the promotion of harmonised measurement and monitoring methodologies and the creation of programmes to support the deployment of technological solutions facilitate a more uniform application of measures to reduce microplastic pollution. Furthermore, the integration of this issue into policies on the circular economy, waste management and the protection of the marine environment, together with information and awareness-raising actions aimed at citizens and stakeholders, contributes to a coordinated response at national level.

Lithuanian higher education institutions play a crucial role in preparing specialists to address the microplastics problem using a multidisciplinary approach. To this end, priority is given to integrating specific content on microplastics and textile microfibres into relevant study programmes, strengthening eco-design training aimed at reducing the amount of microfibres emitted. HEIs also develop specialised and continuing education programmes, and carry out applied research in cooperation with leading companies. It is also crucial to promote knowledge transfer and dissemination of scientific results to industry and public administration institutions.

13.24. References

CPVA. https://cpva.lt

EEA. Microplastics from textiles: towards a circular economy for textiles in Europe. (Retrieved 4 January 2025, from https://www.eea.europa.eu/en/analysis/publications/microplastics-from-textiles-towards-a-circular-economy-for-textiles-in-europe).

EVRK. https://osp.stat.gov.lt/static/EVRK2/EVRK2red_lt_RIGHT.htm#13.

Every sample is contaminated: new research shows the extent of microplastic pollution in Lithuania (in Lithuanian), 2024. (Retrieved 4 January 2026 from: https://cpva.lt/naujienos/kiekvienas-meginys-uzterstas-nauji-tyrimai-rodo-mikroplastiko-tarsos-masta-lietuvoje#:~:text=%C5%A0iandien%20viso%20pasaulio%20j%C5%ABros%20ir%20vandenynai%20susiduria,keli%C4%85%20efektyvesniam%20j%C5%ABr%C5%B3%20%C5%A1iuk%C5%A1li%C5%B3%20steb%C4%97jimui%20ir%20valdymui).

Gago, J.; Carretero, O., Filgueiras, A.V., Viñas, L. (2018). Synthetic microfibers in the marine environment: A review on their occurrence in seawater and sediments. *Marine Pollution Bulletin*, 127, 365–376.

Geyer, R., Jambeck, J. R., Law, K. L. (2017). Production, use and fate of all plastics ever made. *Science Advances*. 3: e1700782.

IBISWorld. (Retrieved 2 January 2026, from https://www.ibisworld.com/lithuania/industry/clothing-manufacturing/200145/#IndustryStatisticsAndTrends).

LMT. https://lmt.lrv.lt/lt/

Marine Valley. https://jti.ku.lt/en/

MicroPlastGuard. https://en.ktu.edu/projects/mitigating-microplastics-pollution-through-advanced-baltic-cooperation-microplastguard/

Rathinamoorthy, R., Balasaraswathi, S. R. (2020). A review of the current status of micro-fiber pollution research in textiles. *International Journal of Clothing Science and Technology*, 33, 364–387.

Statistika. (Retrieved 30 December 2025 from: https://osp.stat.gov.lt/.

Tanaka, S. (2022). Environmental Pollution and Remediation. *In Book: Design of Materials and Technologies for Environmental Remediation*. Springer. DOI: 10.1007/698-2021-819.

UWWTD. Urban Waste Water Treatment Directive. (Retrieved 4 January 2026 from: https://www.eea.europa.eu/en/datahub/datahubitem-view/6244937d-1c2c-47f5-bdf1-33ca01ff1715).

Annex III: National Report – Poland

13.25. Introduction

13.25.1. Purpose of the national report

Microplastics pose a growing threat to the environment and human health. Microplastics are present almost everywhere: in the air, water, soil, and even in the bodies of humans and animals. Scientists have detected these particles in every aquatic environment studied, and their impact on ecosystems and human health is a growing concern. One of the most serious sources of microplastics are products of the textile industry: textiles and clothing, at various stages of their life cycle. Taking it into consideration, it is necessary to recognize the scale, status and current situation of the textile industry in order to take action to reduce environmental pollution originating directly or indirectly from this industry.

The aim of the report is to present the current situation of the textile industry in Poland in the context of the impact of the domestic textile industry on the formation of microplastics and microplastic pollution of domestic waters, as well as to identify mitigations taken to reduce microplastic pollution of waters.

13.25.2. Background Brief history of sector-Economic significance

Over the past decade, the Polish textile industry has undergone a transformation from mass production based on low labour costs towards niche, specialized solutions with high added value. Changes in the structure and size of the Polish textile and clothing industry were caused by both political factors (systemic transformation at the turn of the 1980s and 1990s), as well as economic changes on a global scale – market globalization. Although facing significant cost pressures and competition from Asia, the Polish industry maintains a stable position as one of the leading producers in the European Union.

The key factors in the current position of Polish textile industry are the following:

• high position of Polish textile industry in the European Union – Poland ranks third in the EU in terms of the number of textile companies (after Italy and France) and employment (after Italy and Germany).

• export expansion – Polish textile industry is strongly focused on exports, which generate over 60 % of sales revenue. The main export destinations are Germany, France, and Ukraine.

• structure of Polish textile industry – the industry is highly fragmented; approximately 97 % of companies in the clothing sector are micro-enterprises [Polska branża odzieżowa na tle światowych rynków, 2025].

• Production value - the value of textile production sold in 2025 is estimated at approximately €4.8 billion.

The textile and clothing industry is estimated to be one of the Polish industries with the greatest growth potential. The subsectors with the greatest potential for productivity improvement due to their large scale and the added value generated are: automotive (€8 billion), furniture (€6.8 billion), **and textiles and clothing** (€5.7 billion).

The textile, and clothing sectors belong to the national sectors of the greatest opportunities to bridge the productivity gap with the EU-15.

13.26. National textile industry overview

13.26.1. Structure of the polish textile industry

Currently, a characteristic feature of the broadly defined textile manufacturing industry is the relatively small number of operating entities in Poland. According to Dun & Bradstreet estimates, there were just over 9,500 companies operating in the sector at the end of February 2024 [Od potęgi do niszy dla wytrwałych. Co czeka branżę włókienniczą? 2024].

Moreover, the number of textile companies has been declining over the past three years. In 2023 alone, compared to 2022, it decreased by nearly 1.6 %. The number of companies suspending their operations is also increasing. In 2023 alone, there were nearly 500 of them. However, this doesn't mean that the textile industry has completely disappeared from the Polish economic landscape. There are still regions where the textile industry is thriving [Producenci tekstyliów, 2025]. The structure of Polish textile industry according to Polish Classification of Activities (PKD) is presented in the Table 2.

Table 2: The structure of Polish textile industry according to Polish Classification of Activities PKD [Producenci tekstyliów, 2025]

Category	Number
13.10.A Manufacture of cotton yarn	19
13.10.B Manufacture of wool yarn	9
31.10.C Manufacture of man-made fibres yarn	10
13.10.D Manufacture of yarn from other textile fibres, including manufacture of sewing threads	20
13.10.Z Preparation and spinning of textile fibres	3
13.20.A Manufacture of cotton woven fabrics	32
13.20.B Manufacture of wool woven fabrics	4
13.20.C Manufacture of man-made woven fabrics	15

13.20.D Manufacture of other woven fabrics	18
13.20,Z Manufacture of woven fabrics	7
13.30 Finishing of textiles	12
13.30.Z Finishing of textiles	141
13.91.Z Manufacture of knitted and crocheted fabrics	50
13.92.Z Manufacture of made-up textile articles	651
13.93.Z Manufacture of carpets and rugs	26
13.94.Z Manufacture of cordage, rope, twine and netting	30
13.95.Z Manufacture of nonwovens and articles made from nonwovens, except apparel	56
13.96.Z Manufacture of other technical and industrial textiles	73
13.99.Z Manufacture of other textiles not elsewhere classified	149
Total number	**1325**

The structure of Polish apparel industry by product according to Polish Classification of Activities (PKD) is presented in the Table 3.

Table 3: The structure of Polish apparel industry according to Polish Classification of Activities (PKD) [4.Producenci odzieży, 2025]

Category	**Number**
14.10.Z Manufacture of knitted clothes	40
14.11.Z Manufacture of leather clothes	39
14.12.Z Manufacture of workwear	188
14.13.Z Manufacture of other outerwear	690
14.14.Z Manufacture of underwear	98
14.19.Z Manufacture of other wearing apparel and accessories	344
14.20.Z Manufacture of articles of fur	6
14.21.Z Production of outerwear	53
14.22.Z Production of underwear	7
14.23.Z Production of workwear	14
14.29.Z Production of leather clothing and fur products	1
14.29.Z Manufacture of other clothing and clothing accessories not elsewhere classified	25
14.31.Z Manufacture of knitted and crocheted hosiery	41
14.39.Z Manufacture of other knitted and crocheted apparel	72
Total	**1618**

Production and sale of textile products

Production

The textile industry in Poland processes all kinds of textile raw materials and produces different kinds of linear and flat textile products. However, in the aspect of textile microplastics, the production and sale of synthetic fibres, yarns and fabrics is relevant.

Figures below (Fig. 2, 3) present the production amount of selected synthetic textile products in 2020 – 2024.

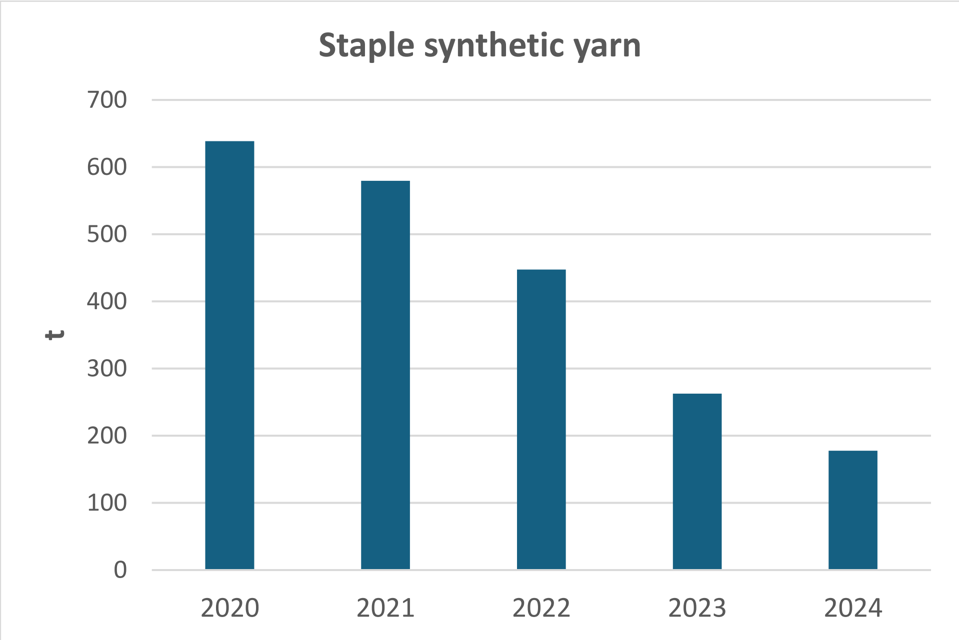

Figure 2: Production of synthetic yarns in Poland in 2020-2024.

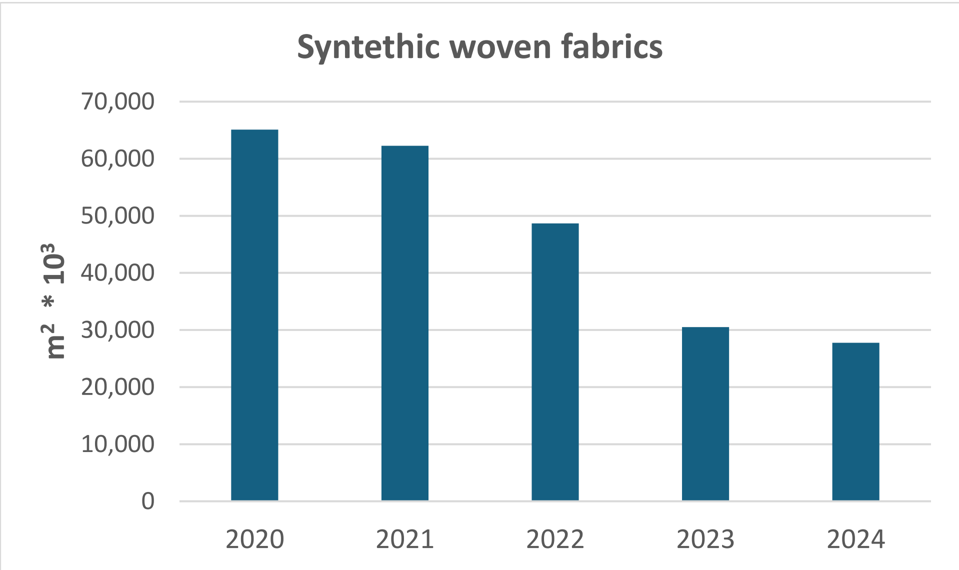

Figure 3: Production of synthetic woven fabrics in Poland in 2020-2024.

On the basis of the presented data it can be stated that the production of synthetic yarns and fabrics in Poland is systematically decreasing since 2020. In the case of yarns, the production of synthetic yarns has decreased threefold since 2020 and reached the level of cotton yarn production (Fig. 4). This should be considered a positive trend from the point of view of reducing microplastics from yarn production in Poland.

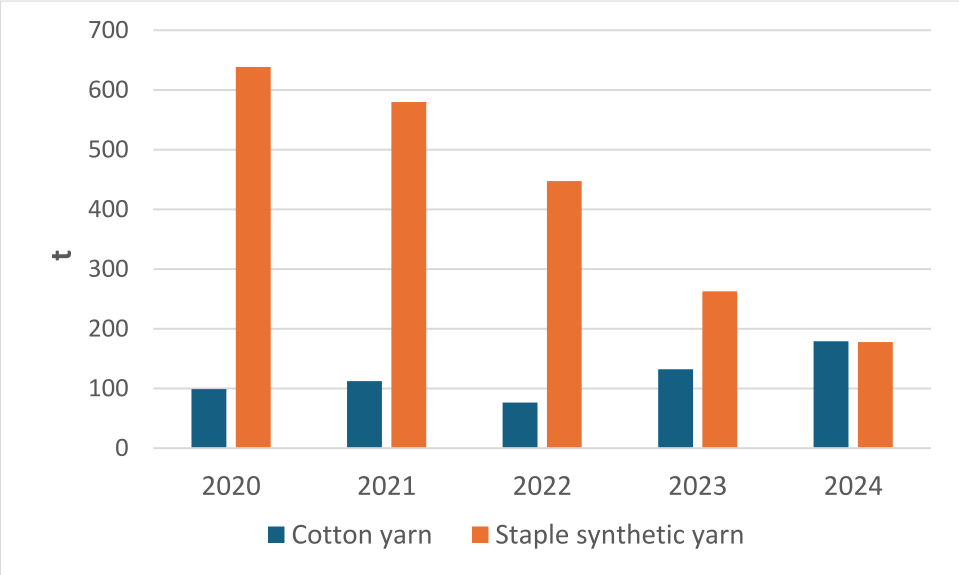

Figure 4: Comparison of production of synthetic and cotton yarns in Poland in 2020-2024.

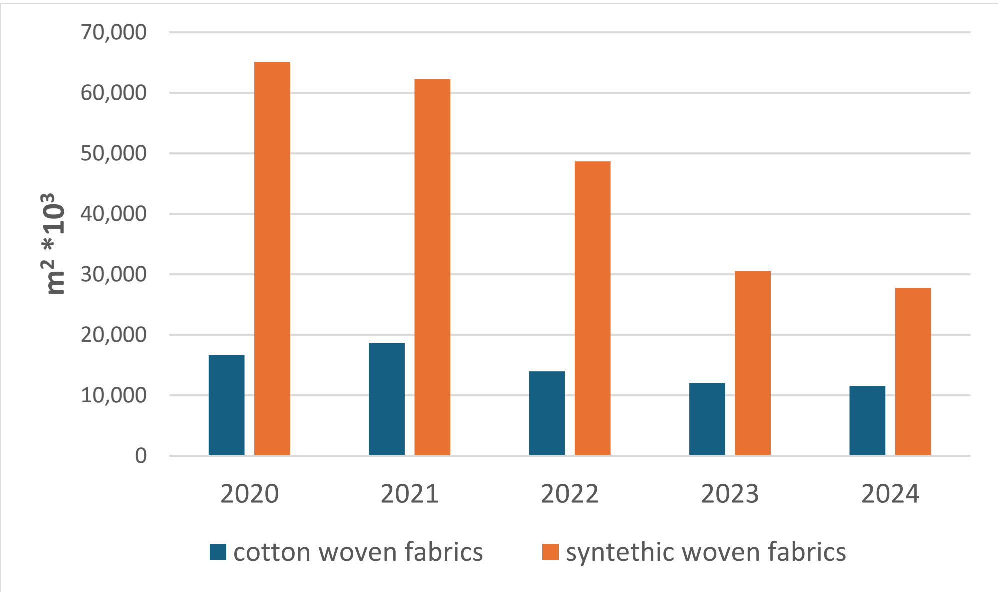

Figure 5: Comparison of production of synthetic and cotton and cotton woven fabrics in Poland in 2020-2024.

The production of synthetic woven fabrics is also decreasing. However, the production in 2024 is twice as large as the production of cotton fabrics (fig. 5). Comparing the figures 5 and 6 it can be concluded that the production of synthetic woven fabrics in Poland in 2024 is based half on the import of synthetic yarns.

Fig. 6. presents a value of Polish import of fibres and knitted fabrics in 2022-2024 [Yearbook of Foreign Trade Statistics of Poland 2022, Yearbook of Foreign Trade Statistics of Poland 2023, Yearbook of Foreign Trade Statistics of Poland 2024]

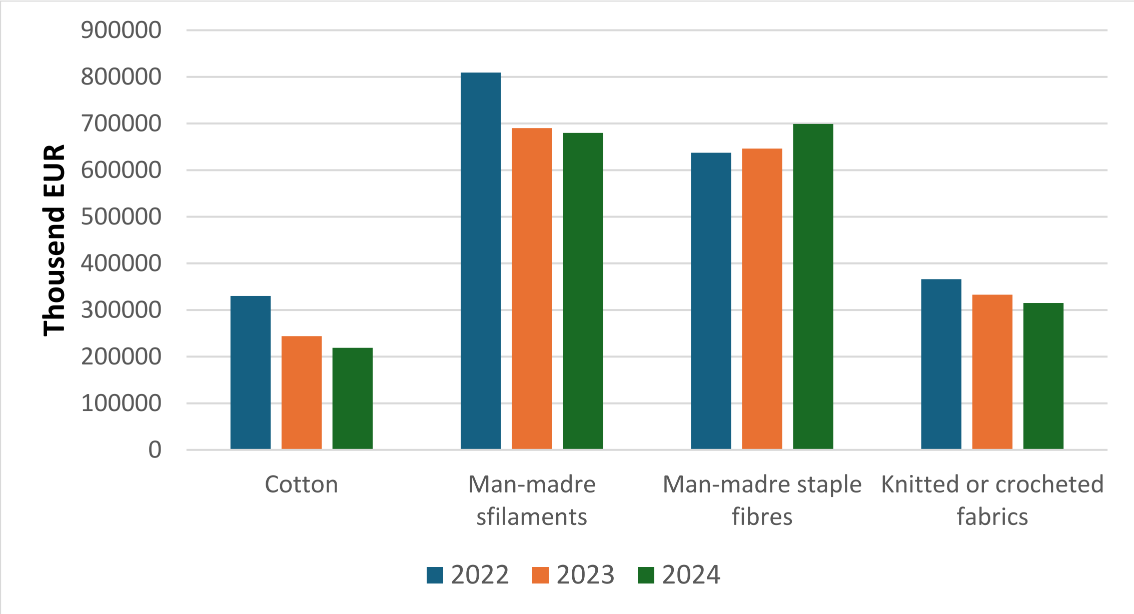

Figure 6: The value of Polish import of fibres and knitted fabrics in 2022-2024 [Yearbook of Foreign Trade Statistics of Poland 2022, Yearbook of Foreign Trade Statistics of Poland 2023, Yearbook of Foreign Trade Statistics of Poland2024].

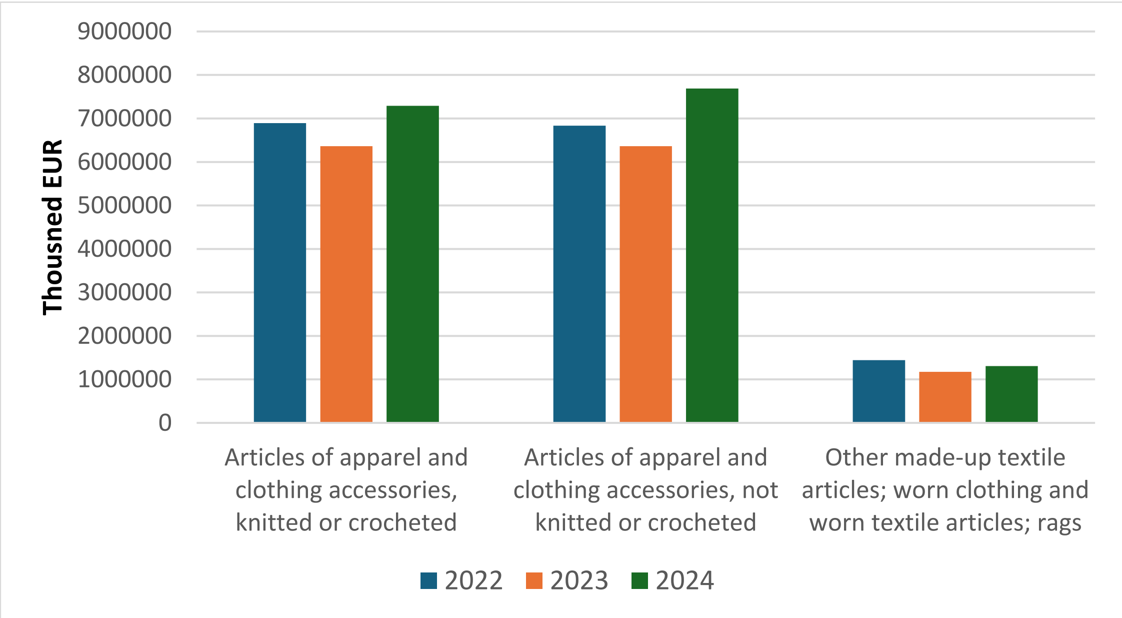

Figure 7: The value of Polish import of apparel and other made-up textile articles in 2022-2024 [Yearbook of Foreign Trade Statistics of Poland 2022, Yearbook of Foreign Trade Statistics of Poland 2023, Yearbook of Foreign Trade Statistics of Poland 2024].

It is clearly seen that value of import of synthetic fibres is almost three times larger than cotton import value. What's more, the import of mane mad-staple fibres is increasing since 2022. This is not a favorable trend from the point of view of reducing the amount of microplastics coming from Polish textile industry.

In turn, the value of clothing imports (Fig. 7) significantly – tenfold – exceeds the value of imports of fibres, yarns and knitted fabrics, presented in Fig. 6.

What's more, the import value of apparel products significantly increased in 2024 in comparison to 2023. It can be caused by the increase of price. However, there are no data available, to confirm it.

According to estimates by the Polish Chamber of Clothing and Textiles (PIOT), the Polish clothing market was worth PLN 66.9 billion in 2024, of which PLN 10 billion came from domestic production. The data included in the PMR Market Experts report, however, is worth PLN 60 billion, of which clothing sales alone (excluding underwear, footwear, and accessories) account for approximately 70 % of this amount.

According to the "Digital Fashion Gap 2025" report and Puls Biznesu, the clothing market in Poland is primarily driven by women's clothing, which accounts for approximately 53 % of the industry's revenue, while men's and children's clothing account for 32 % and 15 %, respectively. In 2023, the women's clothing segment was worth PLN 36 billion, accounting for more than half of the market [Rosalio. Blog 2025].

The value of imports of last category: "Other made-up textile articles; worn clothing and worn textile articles rags" is worrying. The value in 2024 is greater than that in 2023 but lower than that in 2022. However, this can also be viewed as a positive trend with cross-border reach. The increase in the value of used clothing imports means that the clothing will last longer.

The value of sales of textile and clothing products in Poland in 2020-2024 is presented in the chart below (Fig. 8)

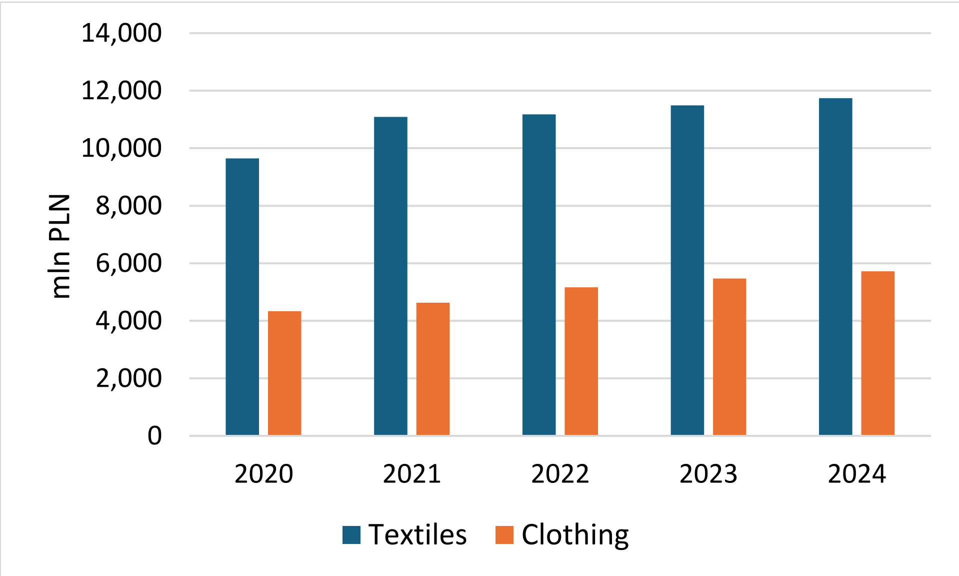

Figure 8: The value of sales of textile and clothing products in Poland in 2020-2024 [Walkowska –Macias; 2025]

13.27. Relevance of microplastics/microfibres in the national context

13.27.1. National sources of microplastic

Investigations showed, that the main sources of microplastics are synthetic fabrics and tires, which are responsible for nearly two-thirds of this type of pollution in the oceans [10]. Poland is a significant producer and also importer of both categories: synthetic fabrics (Fig. 3) and tires. Due to this fact the problem of microplastics in water is current and significant in Poland.

The value of the Polish clothing market reached PLN 66.9 billion, of which PLN 10 billion comes from domestic production, the rest is the import vale. Generally, the Polish household spending on clothing and footwear reached EUR 5.3 billion in 2023, which placed Poland in sixth place in Europe [Eurostat. Statistics]. The clothing and footwear market is expected to grow by approximately 4 % per year.

Takin it into account the national sources of microplastic are both:

- textile production,
- textile usage

with a predominance of textile usage, most of which are imported.

Textile production in Poland includes all mechanical technologies, i.e. spinning, weaving, knitting and nonwoven production, but also chemical textile processes, such as finishing and functionalization of fabrics.

Usage of textiles in Poland is very high. The “fast fashion” trend continues to dominate the clothing market.

13.28. National sources of microfibre release

13.28.1. Production stage

All kinds of textile production are sources of micro plastic in Poland. Polish textile industry includes manufacturing the synthetic yarns and fabrics in amount presented above. Apart from the yarns made of natural fibres – cotton and linen – then great share of yarn production concerns the synthetic yarns. This segment includes texturing, braiding, twisting and grafting of synthetic filaments. Mechanical impacts occur in each mentioned production segments. They can damage the surface of the fibres and lead to the formation of microplastics.

13.28.2. Use phase

Similarly to all countries, the usage of clothing and textile product is source of microplastic. It is connected with textile product maintenance, especially with washing. In Poland, home laundry is most commonly used. Industrial laundries are much less common.

13.28.3. End-of-life handling

As of January 1, 2025, textile waste cannot be disposed of as mixed waste. Separate collection of used textiles and clothing is applied. Used, undamaged clothing that can be used by subsequent users is disposed of in appropriate containers. Clothing and textiles that are no longer suitable for use must be taken to selective waste collection points. It is according to the governmental regulations.

13.29. National scientific and technical studies

13.29.1. Active research institutions

Institutes of the Polish Academy of Sciences (e.g. ERCE PAN Lodz, IOP PAN Cracow), departmental institutes (e.g. IRS Olsztyn, IMWM PIB) and faculties of universities, universities of technology, Warsaw University of Life Sciences (SGGW), AGH University of Cracow, as well as associations (e.g. WWF Poland, OTOP, Naturalists' Club) are active in analysis and prevention of microplastic.

13.29.2. University research projects

- **The Impact of Physicochemical Water and Wastewater Treatment Processes on the Fate of Microplastics**

Funded by the National Science Centre (NCN); research project number: 2021/05/X/ST8/00567. Implementation period: November 3, 2021 - November 2, 2022, Project manager: Dr. Sabina Ziembowicz, Eng.

The aim of this research is to determine the impact of physicochemical water and wastewater treatment processes on microplastics present in water and wastewater. Interactions between selected individual processes and the amount, size, mass, shape, and surface structure of microplastic particles were determined. The project examined four microplastics (PE, PP, PVC, PS), which are most frequently detected in the aquatic environment and wastewater. The analysis covered the coagulation process, disinfection using ozone and UV radiation, and the Fenton process, which is a promising and effective method for removing difficult-to-decompose organic pollutants, which is why it is increasingly considered as one of the stages of wastewater treatment.

- **Analysis of the Presence of Microplastics in Water and the Adsorption of Various Pollutants on Their Surfaces**

Implementing Unit: Faculty of Building Installations, Hydrotechnics, and Environmental Engineering, Warsaw University of Technology, Project Leader: Aleksandra Bogdanowicz, M.Sc. Eng., Funding Sources: YOUNG PW, IDUB ("Excellence Initiative – Research University").

The project aims to: (1) identify microplastics in water intakes and at selected points in the water supply system, and (2) assess the potential for microplastics to adsorb selected contaminants (such as heavy metals and organic dyes) in both laboratory and field conditions.

- **Biodegradation activity of fungi and fungus-plant interactions in the presence of microplastics**

Implementing Unit: Lodz University, Project Leader: dr hab. Przemysław Bernat; Funded by the National Science Centre (NCN).

Scientists from the Department of Industrial Microbiology and Biotechnology at the Faculty of Biology, Environmental Protection and Environmental Protection are studying two types of microscopic fungi found in soil. Trichoderma fungi promote plant growth, while Fusarium fungi cause plant disease. The researchers are focusing on studying the impact of these fungi on wheat and how microplastics present in the soil might alter this impact.

13.29.3. Industry research

- **A system for collecting and processing real-time data on the presence of microplastics and petroleum-derived substances in water**

Project realized by the consortium with the industrial partner. The project is funded under the Government Strategic Program "Hydrostrateg," – In the frame of the 3rd competition of the Program: "Innovations for water management and inland navigation".

Date of signing the funding agreement: August 14, 2025.

The project's goal is to develop and market the first comprehensive system (set of devices) for continuously and automatically monitoring the presence of microplastics (MP) in water, without the need for manual operation by an employee or the need to deliver samples to a specialized laboratory [Mateja-Furmaniak; 2025].

13.29.4. EU Project Participation

- **Lakes Connect (Interreg Baltic Sea Region)**

The project focuses on protecting lakes from plastic microparticles, with educational activities in Warsaw. Polish Lead Partner: CNBCh UW (Analytical Expert Center, Faculty of Chemistry, University of Warsaw).

- **Multilevel assessment of microplastics and associated pollutants in the Baltic Sea (MICROPOLL)**

Coordinator: IVL SVENSKA MILJÖINSTITUTET AB - IVL Svenska Miljöinstitutet Stockholm. Project duration: July 2017 - September 2020. The project aimed at the assessment of the current status of microplastic input and distribution in the Baltic Sea, emanating risks originating from microplastics, and the suggestion of cost-effective and user-friendly monitoring strategies regarding microplastics and associated pollutants. Polish Partner: National Marine Fisheries Research Institute, Gdynia.

- **Mitigating Microplastics Pollution Through Advanced Baltic Cooperation – MicroPlastGuard**

Implementation period: 01.10.2024 - 30.09.2026

Polish partner: Lodz University of Technology,

Kaunas University of Technology, Funded in the frame of the Programme: SI Baltic Sea Neighbourhood Programme - Cooperation projects, Funding Agency: Swedish Institute

The project aims to address the urgent issue of microplastic pollution in the Baltic Sea region, particularly focusing on the threat posed by microplastics originating from synthetic textiles. The project seeks to collaborate with stakeholders in the textile production sector to establish standardized test methods for quantifying the release of microplastic fibre during washing and to address the knowledge deficit among fashion brands and factories regarding the release of dry state microplastics during production, processing, and recycling of synthetic textiles. Additionally, the project emphasizes the essential role of scientific and social awareness, international expert networking, and discussions among businesses and policymakers in addressing these issues. Furthermore, the project aims to develop innovative coatings and finishes mitigating the emissions of microplastics from synthetic fabrics. Partnerships include Kaunas University of Technology and Lodz University of Technology.

Publications

- Połeć M., Aleksander-Kwaterczak , Wątor K., Kmieci E., The occurrence of microplastics in freshwater systems – preliminary results from Krakow (Poland) Geology, Geophysics and Environment, 2018, 44 (4): 391–412
- Piotr Zieliński*1) , Karolina Mierzyńska. Microplastics in Polish freshwater ecosystems: Current state of knowledge and research gaps . JOURNAL OF WATER AND LAND DEVELOPMENT
- Dacewicz, E., Łobos-Moysa, E. and Chmielowski, K. (2024) "Identification tools of microplastics from surface water integrating digital image processing and statistical techniques," Materials, 17(15), 3701. Available at: https://doi.org/10.3390/ma17153701
- Kaliszewicz, A. et al. (2020) "The contamination of inland waters by microplastic fibres under different anthropogenic pressure: Preliminary study in Central Europe (Poland)," Waste Management & Research, 38(11), pp. 1231–1238. Available at: https://doi. org/10.1177/0734242X20938448.
- Citation: Świątek, O.; Dąbrowska, A. A Feasible and Efficient Monitoring Method of Synthetic Fibers Released during TextileWashing. Microplastics 2024, 3, 67–81. https://doi.org/ 10.3390/microplastics3010005
- Ormaniec P. Occurrence and analysis of microplastics in municipal wastewater, Poland. Environmental Science and Pollution Research (2024) 31:49646–49655; https://doi.org/10.1007/s11356-024-34488-z

13.30. Case studies

13.30.1. Case study 1: Hydrostrateg

A system for collecting and processing real-time data on the presence of microplastics and petroleum-derived substances in water

The project, funded under the Government Strategic Program "Hydrostrateg," – In the frame of the 3rd competition of the Program: "Innovations for water management and inland navigation" – an initiative of the National Center for Research and Development, involves developing an innovative system for automatic monitoring of microplastics and petroleum-derived substances in water. The members of the consortium implementing the project are:

- the Municipal Water and Sewage Company in Wrocław,

- the Techsy company,
- the Wrocław University of Science and Technology,
- the State Water Management Company Wody Polskie.

The project's goal is to develop and market the first comprehensive system (set of devices) for continuously and automatically monitoring the presence of microplastics (MP) in water, without the need for manual operation by an employee or the need to deliver samples to a specialized laboratory. The system is designed to operate in real-world (field) conditions, enabling the monitoring of microplastics in water flowing in rivers, surface streams, water supply networks, and sewage treatment plant outlets, enabling ongoing assessment of contamination levels directly at the point of collection.

Date of signing the funding agreement: August 14, 2025

The devices developed as part of the project will analyse water samples on-site and immediately transmit the results 24/7, including at night and on weekends. Using such a monitoring system on a larger scale in the future will enable continuous monitoring of water quality for microplastics, similar to the ongoing monitoring of air quality for pollutants such as particulate matter, carbon monoxide, and benzene through an entire system of measurement stations.

The project will include the development of a sampling method, research on the use of markers, and the development of analysis methods that will enable the precise identification of microplastics without the need for complex laboratory techniques.

The project's target groups are water and sewage utilities, industrial plants, and institutions responsible for environmental protection. Through the project, users will gain access to an innovative tool that will enable easier and faster analysis of microplastics in water.

The project will result in a ready-to-implement system that will enable ongoing monitoring of water quality, supporting environmental protection and ensuring safe water quality for the public.

https://techsy.com.pl/projekty/

13.30.2. Case study 2: FanpLESStic-sea

Context (company/municipality/industry)

FanpLESStic-sea is a project, working with preventing and decreasing the pollution of microplastics in water and the Baltic Sea.

International project – The FanpLESStic-sea project brought together partner organizations from eight Baltic countries: Sweden, Finland, Norway, Denmark, Poland, Latvia, Lithuania, and Russia. Poland was represented by two entities from Gdańsk: Gdańska Infrastruktura Wodociągowo-Kanalizacyjna Sp. z o.o. and Gdańskie Wody Sp. z o.o.

Problem identified

Microplastics have been found in the most remote areas of the Baltic Sea as well as in drinking water, but the real extent and consequences of the problem is unknown. Recovering microplastics from the sea is extremely difficult and costly, if not impossible with existing technologies. Therefore, measures should be focused on mitigating sources and removing the microplastics before they enter the sea.

There is currently a knowledge gap on actual removal technologies and policies to implement preventive measures or removal technologies.

Intervention implemented

The international research project FanpLESStic-sea focused on activities aimed at reducing the amount of microplastics discharged into the Baltic Sea and eliminating their potential sources. The project also aimed to increase awareness and knowledge regarding the routes of microplastics spread and their sources. To acquire the necessary knowledge to achieve its goals, the project conducted research on microplastics content in various environmental media, in areas associated with human activity. Additionally, the feasibility of using cost-effective methods/technologies to eliminate microplastics in areas where they potentially occur, was verified.

Quantitative results (kg/year reduction, %, etc.)

As part of the project, GIWK Sp. z o.o. conducted research on microplastic content in drinking water and wastewater, verified its removal rate through water and wastewater treatment processes, and also through a process using constructed wetlands, tested at a pilot station built on the treatment plant grounds as part of another international project. The company also implemented an educational campaign on microplastics and their harmful effects on the environment and human health, and supervised the implementation of similar campaigns by other project partners. The starting point for implementing the campaign were activities conducted as part of the well-received and highly publicized educational campaign, "City on Detox," which was widely recognized in Gdańsk and beyond.

Stakeholder engagement

Two local government units participated in the project implementation:

- Gdańska Infrastruktura Wodociągowo-Kanalizacyjna Sp. z o.o.,
- Gdańskie Wody Sp. z o.o.

Lessons learned

- knowledge was gained about the origins of microplastics and their spread pathways,
- the effectiveness of technologies that reduce microplastic loads or reduce the risk of them entering waterways was assessed,
- and decision-makers were increased in knowledge and engagement by providing suggestions on how to implement cost-effective microplastic reduction methods.

Contact information (optional)

https://www.giwk.pl/dla-srodowiska/zrealizowane-projekty/projekt-fanplesstic-sea/

13.31. Main challenges and barriers

In Poland there are different barriers for microplastic mitigation. First of all, the economical limitations should be mentioned here. They influence both the technical opportunities of microplastic mitigations and ways of behaving and making decisions of textile and clothing consumers. The war in Ukraine is causing a significant increase in budget allocations to defense, significantly higher than in previous years. This is leading to maintenance at level to previous years or even reduction of funding for research and investment.

The financial and market situation of Polish textile and clothing industry is difficult. The industry is grappling with problems stemming from the excessive import of textiles from the East, primarily China. These products are significantly cheaper than domestically produced goods. At the same time, the high minimum wage, social benefits and taxes imposed on entrepreneurs prevent them from competing with imported products, while at the same time, they have very limited funds for investment.

The financial situation forces many people to buy lower-quality clothing, often imported (e.g., from China) with unknown quality parameters and raw material composition. Lower-quality textile products are a greater source of microplastics compared to high-quality textiles and clothing, including luxury goods, which have a small share in the Polish textile and clothing market.

Another challenge is changing the awareness of textile and clothing consumers. Fast fashion remains dominant in Poland. The age structure of Polish society, dominated by older people, may be a barrier. These individuals rarely access information from online sources about environmental threats, microplastics in water, and possible methods for reducing microplastics. Older Poles still remember the market situation in the 1980s and 1990s, when industrial goods were very difficult to obtain. Back then, people bought everything that was available in the store, regardless of the need for it, fearing that in the future, when needed, these products might not be available. These habits and customs are still present among parts of society.

13.32. National success stories and best practices

13.32.1. Innovative technologies

Polish scientists at the Silesian University of Technology in Gliwice are developing materials with a lower environmental impact by using chitosan, sodium alginate, and starch, which can replace traditional plastic. This study introduces an innovative multilayer film production method, combining electrospun polycaprolactone (PCL) fibres with a chitosan matrix. The newly-developed materials ensure tangible reduction in microplastic and a contribution to creating a cleaner, more environmentally friendly packaging solution [Jakubska at el. 2025].

13.32.2. Industry or municipal initiatives

The Polish Plastics Pact –initiative of the 17 Goals Campaign Foundation. It brings together enterprises and organizations involved in the plastics value chain to work together to close the plastic packaging loop in Poland. It is a multi-stakeholder, cross-sectoral, and industry-led collaboration platform that aims to mitigate waste and pollution from plastic packaging by integrating various value chain partners, including businesses, NGOs, and other key players in the national plastics value chain

https://paktplastikowy.pl/english-version/?utm_source=chatgpt.com

13.32.3. Certifications or voluntary schemes

Plastic Free Certification - an international and voluntary product certification standard. It certifies that end products, packaging, and materials do not contain conventional plastic. This global system, owned by the benefit company PlasticFreeCertifications, an innovative startup, focuses on eliminating fossil-based plastics and encouraging the use of more sustainable materials. The program is available for various sectors.

13.32.4. Successful partnerships or projects

- Project "Study of the mechanism of transport of macroplastic waste in a stream with vegetation".

The project focuses on rivers with vegetated banks. Its main goal is not only to reconstruct the path of plastic waste but, above all, to develop solutions that limit its spread in inland waters and runoff into seas and oceans. The project will develop a mathematical model that will enable numerical simulations of plastic transport under various water flow conditions. This knowledge will help monitor waters for this type of pollution more quickly and cost-effectively and prevent its spread.

https://zielonyrozwoj.pl/polscy-naukowcy-opracuja-model-sledzenia-mikroplastiku-w-rzekach/

- Aquacollector,

Aquacollector is a portable device designed to collect and dispose of microplastics from water bodies. The device is intended for both public and private water tank owners. The prototype is powered by photovoltaic panels. The energy thus obtained drives a submersible pump, which increases water flow through a system of filters that trap contaminants. The Aquacollector is equipped with a built-in locator and filter clogging sensor. A mobile app has also been developed that allows remote location of the device and monitoring of the filter mesh filling level.

https://slaskifestiwalnauki.pl/aquacollector-przenosne-urzadzenie-do-zbierania-i-utylizacji-zanieczyszczen-syntetycznych-z-akwenow

- C-TRUE

Startup C-THRUE, in collaboration with the Warsaw University of Technology and the Selvita biotechnology company, is developing a biosensor capable of detecting polystyrene microplastics. The key element is a microfluidic cartridge—a small device into which the user drops a water or food sample. The result can be read using a mobile app and a phone camera. The technology is in the MVP stage. C-TRUE has already tested the biosensors using peanut allergens as an example. The researchers are now developing a solution for polystyrene, with additional types of microplastics in mind.

https://www.gazetaprawna.pl/wideo/z-pierwszej-strony/wideo/9884144,mikroplastik-na-talerzu-polski-start-up-chce-pomoc-nam-go-wykrywac.html

13.33. National policies and regulatory framework

13.33.1. National laws related to microplastics

The Act of 19 July 2019 amending the Act on Maintaining Cleanliness and Order in Municipalities and certain other acts

The Act introduced the obligation to separate textile waste from 1 January 2025.

(Ustawa z dnia 19 lipca 2019 r. o zmianie ustawy o utrzymaniu czystości i porządku w gminach oraz niektórych innych ustaw - in Polish, Dz. U. z 2018 r. poz. 1454 i 1629 oraz z 2019 r. poz. 730 i 1403)

13.33.2. Alignment with EU legislation

- Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste (Text with EEA relevance)

13.33.3. Strategic plans, incentives and programmes

- **Hydrostrateg**

Governmental Strategic Program Hydrostrateg "Innovations for water management and inland navigation"

The main objective of the program is to implement new solutions to improve the efficiency of water use and management in Poland.

The program covers three research areas:

- water in the environment - biodiversity/bioproductivity
- water in the city
- inland sailing

The specific goals are:

1. Increase of retention and improvement of water quality (using the principles of sustainable development and sustainable water and sewage management).
2. Implementation of new research methods, observations and tools supporting the monitoring and assessment of the condition of aquatic ecosystems and water-dependent ecosystems.
3. Increasing the use of waterways for inland navigation with the existing resources.

13.33.4. National standardization activities

Standardization activities in Poland are based on the principle of adopting European and international standards as Polish standards.

PN-EN ISO 24187:2024-02 Principles for the analysis of microplastics present in the environment

13.34. Training needs and educational proposals

13.34.1. Training needs and education proposals

There is a need to raise public awareness of the harmful effects of microplastics and ways to prevent them. Awareness among Poles is relatively high. A wealth of information, reports, scientific publications, and interviews on this topic can be found online. However, there is a need to continue and strengthen this activity.

Study programs, including those in the Textile Studies program at Lodz University of Technology, incorporate broadly understood environmental protection and sustainable development, including preventing the formation of microplastics, into their subject content.

13.34.2. Recommendations for curriculum integration and professional training

The transfer of knowledge and good practices in area of microplastic, its sources and mitigations should take place at all levels of education, including universities of the third age.

The content of such education should be tailored to the age and competencies of the participants. For example, for children and adolescents, it would be advisable to introduce content related to microplastics into computer games.

13.35. Conclusions

In Poland, microplastics are generated in all phases of the textile lifecycle: production, use, and disposal.

Awareness of the threat posed by microplastics to health and the environment is very high, as evidenced by the number of projects, scientific publications, and social media content.

Many scientific and educational projects are underway regarding sustainable development, including microplastics.

All efforts should be continued and intensified.

The financial factors are the greatest barrier to counteracting the generation of microplastics because their influence decisions of both businesses and individual textile users.

13.36. References

Eurostat. Statistics. Household consumption by purpose, explained https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Household_consumption_by_purpose

Jakubska, J.; Hudecki, A.; Kluska, D.; Grzybek, P.; Gołombek, K.; Pakieła, W.; Spałek, H.; Włodarczyk, P.; Kolano-Burian, A.; Dudek, G. Innovative Multilayer Biodegradable Films of Chitosan and PCL Fibers for Food Packaging. Foods 2025, 14, 2470. https://doi.org/10.3390/foods14142470

Mateja-Furmanik M. Nowatorski system do walki z mikroplastikiem. Wrocławskie wodociągi testują przełomowe rozwiązanie, 2025. https://zielony.onet.pl/przyroda/mikroplastik-w-wodzie-innowacyjny-projekt-wroclawskich-wodociagow/cw7v52v

Od potęgi do niszy dla wytrwałych. Co czeka branżę włókienniczą? 2024; https://media.big.pl/informacje-prasowe/832884/od-potegi-do-niszy-dla-wytrwalych-co-czeka-branze-wlokiennicza

Polska branża odzieżowa na tle światowych rynków, https://www.trade.gov.pl/wiedza/polska-branza-odziezowa-na-tle-swiatow, 25.11.2025; KO BP, Departament Analiz Ekonomicznych, „Rynki międzynarodowe: odzież. Sytuacja bieżąca i prognozy do 2029”, sierpień 2025

Producenci odzieży 24-11-2025; https://www.coig.com.pl/wykaz_lista_producentow-tekstyliow.php]

Producenci tekstyliów 24-11-2025; https://www.coig.com.pl/wykaz_lista_producentow-tekstyliow.php

Rosalio. Blog. 2025**.** Polska jest 6. w Europie w wydatkach na modę, ale 78% nadal kupuje stacjonarnie. Co się zmieni? https://rosalio.pl/blog/polska-rynek-mody-digitalizacja-2025-prognozy/?srsltid=AfmBOoob_Z-Ee1RcJgoWtDdwVfWktDVhfug5EtEjB8HtazUs8wZsNues#badanie-cyfrowa-przepasc

Walkowska-Macias K. Produkcja wyrobów przemysłowych w latach 2020–2024, GUS, Warszawa 2025

Yearbook of Foreign Trade Statistics of Poland 2022,

Yearbook of Foreign Trade Statistics of Poland 2023,

Yearbook of Foreign Trade Statistics of Poland 2024,

https://www.oliviacentre.com/news/dzien-bez-opakowan-foliowych/;https://www.theworldcounts.com/challenges/planet-earth/waste/plastic-bags-used-per-year

https://www.medexpress.pl/nauka-medycyna/rewolucja-w-walce-z-plastikiem-badania-polki-daja-nadzieje-na-czystsza-planete/

Annex IV: National Report – Spain

13.37. Introduction

Microplastic pollution has become established in recent years as one of the main environmental challenges associated with modern production systems, with significant implications for aquatic ecosystems, human health and economic sustainability. Among the various sources identified, the textile sector stands out as one of the main contributors to the release of synthetic microfibres, generated both during manufacturing and finishing processes and throughout the use and washing phase of garments.

In the European context, the textile industry has been the subject of increasing attention in the framework of circular economy, pollution prevention and industrial sustainability policies, reflected in initiatives such as the European Green Deal, the EU Strategy for Sustainable and Circular Textiles and successive Circular Economy Action Plans. These strategies explicitly recognise the need to act on the generation of microplastics at source, improve their control in water treatment systems and promote technological and design solutions that minimise their release into the environment.

Spain, as one of the countries with the longest tradition and greatest industrial weight in the European textile sector, actively participates in collective efforts aimed at preventing and reducing microplastic pollution. Universities, technology centres, textile companies, integrated water cycle managers and Spanish public administrations are involved in projects funded by the European Union through programmes such as LIFE, Horizon 2020, Horizon Europe and Interreg. These initiatives complement each other in addressing the reduction of microplastics at source, as well as their detection, monitoring and elimination in aquatic systems.

Their importance for the textile sector is particularly significant, given that a considerable proportion of the microfibres released during the use and washing of garments is transported to wastewater treatment plants, from where it can reach the receiving environment. At the same time, other projects with Spanish participation focus on the development of innovative technological solutions and the reduction of microfibre generation from the design, material selection and manufacturing stages of textiles, acting preventively on the source of the problem.

All these actions reflect an approach that combines prevention at source, improvement of industrial processes, innovation in materials and advanced water treatment, in line with European priorities and national objectives in terms of industrial sustainability and environmental protection. However, the widespread implementation of these solutions continues to face technical, economic and regulatory challenges, highlighting the need for a national framework for analysis and reference that standardises existing knowledge, identifies good practices and facilitates decision-making by the various stakeholders involved.

This National Report on Microplastics in the Textile Sector in Spain has been prepared with the aim of providing a structured and up-to-date overview of the issue of microplastics, and in particular textile microfibres, in the national context. The report aims to present the available scientific and technical knowledge, identify the main sources of emissions throughout the life cycle of textile products, analyse the regulatory framework and existing research, innovation and cooperation initiatives, and highlight the good practices and technological solutions developed by the industrial sector and R&D&I stakeholders.

This report also aims to serve as a decision-making support tool for public administrations, companies, technology centres and other relevant actors, facilitating the definition of strategies and measures aimed at preventing and reducing the release of microplastics, in line with European policies and national commitments on sustainability, the circular economy and environmental protection. In this regard, the document aims to contribute to the design of coordinated and evidence-based actions that promote the transition of the Spanish textile sector towards more sustainable and environmentally responsible production models.

13.38. National textile industry overview

13.38.1. Introduction and definition of the sector

The textile and clothing sector is a traditional industrial activity in the Spanish economy, with a significant impact in terms of both employment and business fabric. According to the National Classification of Economic Activities (CNAE-2009), the sector includes the preparation and spinning of fibres, the manufacture and finishing of fabrics, the production of other textile items and the manufacture of clothing (Instituto Nacional de Estadística, 2023). Historically, this industry has been characterised by high business fragmentation and strong territorial concentration.

Since the mid-1990s, Spanish textile production has been deeply affected by the process of international trade liberalisation resulting from the Agreement on Textiles and Clothing, which was fully integrated into World Trade Organisation rules in 2005 (Moral, 2004). This new framework has intensified international competition, especially from Asian countries, forcing the sector to adapt through processes of productive restructuring, partial relocation and strategies based on differentiation through quality, design and rapid response to the market (European Commission, 2004).

13.38.2. Recent developments and current production data

Textile production in Spain has experienced a gradual decline in relative importance within the manufacturing industry as a whole, in line with developments in other traditional industrial sectors. Since the 2000s, growth has slowed, with significant impacts on production and employment (Moral, 2004). However, the sector continues to play an important role in certain regions and specialised segments.

According to the latest report from the Textile and Clothing Information Centre (Centro de Información Textil y de la Confección-CITYC, 2025), In 2024, the Spanish textile industry achieved a turnover of €5.996 billion, representing a decrease of 2.7 % compared to the previous year (Centro de Información Textil y de la Confección [CITYC], 2025). The number of active companies stood at 3,426, a year-on-year decrease of 2.3 %, while direct employment reached 45,429 workers, representing a fall of 1.1 % compared to 2023 (Centro de Información Textil y de la Confección-CITYC, 2025). These data reflect a period of adjustment following the growth recorded in the years after the pandemic.

From the point of view of the productive structure, turnover is mainly concentrated in the subsectors of fabrics, technical textiles and home textiles, which together account for a substantial part of total production. This productive specialisation has made it possible to maintain a certain stability in segments with higher added value, although it has not prevented a reduction in the number of companies and jobs.

13.38.3. Territorial dimension and business structure

Textile production in Spain is highly concentrated geographically. Cataluña and the Comunitat Valenciana account for a significant proportion of textile activity, particularly in the spinning, weaving and finishing stages, while clothing manufacturing is more widely distributed across the country, with a particular presence in Andalucia, Galicia, Madrid and Castilla-La Mancha (Instituto Nacional de Estadística, 2023).

The sector is dominated by small and medium-sized enterprises. More than 50 % of companies have fewer than five employees, and a significant proportion have no employees at all, reflecting a highly fragmented production model (Moral, 2004). This structure limits the capacity for investment in innovation, digitalisation and international expansion, although in recent years there have been signs of incipient processes of business cooperation and production specialisation.

13.38.4. Production, international trade, and competitiveness

The evolution of Spanish textile production is closely linked to international trade. In 2024, textile exports reached €4.72 billion, representing growth of 1.6 % compared to 2023, while imports stood at €5.107 billion, an increase of 6.3 % year-on-year (Centro de Información Textil y de la Confección-CITYC, 2025). As a result, the sector's trade balance showed a deficit of €387 million, widening compared to the previous year.

The main destinations for Spanish textile exports are Morocco, France, Italy, Portugal and Germany, reflecting a strong focus on European and Mediterranean markets. In terms of imports, countries such as China, Turkey, Italy and Pakistan stand out, accounting for a significant share of foreign supply (Centro de Información Textil y de la Confección-CITYC, 2025). Faced with this competitive pressure, Spanish companies have opted for strategies of differentiation, production flexibility and control of the value chain, especially in the segments with higher added value.

13.38.5. Conclusions

Textile production in Spain faces a highly competitive and constantly changing environment. Although the sector has lost relative weight within the manufacturing industry, it remains economically and socially significant, especially in certain regions. The latest CITYC data show a period of adjustment characterised by a reduction in the number of companies and jobs, as well as a deterioration in the trade balance.

The future of the sector will depend on its ability to advance in technological innovation, digitalisation, sustainability and specialisation in higher value-added products, as well as on improving productivity and average company size. In this context, strengthening business cooperation and supporting industrial policies are key elements in ensuring the viability and competitiveness of textile production in Spain.

13.39. Relevance of microplastics/microfibres in the national context

The presence of microplastics in the environment has become a major environmental concern in Spain, especially in relation to marine and freshwater ecosystems. Among the different types of microplastics, synthetic textile microfibres have been identified as one of the most prevalent forms, due to the widespread use of synthetic polymers such as polyester, polyamide and acrylic in the textile and fashion industry (Duch, 2024).

Spain, with an extensive coastline of more than 7,900 km and a strong dependence on marine ecosystems for tourism, fishing and biodiversity, is particularly vulnerable to microplastic pollution (Filgueiras et al., 2019). Several national studies have confirmed the presence of microplastics, including microfibres, in coastal waters, sediments, freshwater bodies and wastewater treatment plants (PTAR)(*Los Microplásticos, Más Allá de Los Pellets - Campus de Gandia Ciencia - UPV Universitat Politècnica de València*, n.d.). The Mediterranean Sea, which borders a significant part of the Spanish coastline, has been identified as one of the marine regions with the highest concentration of microplastics in the world (Simon-Sánchez et al., 2022).

Textile microfibres are released throughout the life cycle of textile products, but the use phase, particularly domestic washing, has been identified as the main source of emissions. During washing, synthetic garments shed large quantities of microscopic fibres that are transported through wastewater systems (*Reciclar Está de Moda - Recuperación Textil En Madrid - Ayuntamiento de Madrid*, n.d.). Although wastewater treatment plants can retain a high percentage of these particles (López-Castellanos et al., 2020), a considerable proportion continues to reach aquatic environments, while retained microfibres accumulate in wastewater.

This concern has been growing due to:

- The high consumption of textile products, influenced by fast fashion models (*Briefing-Textiles-in-Europe-s-Circular-Economy*, 2019).
- The importance of the textile and clothing industry at the national level, especially in regions such as Cataluña, Galicia, and the Comunitat Valenciana. (*251007_informe-Economico-de-La-Moda-En-Espana-2025*, 2025).
- Extensive use of treated wastewater and sewage sludge in agriculture, increasing the risk of terrestrial contamination by microfibres (Nizzetto et al., 2016).

Furthermore, recent scientific evidence suggests that microfibres may act as vectors for chemical contaminants and microorganisms, raising concerns about their potential impacts on ecosystems and human health (Delgado Fimia, 2019). Although knowledge gaps remain, the growing number of national research studies highlights the need to address microplastic pollution related to textiles through preventive measures, technological solutions, and regulatory frameworks.

As a result, microplastics, and specifically textile microfibres, represent a priority environmental challenge in Spain, closely linked to sustainable textile production, consumption trends and wastewater management. Addressing this issue is in line with national environmental strategies, as well as Spain's commitments under European Union policies related to the circular economy, pollution prevention and sustainable textiles.

13.40. National sources of microfibre release

13.40.1. Production phase

The textile production stage is an initial source of microfibre release, especially in processes involving mechanical stress and surface modification of fibres, such as spinning, weaving, knitting and finishing processes. During spinning and fabric formation, friction, mechanical stress and cutting generate short fibres and fragments that can be released into the working environment or subsequently incorporated into wastewater streams during wet processes (Luzi et al., 2025).

Finishing processes, industrial washing, dyeing and the application of chemical treatments represent a critical point in the release of microfibres, as they combine intensive use of water, mechanical agitation and chemicals, favouring the detachment of fibres that are weakly bound to the textile structure. Experimental studies have shown that fabrics can release microfibres even before reaching the end consumer, contributing to early emissions throughout the product life cycle (Cesa et al., 2020;De Falco et al., 2020).

In Spain, industrial textile effluents have been identified as a significant source of microfibres entering the environment. Research carried out at treatment plants that treat wastewater from areas with textile activity shows the presence of microplastics, including microfibres, in both the incoming water and the treated effluent, with variable removal efficiencies depending on the technology used (Carr et al., 2016).

Although conventional systems can retain a high proportion of microplastics, fibres have lower retention efficiency and can pass through secondary and tertiary treatments.

In terms of fibre type, synthetic fibres (mainly polyester and polyamide) are more persistent in the environment due to their resistance to biodegradation. However, natural fibres can also contribute to pollution when they have been chemically treated or are mixed with synthetic fibres, which complicates their degradation and environmental behaviour (Cesa et al., 2020;De Falco et al., 2020). This difference is particularly relevant for the Spanish textile industry, which is characterised by its extensive use of blended fabrics.

13.40.2. Use phase

The use phase, and in particular domestic washing, has been consistently identified as the main source of microfibre release into the environment. During washing, garments are subjected to water flow, mechanical friction, temperature changes and the action of detergents, which promotes the detachment of microscopic fibres. Several studies have shown that a single wash cycle can release thousands to millions of microfibres, especially in the case of garments made from synthetic fibres (De Falco et al., 2018; Cesa et al., 2017).

The amount of microfibres released depends on multiple factors. The type of fabric and the structure of the yarn are key determinants, with higher emissions observed in knitted fabrics, fleece and structures with low yarn twist compared to weaving or more compact fabrics (De Falco et al., 2020). Likewise, the age and number of previous washes of the garment have a significant influence, as the progressive wear of the textile surface increases the release of fibres over time (Cesa et al., 2017).

Washing parameters also play an important role. Long wash programmes, with higher water volumes and greater mechanical agitation, tend to increase the release of microfibres, while shorter, gentler cycles can partially reduce it (De Falco et al., 2018). This issue is particularly relevant in Spain, where the widespread use of domestic washing machines makes laundry a diffuse but significant source of microfibre pollution.

Once released, microfibres reach wastewater treatment plants (WWTPs). Studies carried out in Spanish WWTPs indicate that conventional technologies can remove between 80 and 90 % of total microplastics; however, fibres show lower retention rates and are frequently detected in treated effluents (Olmos Espinar et al., 2020)

13.40.3. End-of-life management

At the end of their life cycle, textile products can indirectly contribute to the release of microfibres through inadequate waste management and secondary fragmentation processes(Weis & De Falco, 2022). In Spain, despite recent regulatory advances, a significant proportion of textile waste continues to be sent to landfill or incineration, while selective collection and recycling rates remain limited compared to other waste flows (Gobierno de España, 2020).

In landfills, textile materials are exposed to variable environmental conditions, such as ultraviolet radiation, humidity, temperature changes and mechanical stress, which promote the progressive degradation of fibres. These processes can cause synthetic fibres to fragment into micro- and nanoplastics, contributing to soil contamination and, potentially, dispersion into surface and groundwater (Shahul Hamid et al., 2018).

Incineration reduces the volume of textile waste, but it does not eliminate the impacts associated with the release of microfibres in earlier stages of the product life cycle. It also generates ash and secondary waste that must be managed in a controlled manner, which limits its contribution to a truly circular economy (Gobierno de España, 2020).

Mechanical recycling, which is currently the main method of textile recycling in Spain, has significant limitations in relation to the generation of microfibres. The cutting, shredding and defibration processes subject textile materials to high mechanical stress, promoting the formation of short fibres and fragments. Several studies have indicated that these processes can increase the release of microfibres, especially in the case of mixed or low-quality textiles, which also leads to a degradation of the mechanical properties of the recycled material (Godoy Calero, 2021; Lanz et al., 2024).

These limitations are particularly relevant in the Spanish context, where a significant proportion of textile waste consists of mixtures of natural and synthetic fibres, which makes both separation and high-quality recycling difficult. In this regard, recent national initiatives, such as the implementation of extended producer responsibility (EPR) systems for textiles (MITERD, 2022), promoted by the Ministry for Ecological Transition and Demographic Challenge and by collective extended producer responsibility systems (SCRAP) such as RE_VISTE (*Sobre La Asociación - Gestión de Residuo Textil*, n.d.), seek to improve the collection, sorting and recovery of textile waste. However, specific control of microfibre generation at this stage remains a challenge that requires an integrated approach based on eco-design, material selection and advanced recycling technologies (Gobierno de España, 2020).

13.41. National scientific and technical studies

In recent years, Spain has developed growing activity in the field of scientific and technical research related to microplastics and, in particular, textile microfibres. This activity is carried out through public research centres, universities, technology institutes and collaborative projects with industry, contributing to the advancement of knowledge about emission sources, environmental impacts and possible technological solutions for reducing microfibres throughout the textile life cycle.

13.41.1. Active research institutions

Various national research institutions play a key role in studying microplastics and their relationship with the textile sector. Among them is the Spanish National Research Council (CSIC), which has developed multiple lines of research focused on the detection, characterisation and environmental fate of microplastics in marine and continental ecosystems and wastewater treatment systems. Some of these studies have identified the high presence of microfibres in coastal waters and sediments, as well as their transfer through wastewater treatment plants (*Detectan Concentraciones*

"Excepcionalmente Altas" de Microplásticos En Las Islas Columbretes | Consejo Superior de Investigaciones Científicas, n.d.).

Likewise, technological institutes specialising in the textile sector, such as AITEX (Textile Industry Research Association), play an important role in applied research. AITEX has developed studies and projects aimed at evaluating the release of microfibres during the manufacturing, washing and use of textiles, as well as developing solutions based on eco-design, new materials and textile treatments that reduce fibre shedding (*E-MICROPLAST 2025 - SOLUCIONES AMBIENTALES III - Aitex*, n.d.; *Microplásticos, El Nuevo Reto Ambiental Del Sector Textil*, n.d.) .

Other technology centres, such as ITENE, also contribute from a broader perspective of sustainability, materials and the circular economy, addressing the issue of microplastics in relation to packaging, waste and treatment technologies, with potential application to the textile sector (*UPRISE: Análisis Repercusiones Partículas y Microplásticos En Salud Fetal*, n.d.).

13.41.2. University research projects

Spanish universities are developing numerous research projects focused on the study of microplastics, integrating experimental, analytical and environmental assessment approaches throughout the life cycle of materials. Among them, the Universitat Politècnica de València (UPV) has established itself as one of the leading national references in research on textile microfibres, with specific lines of work focused on analysing fibre release during domestic and industrial washing, the characterisation of microfibres in wastewater and wastewater sludge, and the evaluation of the effectiveness of different retention technologies applied in wastewater treatment plants (García-Haba et al., 2024; Pérez et al., 2022; *Un Estudio de La Cátedra Aguas de Valencia Demuestra La Alta Capacidad de Los Humedales Artificiales Para Retener y Degradar Microplásticos | SIECATEDRAS | UPV*, n.d.; *UPV: Un Equipo de La UPV Desarrolla Una Aplicación Que Identifica y Cuantifica Microfibras Plásticas En Aguas y Lodos Residuales Con Inteligencia Artificial | Universitat Politècnica de València*, n.d.; *UPV: Una Investigación de La UPV y La UA Revela La Eficacia de Los Pavimentos Permeables En La Captura de Microplásticos Urbanos | Universitat Politècnica de València*, n.d.) .

The Universidad de Girona has conducted studies on the presence of microplastics in aquatic systems and wastewater treatment plants, contributing to the understanding of the mechanisms of retention and transfer of microfibres to sewage sludge. This work has provided relevant data for the national context and has served as a basis for further research (*PlastikHUM*, n.d.; *Sorigué Instala Una Planta Piloto En La EDAR de Quart Para Probar Una Nueva Tecnología de Tratamiento de Aguas de Bajo Impacto Ambiental | Sorigué*, n.d.).

Other universities, such as the Universidad de Granada (Olea, n.d.) or the Universidad Autónoma de Barcelona (*Un Proyecto Pionero Liderado Por La UAB Revela Los Riesgos de Los Micro- y Nanoplásticos Para La Salud Humana - Universitat Autònoma de Barcelona - UAB Barcelona*, n.d.), have addressed the issue of microplastics from complementary perspectives, including ecotoxicology, environmental engineering and environmental risk assessment, strengthening the national scientific base in this field.

13.41.3. Industry research

The Spanish industrial sector, in collaboration with technology centres and universities, actively participates in applied research projects aimed at reducing the release of microfibres. Some textile companies have developed initiatives focused on:

- Optimisation of manufacturing processes to minimise the generation of free fibres (Ramírez, 2019).
- The development of fabrics with greater structural stability and less fibre shedding, as is the case with Ecoalf (*OCEAN YARN & ZERO MICROPLASTICS | ECOALF*, n.d.).
- The application of finishes and treatments that reduce abrasion during use and washing, as is the case with Inditex and Jeanologia, which are working to develop technologies that reduce the release of microplastics during production (*Inditex y Jeanologia Se Alían Para Recuperar Microfibras En La Producción de Prendas Textiles*, n.d.).

Likewise, companies in the water treatment sector and equipment manufacturers have participated in the development and validation of microplastic filtration and retention technologies (*CAPTOPLASTIC – CAPTOPLASTIC, S.L Technology Can Remove Microplastics from the Aqueous Media.*, n.d.-a; *EFFITEX, Una Solución Eficiente Para La Eliminación de Microplásticos En La Industria Textil - Agua*, n.d.), both on an industrial and domestic scale (e.g. filters for washing machines), with potential for application in the Spanish market.

These industrial initiatives contribute to the transfer of knowledge from research to practical solutions, although their large-scale implementation continues to face technical, economic and regulatory barriers.

13.41.4. EU Project Participation

Spain actively participates in projects funded by the European Union that address the issue of microplastics and the sustainability of the textile sector and the integral water cycle. Programmes such as LIFE, Horizon 2020, Horizon Europe and Interreg have funded initiatives involving Spanish universities, technology centres, public administrations and companies, strengthening the national role in applied research and environmental innovation.

Among the most relevant projects are initiatives focused on the detection, reduction and elimination of microplastics, both in the field of water treatment and in the textile origin of microfibres, addressing aspects such as:

- Identification of sources of textile microfibres and microplastics in urban and river environments.
- Development of methodologies for measurement, detection and monitoring in wastewater and natural waters.
- Implementation of technological solutions for reduction at source and elimination during treatment processes.

- Full-scale demonstration of innovative technologies and knowledge transfer to industrial agents and water managers.

In the field of water treatment, the LIFE-PHOENIX project focuses on the removal of microplastics and other emerging pollutants from wastewater, with the aim of enabling its regeneration and safe reuse, especially for agricultural purposes (*Inicio - Life-Phoenix*, n.d.). Complementing this, the Horizon Europe-funded Upstream project demonstrates advanced solutions for detecting and removing microplastics and waste from European rivers before they reach the marine environment, with the city of Zaragoza participating as a pilot site (*Upstream Project - for Waste Free European Rivers*, n.d.). Similarly, the BlueWWater cross-border project, within the framework of the Interreg Spain-Portugal programme (POCTEP), works on the control, treatment and reduction of microplastics and emerging pollutants in urban wastewater and river and coastal water bodies, evaluating the effectiveness of different purification technologies and developing environmental monitoring methods (*BlueWWater | Control, Tratamiento y Reducción de Microplásticos y Contaminantes Emergentes En Aguas Residuales Urbanas y En El Medio Costero Transfronterizo*, n.d.).

In relation to the textile origin of microplastics, the GLAUKOS project, funded by Horizon 2020 through the Bio-based Industries Joint Undertaking, addresses the reduction of microplastic release by developing more biodegradable and recyclable bio-based textile fibres and coatings. This project involves Spanish participation through the University of Vigo and aims to reduce the environmental impact of textile garments and other fibrous products (*Circular Solution for the Textile Industry*, n.d.).

For its part, the LIFE ANHIDRA project, funded by the LIFE programme, focuses on sustainable water management in textile processes. Spanish partners such as AITEX and Jeanologia (coordinator) are participating in the project, together with the Portuguese company Pizarro SA. The project is developing a closed-loop textile production system that allows washing and finishing water to be reused, significantly reducing waste and, with it, the release of microfibres and other pollutants into the environment (*LIFE 3.0 - LIFE21-ENV-ES-LIFE-ANHIDRA/101074372*, n.d.).

These projects reflect the alignment of Spanish research and innovation with European priorities in the areas of the circular economy, protection of the aquatic environment and sustainability in the textile sector, and contribute to the transfer of practical solutions and good practices to the Spanish industrial and territorial context.

13.42. Case studies

In Spain, applied initiatives and pilot projects aimed at reducing and mitigating microplastics in water and the textile sector have been developed in recent years. These case studies reflect the practical implementation of technological, industrial and municipal solutions, as well as collaboration between companies, infrastructure operators and public administrations. The analysis of these cases allows for the identification of specific measures, quantifiable results and lessons learned, contributing to the transfer of good practices and the replicability of solutions in other national and European contexts.

13.42.1. CAPTOPLASTIC - Filtration technologies for microplastic reduction

Context

CAPTOPLASTIC is a Spanish company based in Madrid and founded in 2020, specialising in the development of solutions for the identification, capture and removal of microplastics from aqueous media. Its technologies are designed for use in various facilities such as wastewater treatment plants (WWTPs), drinking water treatment plants, water bottling plants, wastewater treatment plants in the plastics and textile dyeing industries, recycling plants, textile fibre removal in water, the personal care industry, etc.

The company operates in the field of microplastic pollution prevention and mitigation, offering technical solutions aimed at complementing existing infrastructure and improving the overall efficiency of microplastic retention before release into the environment (*CAPTOPLASTIC – CAPTOPLASTIC, S.L Technology Can Remove Microplastics from the Aqueous Media.*, n.d.-b).

Problem identified

The growing presence of microplastics in wastewater and treated effluents poses a significant environmental challenge. Conventional water treatment systems are not specifically designed to capture microplastics, which limits their effectiveness against small particles with complex behaviour, such as microfibres.

The lack of specific technological solutions that can be easily integrated into existing infrastructure and adapted to different operating contexts has contributed to the persistence of microplastics in the aquatic environment. This scenario, combined with growing scientific, social and regulatory concern, has highlighted the need to develop filtration technologies dedicated to microplastic mitigation.

Intervention implemented

CAPTOPLASTIC has developed a continuous microplastic capture technology designed to be integrated into controlled water flows, such as wastewater treatment plants (WWTPs), without altering the natural state of the water or interfering with existing processes. The solution acts as a complementary measure to conventional treatments to improve microplastic retention.

The technology is based on an agglomeration technique, whereby a functional collector is introduced that physically binds with the microplastics present in the water, forming aggregates that can be selectively separated using magnetism. This separation takes place before the particles reach the sludge line, preventing their transfer to this stage of the process, where they usually concentrate. The system operates continuously, allowing for the efficient treatment of large volumes of water.

The recovered aggregates allow for the identification and quantification of the captured microplastics. The collector can be regenerated and reused in multiple cycles, aligning the solution with a zero-waste approach.

Quantitative results

According to technical information and pilot tests carried out by CAPTOPLASTIC, the systems developed can achieve microplastic retention efficiencies of over 80–90 %, depending on the flow rate treated, the installation point and the system configuration.

The technology has been validated in plant-scale installations of up to 100,000 L/h and is currently being scaled up to capacities of around 1,250,000 L/h in 2025 (*CAPTURE TECHNOLOGY – CAPTOPLASTIC,* n.d.). In WWTP applications, these systems improve the overall efficiency of microplastic retention compared to conventional treatments, contributing to the reduction of plastic particle load in treated effluents. The exact quantification of the annual impact depends on the specific conditions of each facility and continues to be validated in demonstration environments.

Stakeholder engagement

The technology developed by CAPTOPLASTIC has been promoted and validated in collaboration with key players in the water and innovation sector, focusing the solution on real applications in treatment infrastructure. The company has established agreements with public operators in the integrated water cycle, notably the agreement with Canal de Isabel II for the construction of an experimental plant at the Arroyo del Soto WWTP (Móstoles), with a capacity of 100,000 L/h. It has also carried out tests in operational environments with Aguas de Burgos, facilitating the integration of the technology into the treatment line at the Villalonquéjar WWTP.

Decision-making and technological scaling have been backed by institutional and financial support, notably the joint investment by CDTI Innovación (through SICC Innvierte) and BeAble Innvierte Kets Fund, with a combined contribution of €994,000, aimed at developing advanced technologies for the detection and removal of microplastics in wastewater. This support has helped to consolidate the solution as a zero-waste technology, applicable in WWTPs and WWTPs, and backed by a portfolio of 10 patents and a multidisciplinary team.

The progress and results have been disseminated through specialised media and industry events. External recognition includes the Best Startup award at Sustainability Actions 2025, selection as a finalist in the SantanderX Spain Awards 2025 and first prize in the NTT DATA Foundation's Global eAwards 2021, consolidating CAPTOPLASTIC as a Spanish technological benchmark in the fight against microplastic pollution (*CAPTOPLASTIC*, n.d.).

Lessons learned

CAPTOPLASTIC's experience confirms that specific microplastic filtration, integrated through modular systems, is an effective solution to complement conventional wastewater treatments. Magnetically assisted separation allows microplastics to be removed before they are transferred to the sludge line, preventing their accumulation, while validation under real conditions and the availability of quantitative data are essential for scaling up and adopting the technology.

Contact information

- Web: https://captoplastic.com/es/
- Contact: info@captoplastic.com

13.42.2. E-µplast - Environmental solutions for reducing microplastics in the textile industry

Context

The *E-µplast*. Environmental Solutions project has been developed by AITEX, a reference technology centre for the textile sector in Spain and one of the leading European institutes specialising in applied research, technology transfer and industrial innovation. AITEX has a long history of collaboration with textile companies, public administrations and funding bodies, acting as a bridge between scientific research and real industrial application.

AITEX has pilot infrastructures, accredited laboratories and technical capacity for the analysis of textile materials, production processes, effluent management and environmental assessment, enabling it to address complex issues in the sector from a comprehensive approach. In this context, the *E-µplast* project is conceived as an applied R&D initiative aimed at offering practical and replicable solutions to the problem of microplastics generated throughout the life cycle of textiles.

The project has received public funding from IVACE, within the framework of the 2023 Plan for Non-Economic Activities, and has been developed in close collaboration with companies in the textile, water treatment and other industrial sectors. Its approach combines experimental research, quantitative validation and industrial feasibility analysis, simultaneously addressing sludge management, garment washing and water reuse in production processes (*E-Mplast - SOLUCIONES MEDIOAMBIENTALES - Aitex*, n.d.).

Problem identified

Microplastics generated during the production and use of textiles are mostly retained in WWTPs, but are mainly transferred to the sludge line, creating environmental risks when this sludge is used for agricultural purposes. In addition, domestic washing produces a continuous discharge of microplastics, the magnitude of which depends on the type of fabric, the number of washes and the capture systems used.

Intervention implemented

The *E-µplast* project implemented three complementary lines of intervention.

- In the first, the removal of microplastics present in wastewater treatment sludge from textile industry effluents was evaluated using anaerobic digestion and vermicomposting.
- In the second, commercial microplastic capture systems were experimentally validated during domestic washing, testing different devices (balls, bags and filters) and detergents on polyester and cotton garments.
- The third addressed comprehensive water management in industry, including the reuse of treated water, dyeing processes with natural dyes, and the removal of contaminants through adsorption.

Quantitative results

The results obtained provide relevant quantitative data. In the sludge line, vermicomposting for 56 days reduced the total sludge mass and allowed approximately 80 % of natural fibres to be degraded, although it did not show significant degradation of synthetic fibres; the total concentration of microplastics increased from 4,882 particles/kg in the raw sludge to 40,624 particles/kg after vermicomposting, due to fragmentation and the concentration effect.

In the domestic washing line, microplastic emissions were quantified according to fabric type, number of washes, capture system and detergent. The comparison between different soaps showed an increase in the release of microplastics in the first washes, resulting in an emission of 0.032 g of microfibres per litre and kilo of fabric compared to 0.009 g of microfibres after the third wash. Analysis of black and white cotton T-shirts showed a higher discharge in white garments with a fabric mass loss percentage of 0.18 %, while the black T-shirt had a loss of 0.11 %. Specific filters proved to be the most effective method of reducing discharge in both polyester and cotton.

In industrial water management, adsorption processes reduced polyphenols in waste brine by up to 80 % and demonstrated the viability of reusing treated water in dyeing processes, with results depending on the dye used (AITEX, 2023).

Stakeholder engagement

The project was developed with the involvement of public actors and with a clear focus on transferring results to the industrial sector. Technical coordination was carried out by AITEX, with funding and monitoring by IVACE. The results obtained aroused the interest of companies in the textile and industrial sector, such as INTERFABRICS, J. Moltó, Pascual y Bernabeu, Estampados Prato and Ondytec, as well as companies in the food sector such as Cándido Miró, especially in relation to the reuse of sludge and wastewater and the application of circular economy principles. The experimental implementation and monitoring of results were carried out by the project's technical team, using reproducible and comparative analytical protocols.

Lessons learned

E-µplast highlights that microplastics management requires a comprehensive approach, as conventional treatments remove these particles from the water line but tend to concentrate them in other parts of the system, such as sludge. The results obtained show that the effectiveness of mitigation measures during washing depends on multiple factors, such as the type of fabric, the number of washes, the detergent and the capture system used, with very different behaviours depending on the case. The project also highlights the importance of having quantitative and comparable data to objectively assess the real effectiveness of solutions, as well as adapting water reuse and waste management strategies to the specific characteristics of each industrial process.

Contact information

More information about the Project *E-µplast:* https://www.aitex.es/portfolio/e-%c2%b5plast-biorreactores-anaerobios-biogas-solucion-eliminacion-microplasticos-industriales/

13.43. Main challenges and barriers

In Spain, the problem of microplastics has been progressively recognised by public bodies, research centres and regulatory entities. However, the adoption of systematic measures for their prevention and mitigation continues to face multiple obstacles. These challenges mainly focus on technical and regulatory limitations, economic and implementation barriers, as well as social, educational and awareness factors that condition the effectiveness of available solutions.

13.43.1. Technical and infrastructural challenges

One of the main challenges in Spain is the technical complexity associated with identifying, quantifying and monitoring microplastics in different environmental matrices. Specialised infrastructures such as the CEDEX Marine Environment Quality Laboratory show that the detection of microplastics requires advanced equipment, highly qualified personnel and complex analytical protocols, which makes it difficult to apply systematically in environmental monitoring networks (*Laboratorio de Calidad Del Medio Marino Del CEDEX: Evaluación Ambiental | CEPYC - CEDEX*, n.d.). In addition, conventional wastewater treatments have not been specifically designed to remove microplastics, which limits their effectiveness and creates uncertainty about the final destination of these particles within the system.

From a regulatory point of view, although the issue of microplastics is included in general strategic frameworks, such as the Spanish Circular Economy Strategy promoted by the Ministry for Ecological Transition and Demographic Challenge, there are still no specific requirements, limit values or harmonised official methodologies for their control (*Estrategia Española de Economía Circular y Planes de Acción*, n.d.). This lack of specific regulation hinders the uniform adoption of measures by administrations and operators and delays the implementation of large-scale technological solutions.

13.43.2. Economic and implementation barriers

Economic barriers represent another significant challenge, especially for small and medium-sized enterprises in the textile sector and for public infrastructure managers. The incorporation of advanced technologies for detecting, capturing or treating microplastics often involves additional investment and operating costs, without there yet being a clear framework of incentives or economic returns. This situation limits the replicability of pilot projects and hinders the transition from experimental experiences to fully operational and widespread solutions.

Furthermore, the absence of specific regulatory obligations reduces the pressure to invest in this type of technology, placing microplastic mitigation on a secondary footing compared to other already established environmental requirements.

13.43.3. Social, educational and awareness barriers

One of the main challenges in Spain is limited social awareness of everyday sources of microplastic generation. Reports from the Spanish Food Safety and Nutrition Agency indicate that, although the presence of microplastics in food and drinking water is an emerging issue, knowledge about their origin remains partial (AESAN, 2019). In particular, there is little perception that washing textiles at home is a significant source of microplastic release.

This lack of knowledge, coupled with scientific uncertainty about the health effects, makes it difficult for the public to adopt preventive behaviours. Likewise, there are gaps in training and specific educational resources, both for consumers and for professionals in the textile and water management sectors, which limits the effectiveness of prevention strategies based on behavioural changes.

13.44. National success stories and best practices

13.44.1. Innovative technologies

Microplastic detection and analysis technologies

The BIOMICRO project, led by AIMPLAS, is one of the main technological innovations in this field. Its objective is to develop reference standards for nano- and microplastics that will enable the standardisation of analysis methods, improve quantification and facilitate the toxicological assessment of these particles in different environmental matrices (*Aimplas lidera el proyecto Biomicro para elaborar patrones de nano y microplásticos - Reciclaje y gestión de residuos, n. d.*). This advance is key to enabling companies and administrations to identify sources of microplastics and reduce their generation.

Textile innovation for microfibre reduction

In the textile sector, several R&D&I projects aimed at minimising the release of synthetic microfibres stand out:

- FIBERCLEAN™, promoted by Textil Santanderina, develops solutions based on textile eco-design and filtration technologies, incorporating scientific tests to measure microfibre emissions during the production, use and washing of garments (*Proyectos I+D – Santanderina Group*, n.d.).
- FIBERPROOF, developed by Techs, focuses on creating fibrillation-resistant fabrics, thereby reducing one of the main causes of microfibre release, with additional benefits in terms of water and energy consumption (*Proyectos I+D – Techs*, n.d.).
- INTESBIOCOM, promoted by Santanderina Group, researches bio-based and compostable fibres as an alternative to conventional synthetic materials, indirectly contributing to the reduction of textile microplastics (*Proyectos I+D – Santanderina Group*, n.d.).

Innovation in circular materials

The Circular Economy startup REACT, supported by the Mares Circulares programme, has developed plastic sheets made from up to 50 % marine waste, reused in furniture and urban products, which is an example of innovation applied to the recovery of marine waste (*Mares Circulares, s. f.*).

13.44.2. National initiatives and corporate initiatives

This section covers both corporate initiatives and national public policies that promote the circular economy and the reduction of marine plastic.

Business initiatives

In the business sphere, several companies stand out for integrating marine waste into their value chains:

- coalf uses marine waste and other recycled materials to manufacture textiles, making it an international benchmark in sustainable fashion and the circular economy (*Materiales | ECOALF*, n.d.)

- Gravity Wave collaborates with fishermen and ports to remove plastics from the Mediterranean and transform them into new industrial materials, working with more than 200 companies (*Gravity Wave*, n.d.).
- The Running Republic manufactures sportswear with a high percentage of recycled fabrics from plastic bottles and marine waste (Ministerio para la Transición Ecológica y el Reto Demográfico (*Proyectos Emprendedores Que Intentan Devolver La Vida al Mar*, n.d.).
- Now-Then produces eco-friendly swimwear using ECONYL®, a nylon regenerated from abandoned fishing nets and other marine waste (Proyectos Emprendedores Que Intentan Devolver La Vida al Mar, n.d.).
- Sea2see manufactures glasses from plastics recovered from Spanish beaches and ports in collaboration with fishermen's associations (*Proyectos Emprendedores Que Intentan Devolver La Vida al Mar*, n.d.)

National public funding initiatives

Public policies play a key role in promoting these initiatives:

- The Circular Economy – Textiles PERTE has funded 37 projects with €30.5 million, supporting eco-design, recycling and the replacement of synthetic fibres (*El MITECO Impulsa La Circularidad En El Sector Textil Con Ayudas Por Valor de 30,5 Millones*, n.d.).
- The Circular Economy – Plastics PERTE has allocated €154.5 million to 125 projects focused on plastic waste management, with an indirect impact on the reduction of textile microplastics (*El MITECO Impulsa La Circularidad En El Sector Del Plástico Con Ayudas Por Valor de 151 Millones*, n.d.).

13.44.3. Certifications or voluntary programmes

Although no specific formal certifications are addressed, relevant voluntary programmes and reference systems are identified:

- ECONYL® is a voluntary system for regenerating nylon from marine and textile waste, used by brands such as Now-Then to reduce the use of virgin raw materials (*Proyectos Emprendedores Que Intentan Devolver La Vida al Mar, n.d.).*
- Mares Circulares, promoted by Coca-Cola Europacific Partners, promotes the cleaning of aquatic environments, recycling and support for circular economy projects such as Economía Circular REACT (*Mares Circulares*, n.d.).
- The LIBERA Project, developed by SEO/BirdLife and Ecoembes, acts as a voluntary framework for the prevention of litter and the generation of scientific knowledge (*Web Microplásticos LIBERA 2023 - Proyecto LIBERA, n.d.*).

13.44.4. Successful partnerships or projects

Multisectoral partnerships have proven particularly effective in combating marine plastic and microplastics.

- The MICRO Platform, developed by the HyT Association together with the LIBERA Project, is the largest national repository of studies on microplastics, bringing together universities, technology centres, NGOs and public administrations (*Web Microplásticos LIBERA 2023 - Proyecto LIBERA, n.d.*).

- The BIOMICRO project stands out as an example of public-private collaboration between technology centres and companies for the transfer of scientific knowledge to the productive sector (*Aimplas Lidera El Proyecto Biomicro Para Elaborar Patrones de Nano y Microplásticos - Reciclaje y Gestión de Residuos*, n.d.).
- FIBERCLEAN™ is a successful case of cooperation between textile manufacturers, technology centres, universities and agents in the washing and purification sector (*Proyectos I+D – Santanderina Group, n.d.*).
- Partnerships between Gravity Wave, Sea2see and fishermen's associations have made it possible to remove waste directly from the marine environment and reincorporate it into industrial value chains, combining environmental impact and local development (*Gravity Wave, n.d.*).

13.45. National policies and regulatory framework

13.45.1. National laws related to microplastics

In Spain, there are currently no specific regulations dedicated exclusively to microplastics or textile microfibres. However, there is legislation that indirectly addresses microplastic pollution through a set of national laws and strategies on waste, the circular economy, marine environment protection and wastewater, which establish a relevant regulatory framework for the prevention and reduction of microplastic release.

Law 7/2022 of 8 April on waste and contaminated soil for a circular economy transposes various European directives and establishes measures aimed at waste prevention, promoting reuse and recycling, and reducing the environmental impact of products throughout their life cycle. Although it does not explicitly mention textile microfibres, it introduces principles such as the waste hierarchy, eco-design and extended producer responsibility (EPR), which are the basis for addressing the issue of microplastics from a preventive approach (Spain, 2022).

Likewise, Law 41/2010 on the protection of the marine environment establishes a framework for the prevention and reduction of marine pollution, including pollution from marine litter, within which microplastics and textile microfibres have been identified as emerging pollutants of particular concern. This law is implemented through marine strategies that incorporate the monitoring and assessment of the environmental status of Spanish seas (Spain, 2010).

With regard to wastewater, we find regulations governing the treatment of urban and industrial water, given that wastewater treatment plants (WWTPs) act as a control point, but also as a possible route for the transfer of microfibres to the aquatic environment and to wastewater sludge (de Publicaciones de la Unión Europea & Luxemburgo, n.d.; Página, n.d.). Although current legislation does not set specific limits for microplastics, it does promote the progressive improvement of treatment systems and the protection of receiving water bodies.

13.45.2. Alignment with EU legislation

Spanish legislation and policies on microplastics and textiles are closely aligned with the European Union's regulatory framework, which in recent years has intensified its efforts to address microplastic pollution from a comprehensive and preventive perspective.

One of the key instruments is the REACH Regulation, which has introduced restrictions on the marketing and use of microplastics intentionally added to products (European Commission, 2023). use of microplastics intentionally added to products (European Commission, 2023). Although this restriction does not apply directly to microfibres released by textiles, it sets an important regulatory precedent and reinforces the European approach to reducing microplastic emissions at source (European Chemicals Agency, 2019).

Furthermore, the EU Strategy for Sustainable and Circular Textiles identifies the problem of textile microfibres as an environmental priority, promoting measures such as eco-design, increasing the durability of textile products, reducing the release of microfibres during use and developing technological solutions, such as filters for washing machines. Spain, as a Member State, has aligned its national policies with these strategic objectives (European Commission, 2022).

Likewise, the revision of the Directive on urban waste water treatment reinforces the role of WWTPs in the removal of emerging pollutants, including microplastics, which will have direct implications for the management of textile microfibres released during domestic and industrial washing. The future transposition of this directive into Spanish law will reinforce technical and control requirements in this area (European Commission, 2022).

In the current context, the Spanish regulatory framework reflects progressive consistency with European policies, adopting an approach based on prevention, the circular economy and shared responsibility between producers, public administrations and consumers.

13.45.3. Strategic plans, incentives and programmes

Spain has developed various strategic plans and support programmes which, although not focused exclusively on microplastics, contribute indirectly to their reduction, especially in the textile sector.

The Spanish Circular Economy Strategy – España Circular 2030 sets out objectives aimed at reducing waste generation, improving resource efficiency and promoting more sustainable production and consumption models. In the textile sector, this strategy promotes eco-design, increasing the useful life of products and developing more effective collection and recycling system (Gobierno de España, 2020).

Likewise, the PERTE linked to the circular economy and industrial decarbonisation include lines of financing aimed at technological innovation, the improvement of industrial processes and the development of new materials, which can contribute to reducing the release of microfibres in the production and use phases (Gobierno de España, 2020; Ministerio para la Transición Ecológica y el Reto Demográfico, n.d.).

These instruments are complemented by funding programmes managed by bodies such as the CDTI, focused on R&D&I in sustainability, advanced materials and water treatment technologies (EECTI, 2021).

13.45.4. National standardization activities

In the field of standardisation, Spain actively participates through the Spanish Association for Standardisation (UNE) in European and international standardisation work related to textiles, sustainability and the environment (Asociación española de Normalización, 2024).

UNE technical committees participate in the development of CEN and ISO standards related to:

- Test methods for the characterisation of microplastics.
- Environmental impact assessment of textile products.
- Eco-design and durability criteria.
- Sustainability and circularity requirements in the textile sector.

Although there are still no widely implemented specific standards for the standardised measurement of textile microfibre release, Spanish participation in these standardisation processes is key to ensuring the future uniform application of methodologies for measuring, controlling and reducing microplastics, in line with the European regulatory framework.

13.46. Training needs and educational proposals

13.46.1. Training needs and education proposals

In the Spanish context, various gaps in knowledge and skills related to the prevention and management of microplastics in the textile sector have been identified, affecting both the industrial and academic and professional fields:

- Limited knowledge about microfibre generation throughout the textile life cycle, especially in the design, manufacturing, washing and end-of-life phases.
- Lack of specific training in textile eco-design aimed at reducing microfibres, including the selection of materials, fabric structures and low-release finishes.
- Need to strengthen technical training in methods for measuring and monitoring microplastics, both in industrial environments and in wastewater treatment systems.
- Limited availability of professionals with integrated training combining knowledge of textile engineering, water treatment, environmental chemistry and the circular economy.
- Limited knowledge transfer between the research sector and industry, especially in textile SMEs, which predominate in the Spanish business fabric.

13.46.2. Recommendations for curriculum integration and professional training

Needs of higher education institutions (HEIs) and vocational training

To address the challenges identified, it is necessary to strengthen the educational offerings of universities and vocational training centres in Spain by:

- The incorporation of specific content on microplastics and textile microfibres into degree programmes such as Textile Engineering, Chemical Engineering, Environmental Sciences, Environmental Engineering, Fashion Design and Materials Technology.

- The development of training modules in vocational training cycles related to textile production, industrial maintenance, water treatment and waste management, with a practical focus.
- Updating curricula to integrate European regulatory requirements (REACH, Sustainable Textiles Strategy, Urban Waste Water Directive) and their application to the Spanish context.
- Strengthening interdisciplinary training, combining technical, environmental and regulatory knowledge.

Necessary HEI course content

It is recommended that training programmes include, among other things, the following content:

- Basic principles of microplastics: types, sources and environmental behaviour.
- Textile microfibres: release mechanisms, influencing factors and quantification.
- Eco-design and product design aimed at reducing microfibres.
- Sustainable textile processes and low-impact finishing technologies.
- Water treatment technologies applicable to microplastic retention.
- Analytical and monitoring methods for microplastics.
- Circular economy applied to the textile sector and textile waste management.
- Relevant European and national regulatory framework for microplastics and textiles.

Suggestions for curriculum development

For the effective integration of this content into the Spanish education system, the following actions are proposed:

- Development of elective subjects or specific modules on microplastics in existing bachelor's and master's degree programmes.
- Creation of continuing education programmes and specialisation courses aimed at professionals in the textile and water cycle sectors.
- Promotion of bachelor's and master's degree final projects focused on textile microfibres and mitigation solutions.
- Promotion of project-based learning in collaboration with companies and technology centres.

Opportunities and recommendations for teacher training

To ensure high-quality training, it is essential to strengthen the skills of teaching staff by:

- Specific training programmes for teachers on microplastics, textile sustainability and the circular economy.
- Access to up-to-date teaching materials, case studies and results from European projects.
- Short-term internships for teachers at technology centres and companies in the textile or water treatment sector.
- Creation of exchange networks between Spanish universities, vocational training centres and technology centres.

Opportunities for integration with WP2 of the MicroWeave-TEX Project

The content and conclusions of this national report can serve as a contextual reference for WP2 activities, providing a specific overview of the situation in Spain with regard to microplastics and the textile sector. The information compiled on emission sources, technical solutions, the regulatory framework and existing experiences can support the identification of training needs and knowledge gaps addressed by this work package.

Likewise, the report can facilitate the adaptation of the results of WP2 to the national context, helping to ensure that the training content and educational proposals better reflect the reality of the industrial fabric, the education system and the environmental challenges in Spain. This connection promotes greater consistency between the analysis of needs, the design of training materials and their practical application.

13.47. Conclusions

13.47.1. Main conclusions and state of the art nationally

An analysis of the state of the art in Spain reveals that microplastic pollution, particularly from textile microfibres, is an emerging environmental challenge of great importance for the textile sector and for aquatic environment management. The available scientific evidence confirms that synthetic microfibres account for the majority of microplastics detected in wastewater, aquatic ecosystems and sewage sludge, with the use phase of textile products, especially domestic washing, being one of the most important sources of release.

Spain has a solid scientific and technical base in this field, supported by the activity of universities, technology centres and public research bodies, as well as active participation in European R&D&I projects. These initiatives have enabled progress to be made in identifying emission sources, characterising microfibres and developing technological solutions aimed at both prevention at source and capture and elimination in water treatment systems.

However, the report shows that the implementation of large-scale solutions remains limited. Technical, economic and regulatory barriers persist, especially in a textile sector dominated by small and medium-sized enterprises with limited capacity to invest in innovation. Furthermore, the absence of specific regulations on textile microfibres and the lack of harmonised measurement methodologies hinder the systematic adoption of preventive and control measures.

In this context, effectively reducing the release of textile microplastics in Spain requires a comprehensive approach based on prevention at source, eco-design, technological innovation, improved treatment systems and training for the various actors involved throughout the value chain.

13.47.2. Recommendations and priority actions

Higher education institutions (HEIs)

Higher education institutions play a fundamental role in training professionals to address the issue of microplastics from a multidisciplinary approach. To this end, it is a priority to integrate specific content on microplastics and textile microfibres into related degree programmes, strengthen training in eco-design aimed at reducing emissions, promote specialisation and continuing education programmes, and encourage applied research and university-business collaboration. It is also essential to promote the transfer of knowledge and the dissemination of scientific results to industry and public administrations.

Textile industry and related sectors

The Spanish textile industry is directly involved in the generation of microfibres, especially in the design and production phases of products. The incorporation of eco-design and durability criteria, together with the optimisation of production and finishing processes, reduces fibre shedding and the microfibre load in industrial effluents. Likewise, the use of technological solutions for microfibre capture, both in the industrial sphere and in collaboration with other sectors, and participation in collaborative initiatives and pilot projects contribute to advancing the mitigation of the associated environmental impact. These actions can be integrated into corporate sustainability strategies and extended producer responsibility systems.

Public officials and policy makers

Public administrations influence the prevention and management of textile microplastics through the regulatory framework, planning instruments and existing support mechanisms. The development of regulations aligned with the European context, the promotion of harmonised methodologies for measuring and monitoring microplastics, and the establishment of programmes to support the adoption of technological solutions facilitate a more uniform application of mitigation measures. Complementarily, incorporating this issue into circular economy, waste management and marine environment protection policies, together with information and awareness-raising actions aimed at citizens and stakeholders, contributes to a coordinated response at the national level.

13.47.3. Final considerations

In summary, Spain has sufficient knowledge and technical capabilities to address the issue of textile microplastics. However, the effective implementation of existing solutions depends largely on coordination between universities, industry and public administrations, as well as the adoption of approaches focused on prevention at source, process improvement and training. This report provides an overview that can serve as a basis for guiding future actions and supporting the evolution of the Spanish textile sector towards more sustainable production models that are aligned with European environmental policies.

13.48. References

251007_informe-economico-de-la-moda-en-espana-2025. (2025). chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://consejointertextil.com/wp-content/uploads/2025/10/251007_informe-economico-de-la-moda-en-espana-2025.pdf

AESAN. (2019). Informe sobre la presencia y la seguridad de los plásticos como contaminantes en los alimentos. *Revista Del Comité Científico No 30*.

Aimplas lidera el proyecto Biomicro para elaborar patrones de nano y microplásticos - Reciclaje y gestión de residuos. (n.d.). Retrieved 26 December 2025, from https://www.interempresas.net/Reciclaje/560397-Aimplas-Instituto-Tecnologico-Plastico-lidera-proyecto-Biomicro-elaborar-patrones-nano.html

AITEX. (2023). *E-µplast SOLUCIONES AMBIENTALES*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.aitex.es/wp-content/uploads/2023/05/Informe_resultados_E-%C2%B5plast.pdf

Asociación española de Normalización. (2024). *Normas de apoyo a la economía circular*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.une.org/normalizacion_documentos/Apoyo_normas_eco_circul-2024.pdf

BlueWWater | Control, tratamiento y reducción de microplásticos y contaminantes emergentes en aguas residuales urbanas y en el medio costero transfronterizo. (n.d.). Retrieved 21 December 2025, from https://bluewwater.eu/

Briefing-textiles-in-europe-s-circular-economy. (2019). chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/file:///C:/Users/raque/Downloads/Briefing-textiles-in-europe-s-circular-economy.pdf

CAPTOPLASTIC. (n.d.). Retrieved 26 December 2025, from https://captoplastic.com/es/noticias/

CAPTOPLASTIC – CAPTOPLASTIC, S.L technology can remove microplastics from the aqueous media. (n.d.-a). Retrieved 21 December 2025, from https://captoplastic.com/es/

CAPTOPLASTIC – CAPTOPLASTIC, S.L technology can remove microplastics from the aqueous media. (n.d.-b). Retrieved 26 December 2025, from https://captoplastic.com/es/

Carr, S. A., Liu, J., & Tesoro, A. G. (2016). Transport and fate of microplastic particles in wastewater treatment plants. *Water Research*, *91*. https://doi.org/10.1016/j.watres.2016.01.002

Centro de Información Textil y de la Confección-CITYC. (2025). *Datos Generales Industria Textil Española*.

Cesa, F. S., Turra, A., Checon, H. H., Leonardi, B., & Baruque-Ramos, J. (2020). Laundering and textile parameters influence fibers release in household washings. *Environmental Pollution*, *257*. https://doi.org/10.1016/j.envpol.2019.113553

Circular solution for the textile industry. (n.d.). Retrieved 21 December 2025, from https://glaukos-project.eu/

Commission, E. (2022). Proposal for a Directive of the European Parliament and of the Council concerning urban wastewater treatment (recast). *Official Journal of the European Union*, *345*.

De Falco, F., Cocca, M., Avella, M., & Thompson, R. C. (2020). Microfiber Release to Water, Via Laundering, and to Air, via Everyday Use: A Comparison between Polyester Clothing with Differing Textile Parameters. *Environmental Science and Technology*, *54*(6). https://doi.org/10.1021/acs.est.9b06892

de Publicaciones de la Unión Europea, O., & Luxemburgo, L. (n.d.). *Directiva (UE) 2024/3019 del Parlamento Europeo y del Consejo, de 27 de noviembre de 2024, sobre el tratamiento de las aguas residuales urbanas, (versión refundida) (Texto pertinente a efectos del EEE)*. http://data.europa.eu/eli/dir/2024/3019/ojhttp://data.europa.eu/eli/C/2023/250/oj.

Delgado Fimia, O. (2019). *Implicaciones de la exposición a microplásticos en salud humana.*

Detectan concentraciones "excepcionalmente altas" de microplásticos en las Islas Columbretes | Consejo Superior de Investigaciones Científicas. (n.d.). Retrieved 21 December 2025, from https://www.csic.es/es/actualidad-del-csic/detectan-concentraciones-excepcionalmente-altas-de-microplasticos-en-las-islas-columbretes?utm_source=chatgpt.com

Duch, J. (2024). El impacto de la producción textil y de los residuos en el medio ambiente | Noticias | Parlamento Europeo. *Parlamento Europeo*.

EECTI. (2021). Estrategia Española de Ciencia, Tecnología e Innovación 2021-2027. *Ministerio de Ciencia e Innovación*.

EFFITEX, una solución eficiente para la eliminación de microplásticos en la industria textil - Agua. (n.d.). Retrieved 21 December 2025, from https://www.interempresas.net/Agua/383837-EFFITEX-solucion-eficiente-para-eliminacion-de-microplasticos-en-industria-textil.html

El MITECO impulsa la circularidad en el sector del plástico con ayudas por valor de 151 millones. (n.d.). Retrieved 26 December 2025, from https://www.miteco.gob.es/es/prensa/ultimas-noticias/2025/octubre/el-miteco-impulsa-la-circularidad-en-el-sector-del-plastico-con-.html

El MITECO impulsa la circularidad en el sector textil con ayudas por valor de 30,5 millones. (n.d.). Retrieved 26 December 2025, from https://www.miteco.gob.es/es/prensa/ultimas-noticias/2025/septiembre/el-miteco-impulsa-la-circularidad-en-el-sector-textil-con-ayudas.html

E-MICROPLAST 2025 - SOLUCIONES AMBIENTALES III - Aitex. (n.d.). Retrieved 21 December 2025, from https://www.aitex.es/portfolio/e-microplast-2025-soluciones-ambientales/?utm_source=chatgpt.com

Estrategia Española de Economía Circular y Planes de Acción. (n.d.). Retrieved 26 December 2025, from https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/economia-circular/estrategia.html

European Chemicals Agency. (2019). Annex XV restriction report proposal for a restriction - microplastics. *Version 1.2, 22 August 2019, August*.

European Commission. (2004). *Study on the implications of the 2005 trade liberalization in the textile and clothing sector*.

European Commission. (2022). EU Strategy for Sustainable and Circular Textiles. *Document 52021DC0573*.

European Commission. (2023). COMMISSION REGULATION (EU) 2023/2055 of 25 September 2023. In *Official Journal of the European Union: Vol. L* (Issue 238).

E-µplast - SOLUCIONES MEDIOAMBIENTALES - Aitex. (n.d.). Retrieved 26 December 2025, from https://www.aitex.es/portfolio/e-%C2%B5plast-biorreactores-anaerobios-biogas-solucion-eliminacion-microplasticos-industriales/

Filgueiras, A. V., Gago, J., Campillo, J. A., & León, V. M. (2019). Microplastic distribution in surface sediments along the Spanish Mediterranean continental shelf. *Environmental Science and Pollution Research*, *26*(21). https://doi.org/10.1007/s11356-019-05341-5

García-Haba, E., Benito-Kaesbach, A., Hernández-Crespo, C., Sanz-Lazaro, C., Martín, M., & Andrés-Doménech, I. (2024). Removal and fate of microplastics in permeable pavements: An experimental layer-by-layer analysis. *Science of the Total Environment*, *929*. https://doi.org/10.1016/j.scitotenv.2024.172627

Gobierno de España. (2020). *Estrategia Española de Economía Circular ESPAÑA CIRCULAR 2030 Por un #FuturoSostenible*. www.miteco.es

Godoy Calero, V. (2021). *Origen, caracterización e impacto de los microplásticos presentes en el medioambiente. Aplicación a la provincia de Granada (España)*. http://hdl.handle.net/10481/69067

Gravity Wave. (n.d.). Retrieved 26 December 2025, from https://www.thegravitywave.com/

Inditex y Jeanologia se alían para recuperar microfibras en la producción de prendas textiles. (n.d.). Retrieved 21 December 2025, from https://www.eleconomista.es/retail-consumo/noticias/12315576/06/23/inditex-y-jeanologia-se-alian-para-recuperar-microfibras-en-la-produccion-de-prendas-textiles.html

Instituto Nacional de Estadística. (2023). *Estadística estructural de empresas: Sector industrial*. https://www.ine.es/dyngs/Prensa/EEESI2023.htm

Laboratorio de Calidad del Medio Marino del CEDEX: evaluación ambiental | CEPYC - CEDEX. (n.d.). Retrieved 26 December 2025, from https://www.cedex.es/centros-laboratorios/centro-de-estudios-de-puertos-y-costas-cepyc/equipamientos/laboratorio-de-0

Lanz, I. E., Laborda, E., Chaine, C., & Blecua, M. (2024). A Mapping of Textile Waste Recycling Technologies in Europe and Spain. In *Textiles* (Vol. 4, Issue 3). https://doi.org/10.3390/textiles4030022

LIFE 3.0 - LIFE21-ENV-ES-LIFE-ANHIDRA/101074372. (n.d.). Retrieved 21 December 2025, from https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE21-ENV-ES-LIFE-ANHIDRA-101074372/unique-and-sustainable-system-for-producing-garments-without-water-discharges

Life-Phoenix. (n.d.). Retrieved 21 December 2025, from https://www.life-phoenix.eu/

López-Castellanos, J., Olmos Espinar, S., & Bernal, J. B. (2020). *Artículo Técnico*. www.tecnoaqua.es

Los microplásticos, más allá de los pellets - Campus de Gandia Ciencia - UPV Universitat Politècnica de València. (n.d.). Retrieved 18 December 2025, from https://cienciagandia.webs.upv.es/2024/01/microplasticos-mas-alla-pellets/?utm_source=chatgpt.com

Luzi, B., Carnevale Miino, M., Rada, E. C., Zullo, R., Baltrocchi, A. P. D., Torretta, V., & Galafassi, S. (2025). Critical review of microfiber release from textiles: Results, comparative challenges, mitigation strategies, and legislative perspectives. *Chemosphere*, *378*. https://doi.org/10.1016/j.chemosphere.2025.144394

Mares Circulares. (n.d.). Retrieved 26 December 2025, from https://www.cocacolaep.com/es/mares-circulares/

Materiales | ECOALF. (n.d.). Retrieved 26 December 2025, from https://ecoalf.com/pages/materiales

Microplásticos, El Nuevo Reto Ambiental Del Sector Textil. (n.d.). Retrieved 21 December 2025, from https://www.aitex.es/microplasticos/?utm_source=chatgpt.com

Ministerio para la Transición Ecológica y el Reto Demográfico. (n.d.). *Proyecto Estratégico para la Recuperación y Transformación Económica en Economía Circular*.

MITERD. (2022). Real Decreto 1055/2022, de 27 de diciembre, de envases y residuos de envases. *Boletín Oficial Del Estado*.

Moral, M. J. , & P. C. (2004). *El sector textil y confección en España ante un futuro incierto.*

Nizzetto, L., Futter, M., & Langaas, S. (2016). Are Agricultural Soils Dumps for Microplastics of Urban Origin? In *Environmental Science and Technology* (Vol. 50, Issue 20). https://doi.org/10.1021/acs.est.6b04140

OCEAN YARN & ZERO MICROPLASTICS | ECOALF. (n.d.). Retrieved 21 December 2025, from https://ecoalf.com/pages/ocean-yarn-zero-microplastics?srsltid=AfmBOoqtKCMIH-rZfHI-18Q5pIXd7zh1gRgxk-IWxL7Spl2Jr03EDunS

Olea, N. (n.d.). Impacto de los microplásticos en la salud humana. *Revista de Salud Ambiental, 24(Especial Congreso)*, *24*, 74–77.

Página. (n.d.). *BOLETÍN OFICIAL DEL ESTADO LEGISLACIÓN CONSOLIDADA*.

Pérez, E. M., Luísa, M., García, M., Ángeles, M., Aracil, B., & Candela, R. V. (2022). *Proceso foto-Fenton como una alternativa en la degradación de microplásticos de poliamida presentes en aguas residuales textiles*.

PlastikHUM. (n.d.). Retrieved 21 December 2025, from https://www.udg.edu/ca/projectes/plastikhum

Proyectos emprendedores que intentan devolver la vida al mar. (n.d.). Retrieved 26 December 2025, from https://www.miteco.gob.es/es/ceneam/carpeta-informativa-del-ceneam/novedades/proyectos-basura-mar.html

Proyectos I+D – Santanderina Group. (n.d.). Retrieved 26 December 2025, from https://santanderinagroup.com/es/proyectos-id/

Proyectos I+D – Techs. (n.d.). Retrieved 26 December 2025, from https://www.techs.es/es/proyectos-id/

Ramírez, J. , A. L. , H. S. , L. E. , & F. S. (2019). Minimización de microfibras en ciclo de vida de los productos textiles y en el tratamiento de aguas residuales: Proyecto Fiberclean. *Tecnoaqua, 36*, 53–57.

Reciclar está de moda - Recuperación textil en Madrid - Ayuntamiento de Madrid. (n.d.). Retrieved 18 December 2025, from https://www.madrid.es/portales/munimadrid/es/Inicio/El-Ayuntamiento/Latina/Reciclar-esta-de-moda/?vgnextfmt=default&vgnextoid=53d2eee2b72b5910VgnVCM1000001d4a900aRCRD&vgnextchannel=a83aca5d5fb96010VgnVCM100000dc0ca8c0RCRD&idCapitulo=12726795

Shahul Hamid, F., Bhatti, M. S., Anuar, N., Anuar, N., Mohan, P., & Periathamby, A. (2018). Worldwide distribution and abundance of microplastic: How dire is the situation? In *Waste Management and Research* (Vol. 36, Issue 10). https://doi.org/10.1177/0734242x18785730

Simon-Sánchez, L., Grelaud, M., Franci, M., & Ziveri, P. (2022). Are research methods shaping our understanding of microplastic pollution? A literature review on the seawater and sediment bodies of the Mediterranean Sea. In *Environmental Pollution* (Vol. 292). https://doi.org/10.1016/j.envpol.2021.118275

Sobre la Asociación - Gestión de Residuo Textil. (n.d.). Retrieved 18 December 2025, from https://re-viste.org/sobre-la-asociacion/

Sorigué instala una planta piloto en la EDAR de Quart para probar una nueva tecnología de tratamiento de aguas de bajo impacto ambiental | Sorigué. (n.d.). Retrieved 21 December 2025, from https://www.sorigue.com/es/sala-de-prensa/actualidad/sorigue-instala-una-planta-piloto-en-la-edar-de-quart-para-probar-una

Spain. (2010). Ley 41/2010, de 29 de diciembre, de protección del medio marino. *Boletin Oficial Del Estado*.

Spain. (2022). Ley 7/2022, de 8 de abril, de residuos y suelos contaminados para una economía circular. *Boletín Oficial Del Estado*, *85*.

TECNOLOGÍA DE CAPTURA – CAPTOPLASTIC. (n.d.). Retrieved 26 December 2025, from https://captoplastic.com/es/tecnologia-captura/

Un estudio de la Cátedra Aguas de Valencia demuestra la alta capacidad de los humedales artificiales para retener y degradar microplásticos | SIECATEDRAS | UPV. (n.d.). Retrieved 21 December 2025, from https://www.upv.es/contenidos/siecatedras/2025/12/01/un-estudio-de-la-catedra-aguas-de-valencia-demuestra-la-alta-capacidad-de-los-humedales-artificiales-para-retener-y-degradar-microplasticos/

Un proyecto pionero liderado por la UAB revela los riesgos de los micro- y nanoplásticos para la salud humana - Universitat Autònoma de Barcelona - UAB Barcelona. (n.d.). Retrieved 21 December 2025, from https://www.uab.cat/web/sala-de-prensa/detalle-noticia/un-proyecto-pionero-liderado-por-la-uab-revela-los-riesgos-de-los-micro-y-nanoplasticos-para-la-salud-humana-1345830290069.html?detid=1345948461434

UPRISE: Análisis repercusiones partículas y microplásticos en salud fetal. (n.d.). Retrieved 21 December 2025, from https://itene.com/casos-de-exito/uprise-analisis-de-las-repercusiones-de-las-particulas-ultrafinas-y-los-microplasticos-nanometricos-en-la-salud-fetal/

Upstream project - for waste free european rivers. (n.d.). Retrieved 21 December 2025, from https://upstream-project.eu/

UPV: Un equipo de la UPV desarrolla una aplicación que identifica y cuantifica microfibras plásticas en aguas y lodos residuales con inteligencia artificial | Universitat Politècnica de València. (n.d.). Retrieved 21 December 2025, from https://www.upv.es/noticias-upv/noticia-14859-ia-contra-los-es.html

UPV: Una investigación de la UPV y la UA revela la eficacia de los pavimentos permeables en la captura de microplásticos urbanos | Universitat Politècnica de València. (n.d.). Retrieved 21 December 2025, from https://www.upv.es/noticias-upv/noticia-14784-pavimentos-ant-es.html

Web microplásticos LIBERA 2023 - Proyecto LIBERA. (n.d.). Retrieved 27 December 2025, from https://proyectolibera.org/actualidad/nace-micro-la-primera-web-que-mapea-los-estudios-de-microplasticos-espanoles

Weis, J. S., & De Falco, F. (2022). Microfibers: Environmental Problems and Textile Solutions. *Microplastics*, *1*(4). https://doi.org/10.3390/microplastics1040043