PLASTIC BIOCARRIERS

POLLUTION OF BEACHES AND WATERWAYS BY BIOMEDIA, PLASTIC CARRIERS FOR BACTERIAL PROLIFERATION USED IN WASTEWATER TREATMENT

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Surfrider Foundation Europe would like to thank all of the citizens, organizations, public authorities, and waste treatment professionals who, over the past 15 years, have helped us by providing insight and collaboration to develop our expertise and produce this report.

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Illustration | ***Cover picture*** | *Biomedia found on the Corsican shoreline, © Mare Vivu*

FOREWORD

This study on pollution of beaches and waterways by plastic carriersfor bacterial proliferation used in wastewater treatment was undertaken by Surfrider Foundation Europe. This report is an update of the report entitled "Sewage Filter Media and the Pollution of the Aquatic Environment" published in 2018. This updated version includes recent findings acquired over the past 5 years.

For the past 30 years, Surfrider Foundation Europe has been working years to protect Europe’s oceans, seas, coast, and the people who enjoy them.

Surfrider is one of the few NGOs to focusing specifically on issues related to the Oceans and coastal development campaigning on 3 principal themes: Water Quality and Health, Marine Litter, and Coastal Development and Climate Change.

Federating more than 12,000 members and 45 local branches in Europe, we advocate with European institutions directly. Surfrider is a major player in Environmental advocacy in Europe and particularly in France.

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1 INTRODUCTION

1.1 OBJECTIVE OF THIS REPORT

This report shares Surfrider Foundation Europe's (SFE) findings on biomedia use and pollution obtained through investigative work over the past 15 years. Several reports and numerous scientific articles (FNDAE…) give overviews of biomedia usage, the various processes implicated, comparisons of different bacterial carriers, and many other parameters. However, none has investigated the impact of their dispersion in the environment after malfunctions. Our work aims to contribute to improved understanding and consideration of the issues leading to the release of biomedia into the environment.

The first Surfrider report on the subject, published in 2018, offered an objective report of the state of the art of biomedia use and related dysfunction. To better understand the origins of this issue, please do not hesitate to consult the document online at: *surfrider.eu/wp-content/uploads/2020/10/surfrider_foundation_europe_biomedias-2018.pdf*

It provided a broad overview of the issue, alerting stakeholders and serving as a preliminary reference. This preliminary report also helped put initial improvements into motion and provided a basis for discussion with wastewater treatment professionals.

At the national level, our work has also been consulted by committees and working groups assembled to analyse and quantify marine litter. The committees have also served as the starting points for action plans to reduce plastic waste from wastewater treatment networks at the source.

At European and regional levels, the information collected by Surfrider Foundation has served as a reference for integrating targeted measures to prevent the loss of biomedia into the environment in the new version of the Urban Wastewater Treatment Directive (UWWTD). It has also been used for the second regional action plan for marine litter in the OSPAR Convention (RAP ML II). In 2023, the Swedish Environmental Protection Agency commissioned Surfrider to make a "Good Practice" guide for reducing biomedia pollution[1].

This second report is an update of our work and observations from the past five years.

Our work began in the Bay of Biscay when massive amounts of biomedia started washing up on shorelines and remained focused in the area for many years. However, we are now confident this is a worldwide issue and have expanded our scope of action to include all of Europe.

***Illustration** | **Left page** | Biocarriers on the beach in the Basque Country. © Surfrider Foundation Europe*

Notes | **1.** *www.norden.org/en/publication/recommendations-use-biocarriers*

1.2 PLASTIC POLLUTION IN THE OCEANS

The accumulation of plastic in the oceans and on coastlines has become a problem worldwide. Each year, it is estimated that over 10 million tons of plastic debris enters the oceans. From surface waters to deep water marine sediments, plastic is now ubiquitous and threatens coastal and marine ecosystems.

Every oceanic and coastal ecosystem is affected by aquatic debris.

Plastic poses a serious threat to the marine and coastal environment. Aside from the harm that plastic can potentially cause to marine species (strangulation, entanglement, ingestion, transportation of invasive species) as well as on the seabed (smothering) and to humans (socioeconomic and physical impacts), plastics also break up into small pieces through exposure to UV light (photodegradation) and mechanical abrasion. Plastics degrade very slowly in the natural environment, and as they do so, they also release toxic substances (chemical additives, flame retardants, etc.), which can act as endocrine disruptors, for example.

Microplastics also accumulate hydrophobic persistent organic pollutants (POP) such as polychlorinated biphenyls and DDT.

***Figure 1** | **Below** | Biocarriers and microplastics removed from the digestive tract of a fulmar from the Faroe Islands. © J.A. van Franeker / Wageningen Marine Research*

Fifteen years ago, a new form of plastic pollution was observed on the coastlines of the Northern Atlantic. It was the biomedia used to improve the efficiency of biological wastewater treatment. Involuntary leakage during various wastewater treatment processes leads to them washing into aquatic environments and onto coastlines, contributing to plastic pollution.

1.3 BIOMEDIA POLLUTION

WHAT ARE BIOMEDIA?
Biomedia are plastic carriers used in wastewater treatment plants (WWTPs) during the secondary (biological) phase of the treatment process. During this phase, bacteria break down organic and nitrogenous material as well as phosphorous[2]. In what are known as fluidised bed systems, bacteria are cultivated on various types of physical carriers to create biofilms. Added by the millions into the tanks, biomedia provide a vastly increased surface area for biofilm growth, increasing wastewater treatment capacity. At the same time, the addition of biomedia enables reducing the footprint of the installations.

Various biomedia-based technologies are used depending on the treatment requirements (type and volume of effluents and the receiving waters). Among the most common are:

- MBBR
- IFAS
- ANAMOX

Since the late 1990s, numerous biomedia-based techniques have been developed to help ensure that wastewater discharges comply with the standards of the European Urban Wastewater Treatment Directive (UWWTD). Biomedia can be immobile or fluidised (meaning in free movement in the water column) and composed of various materials *(see Chapter 2.4)*. They can be natural materials like clay beads or volcanic rocks, or synthetic plastic supports. In the case of spills, the main environmental concern is evidently that of plastic supports.

The three main categories of plastic carriers used in the fluidised processes are the following:

- Biocarriers

Generally small, 1 to 5 cm, cylinders, but can also be in the form of flat disks. They are made of high-density polyethylene (HDPE) or polyethylene (PE) and are principally used in MBBR processes.

• Biobeads
Irregular-shaped 3 to 5 mm diameter beads made of polyethylene (PE) and recycled heterogeneous polyethylene (rPE), which may not meet existing standards regarding dangerous plastic waste[3].

• Polystyrene Beads
Regular-shaped, spherical beads that range in size from 3 to 5 mm.

THE PROBLEM

A number of wastewater treatment plants using the MBBR process experience dysfunctions and may release plastic biocarriers into the environment. Since the late 2010s, massive discharges of biomedia into the marine environment, from thousands to several million units, have been observed in Europe[4].

Other cases of chronic, diffuse environmental leakage have also been recorded. However, a lack of institutional knowledge regarding the processes used by WWTPs combined with an absence of data from monitoring provided by operators renders the identification of this type of discharge difficult.

WHAT ARE THE IMPACTS OF BIOMEDIA POLLUTION?

Biomedia are a supplementary source of plastic pollution with disastrous consequences on the marine environment for several reasons:

→ The amount of biomedia spilled in a single incident can be catastrophic:
A treatment tank can contain several hundred million biomedia. A single accident can thus cause the spillage of millions of pieces of plastic into the environment.

In March 2021, around half a million biomedia were released into the Ringkøbing Fjord (Denmark) and reached the North Sea after an accident at a salmon aquaculture site (see Chapter 7).

→ The pollution can be long-lasting:
In most cases, biomedia that reach aquatic environments are never recovered.

Biomedia that escaped from a WWTP in the Spanish Basque Country in 2010 are still washing up in large numbers on Atlantic Coasts 13 years after the accident.

→ The pollution can spread over far distances and impact protected areas:
The Ocean knows no boundaries, and the same goes for biomedia. Their physical properties, notably their density close to that of the water, make them very mobile pollutants capable of rapid spread in aquatic environments.

In Italy in 2018, 126 to 130 million biomedia from the Capaccio Paestum City WWTP poured into the Sele River that flows into the Tyrrhenian Sea. The pollution spread across the entire western Mediterranean, affecting the coastlines of France, Spain, Tunisia, Malta, and numerous marine protected areas (See Chapter 7).

→ They are ingested by marine fauna and negatively affected marine biodiversity:
Biomedia, like all plastic waste, can be confused with food, as illustrated by the myriad cases of ingestion by birds and sea turtles. (fig. 2). They can have physiological, reproductive, growth, and hormone-disrupting effects on marine species.

→ Their toxicity is worrying:
Designed to support bacteria, biomedia can also carry other things in wastewater like faecal bacteria, viruses, industrial products, detergents, hydrocarbons, pesticides, cosmetics, or drug molecules. In

***Figure 2** | **Below** | Stomach contents of a Mediterranean sea turtle, 2021. © G. Darmon & D. Gambaiani*

Notes** | **2.** Lustig, 2012. **Notes** | **3.** Bencivengo et al., 2018 ; Turner et al., 2019 ; Bautista, 2021. **Notes** | **4. Turner et al., 2019 case of any incidents or discharges, biocarriers can act as a means of transportation for these pollutants within aquatic environments.

SURFRIDER FOUNDATION,
LEADING THE FIGHT AGAINST BIOMEDIA

Surfrider Foundation Europe was among the first organizations to address the issue of biocarrier proliferation in marine environments. Since then, the organization has initiated a monitoring program for biomedia pollution at the European scale. This was accompanied by investigative work to understand biomedia usage and identify the causes of discharges into aquatic environments. To support these initiatives, surveys and interviews were conducted with professionals in the field of wastewater treatment to objectively describe the scenarios that could lead to discharges and then to work together to find sustainable, environmentally friendly solutions.

Surfrider's investigations and expertise have helped develop educational material, tools to track pollution, and technical reports and contributed to improved regulation.

Today, Surfrider Foundation Europe has become a reference on the issue of biomedia loss in the environment.

1.4 REGULATORY CONTEXT

1.4.1 CONSERVATION OF AQUATIC ENVIRONMENTS: CONSIDERATIONS FOR LITTER

WATER FRAMEWORK DIRECTIVE 2000/60/EC

Since 2000, the Water Framework Directive 2000/60/CE (WFD) has defined the objectives for subterranean and surface water (freshwater and coastal waters) preservation and restoration. The general objective was to achieve good ecological and chemical status for the various water bodies throughout Europe by 2015. However, many areas were able to defer targets to 2027 when objectives were not met.

In 2020, only 40% of the water bodies in Europe had good chemical and environmental status[5]. Although rivers are the principal vectors of transportation of plastic pollution to the ocean, the WFD does not include plastic debris as an indicator of the good environmental status (GES) of waterways.

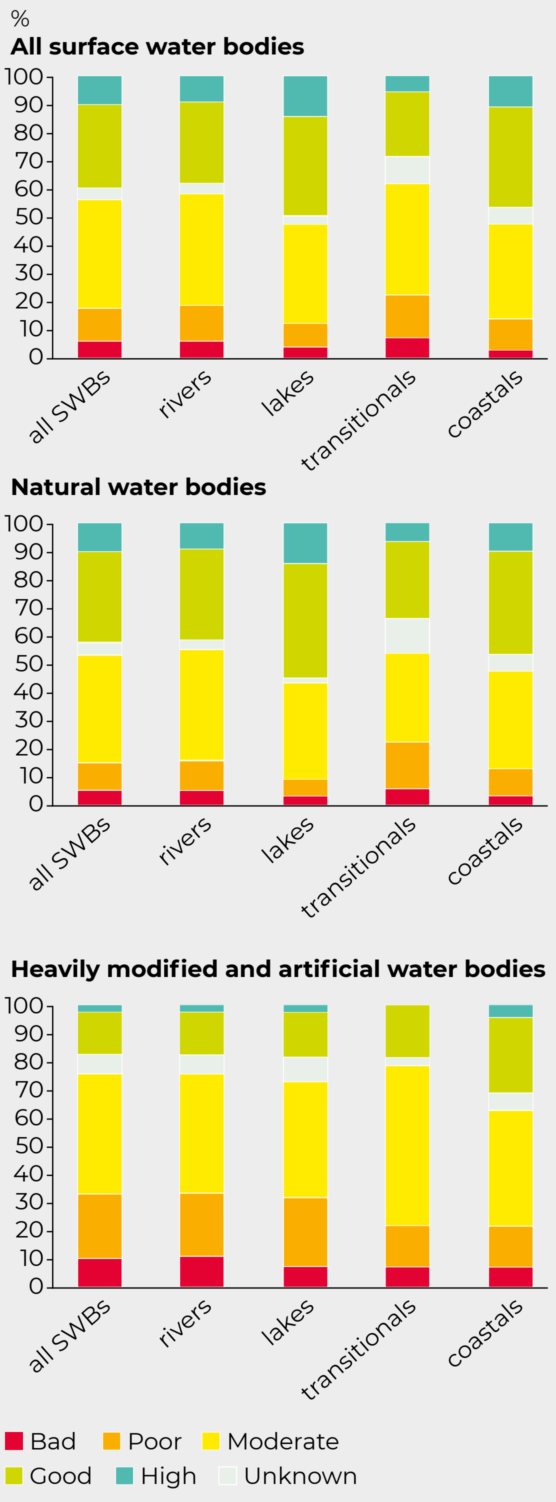
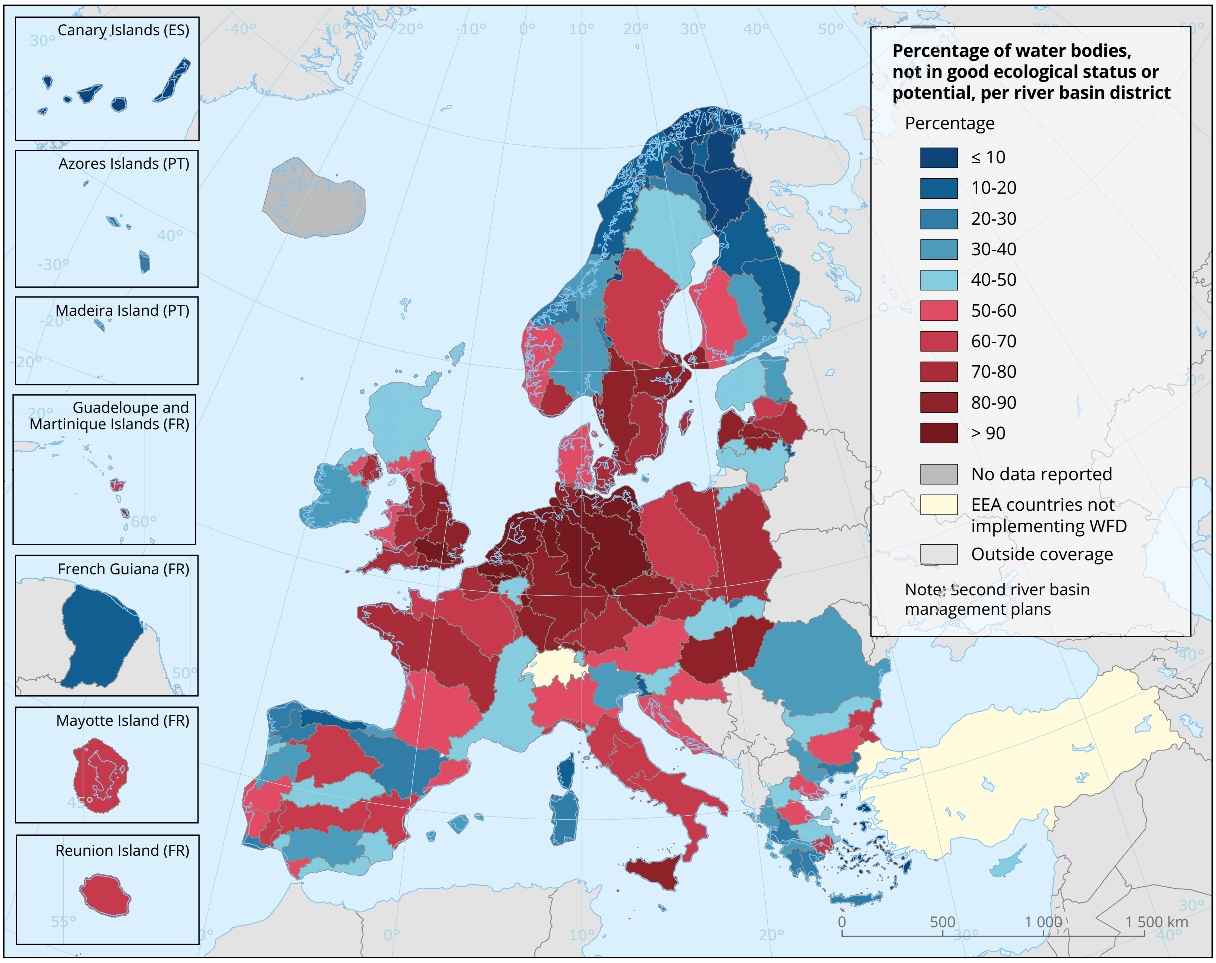


Figure 3 | ***Below and opposite page*** | *Representations of the achievement of good ecological quality objectives for water bodies in Europe (source: EEA)*

Notes | ***5.*** *Source: EEA (European Environmental Agency), www.eea.europa.eu/data-and-maps/daviz/distribution-of-ecological-status-or-5#tab-chart_1*

Figure 4 | Below | % of water bodies not in good ecological status or potential, per river basin district. (Reference data: ©ESRI / ©EuroGeographics)



As such, there is a lack of preventative measures for watersheds.

MARITIME STRATEGY FRAMEWORK DIRECTIVE 2008/56/CE

In 2008, European decision-makers adopted the Marine Strategy Framework Directive (MSFD) 2008/56/EC, establishing a framework for community action in marine environmental policy. Under this Directive, Member States must adopt strategies to reduce the impact of human activities on the environment to achieve or maintain good environmental status in all the marine waters for which they are responsible.

The MSFD lists 11 descriptors to define a good environmental status for a marine sub-region. It is the first time European legislation has recognized marine litter as an indicator of the environmental status of marine waters.
The descriptor N°10 "Marine litter" states, "Properties and quantities of marine litter do not cause harm to the coastal and marine environment."

1.4.2 WASTEWATER TREATMENT

Discharges of urban wastewater in the environment can contain organic pollutants, bacteria, viruses, nitrogen, or phosphorous for example. Adequate treatment of these waters is necessary prior to discharge to limit their environmental impact.

Whatever their origin, wastewater from human activity discharged into the environment must meet the water quality targets of the receiving waters.

URBAN WASTEWATER TREATMENT DIRECTIVE 91/271/CE

Enacted in 1991, the Urban Wastewater Treatment Directive (UWWTD) covers the collection, treatment, and discharge of urban wastewater and the treatment and discharge of wastewater of certain industrial sectors. It aims to protect the environment against deterioration caused by urban wastewater discharge. Wastewater treatment plants play a key role in treating urban wastewater and water from agricultural and industrial activity. At the European level, the UWWTD sets treatment objectives according to the city sizes (counted in Population Equivalents - PE), the types of industrial activities, and depending on the sensitivity of the receiving environment. The more sensitive the receiving environment is, or the more susceptible it is to harbour recreational or aquacultural activities, the higher the level of protection required.

Since 2005, all municipalities treating more than 2000 PE must be equipped with secondary treatments to eliminate a large proportion of organic pollution, bacteria, and viruses.
The presence of plastics or microplastics in discharged water is not an indicator of quality.

According to the 2017 European Environmental Agency report[6], there are wide disparities between Member States concerning the application of the Directive. To take into account current societal and environmental issues, the Directive is being revised to create new treatment objectives. A new, more ambitious text should be adopted in 2024.

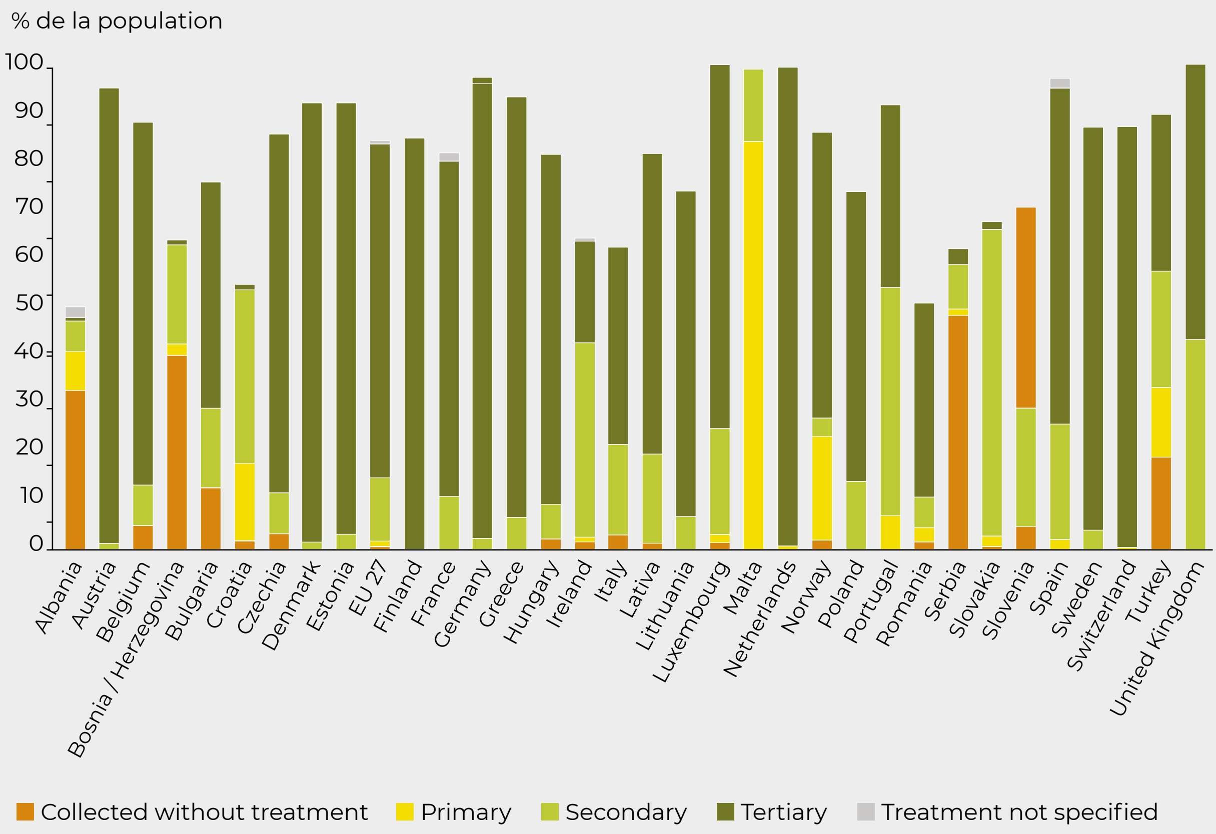
1.4.3 AGRICULTURAL & INDUSTRIAL RUNOFF

INDUSTRIAL EMISSIONS DIRECTIVE 2010/75/UE

In Europe, several types of regulation aim to limit the effect of industrial discharges on the environment.

The Industrial Emissions Directive (IED) is the main text regulating direct and indirect discharges from industrial activities. Thirty-one industrial sectors are concerned, with over 52,000 installations across Europe. Each facility must have a discharge permit validated by the competent national authorities. According to estimations by the European Commission, the installations concerned by the IED emit around 20% of total emissions of regulated pollutants.

***Figure 5** | **Below** | Types of urban wastewater treatment in Europe, 2017 (source: EEA)*



Notes | **6.** *www.eea.europa.eu/data-and-maps/daviz/urban-waste-water-treatment-in-europe#tab-chart_1*

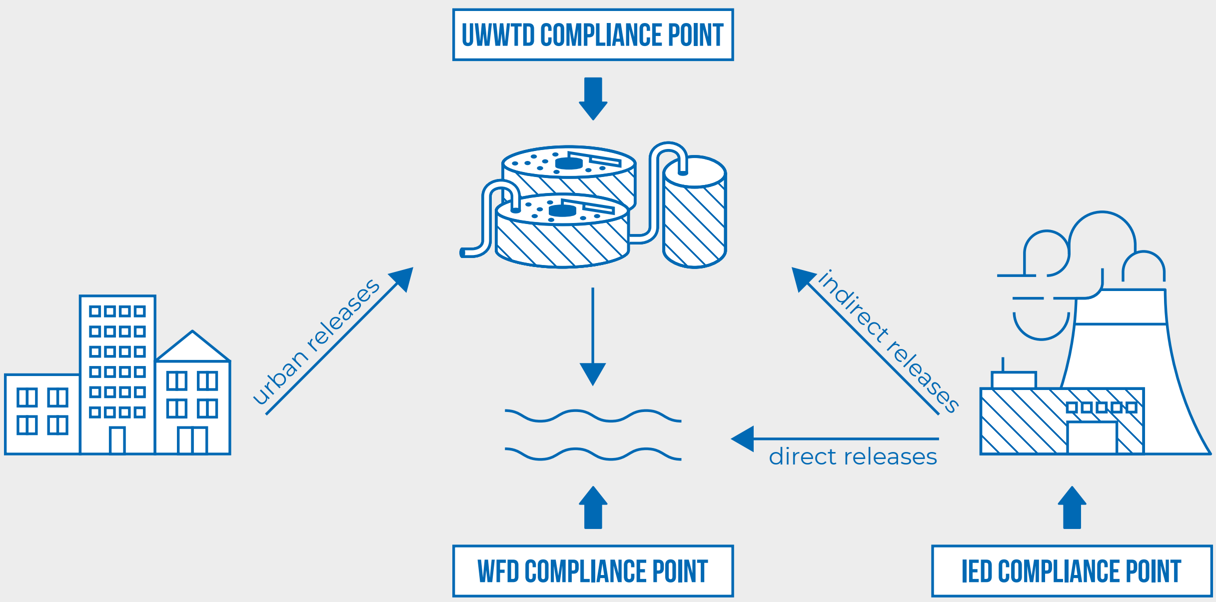


Figure 6 | *Above* | *Relationships between the three key Directives for the protection of aquatic environments (source: EEA)*

Discharges in collective wastewater treatment networks are regulated by the UWWTD.

The plastic and microplastics that may be present in industrial wastewater are not taken into consideration.

This non-exhaustive regulation review demonstrates that biomedia use is currently insufficiently covered by European legislation. The lack of linkages in the land-ocean continuum and the age of certain Directives can also inhibit preventative or corrective measures more coherent with current issues.

The issue of aquatic litter concerns every sector of society and must be the object of suitable regulation at every level. Regulations are also a tool for implementing solutions at source. In recent years, States have multiplied international, European, and national commitments to stop the proliferation of aquatic litter, notably plastic. The following can be cited:

• United Nations Environment Assembly (UNEA): International treaty to end plastic pollution

• OSPAR Convention: Marine Litter Regional Action Plan (RAP ML2)

• Ministère de la transition écologique / France: Plan d'Action Zéro déchet plastique en mer

1.4.4 SURFRIDER'S ADVOCACY IN EVOLVING REGULATION

As both a whistle-blower and an expert on environmental matters, SFE lobbies public and private decision-makers to adapt legislative framework and public policies to the challenges of protecting and preserving the ocean, strengthening environmental policy, and moving the economic model towards an ecological transition that respects aquatic environments, human health, and the climate. Concretely, this means ensuring that existing legislation is effectively applied and that legislative or economic measures are adopted to prevent and reduce pollution at the source. It also means modifying regulations where necessary to enable sustainable, alternative solutions.

Wastewater treatment plants play an essential role in water purification, maintaining aquatic ecosystem resilience, and biodiversity preservation. Biomedia losses compromise this role by doing precisely the opposite. They add to already omnipresent plastic pollution and create supplementary environmental threats. Given the increasing usage of this type of process in Europe, the heightened risk of spillage, and the trans-border nature of this type of plastic pollution, a harmonised and ambitious framework is necessary.

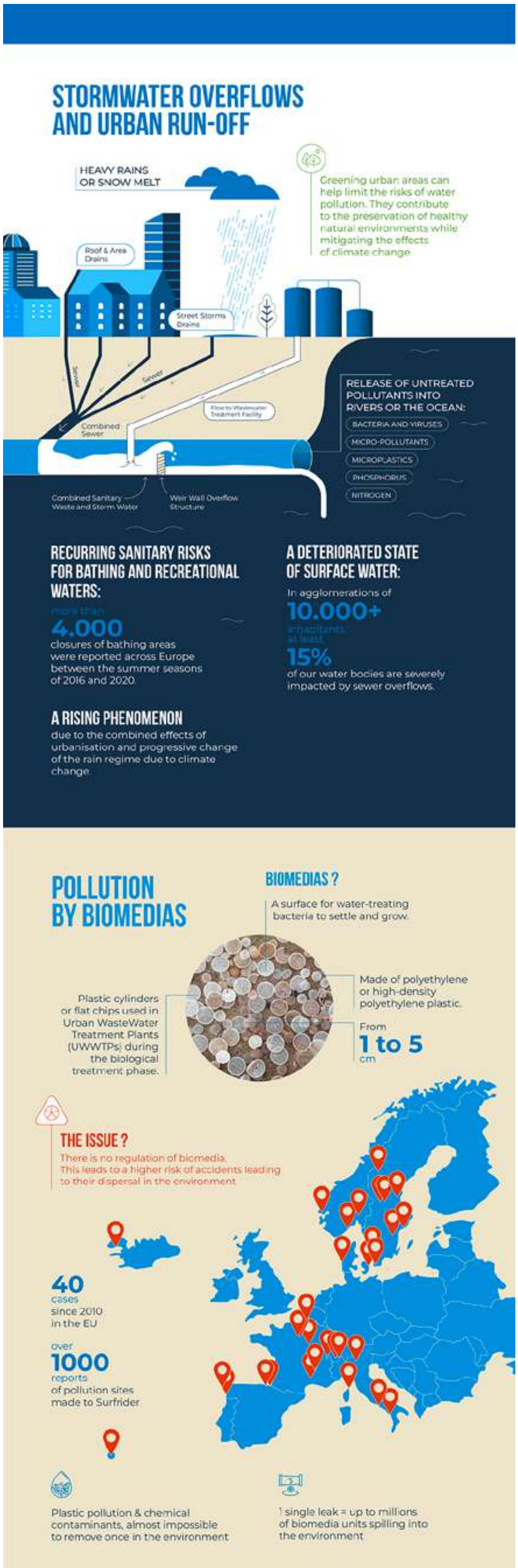
Since its discovery in the field, Surfrider has been advocating at regional, national, and European levels for the consideration of biomedia pollution. We propose the adoption of regulations intended to prevent the spillage of biomedia in the environment and the application of the "polluter pays" principle in the event of accidents. Since 2022, the European Directive on Urban Wastewater Treatment has been under revision. Thanks to its influence in European institutions and the mobilisation of its community, SFE has played a major role in the revision of the Directive. As a result, a new provision has been included to regulate the use of biomedia in municipal wastewater treatment plants.

Through its Brussels office, Surfrider is shaping the revision of the Directive:

- Mobilising European citizens to alert Members of the European Parliament (MEPs) about biomedia pollution;
- Distribution of informational leaflets and position papers to Eurodeputies;
- Meetings with the rapporteurs.

This ongoing action and our alliances with other European NGOs, such as the European Environmental Bureau (EEB), enable us to pool and strengthen demands made of decision-makers. It can then lead to drafting amendments that consider our stance in favour of environmental protection.

Figure 7 | Above | A group of citizens mobilised to collect marine litter on a beach, © Surfrider Foundation Europe. Figure 8 | Right | Educational leaflet sent to Eurodeputies before voting, © Surfrider Foundation Europe



2 WASTEWATER TREATMENT

Here we provide an overview of the wastewater treatment system as a whole, from installation to management, in order to aid understanding of the processes in which biomedia are used.

2.1 KEY PLAYERS IN WASTEWATER TREATMENT

The installation of a wastewater treatment plant in an area is intended to maintain environmental water quality in the face of pressure exerted on it by individual citizens or private enterprises.

Multiple parties intervene to guarantee the conformity of the installation to regulatory requirements and that the treatment is suited to the receiving environment's water quality. Administrative authorities and the companies that design or operate wastewater treatment plants all play important roles in ensuring smooth and long-lasting operational efficiency.

The principal players are described briefly in the following:

Figure 9 | ***Above*** | *WWTP in Zürich, Switzerland.*
© Patrick Federi

DECISION MAKERS

To guarantee effective treatment before discharge into the receiving environment, all urban wastewater from built-up areas of 2000 population-equivalents (PE) or more, and all wastewater from industry, must conform to European and national regulations *(see Chapter 1.4.3)*.

An authorisation to discharge must be issued when a wastewater treatment system is created or modernised. These authorisations are requested from relevant government agencies. Depending on the installation size and type, different agencies with local, regional, or national scope are to be contacted.

CONTRACTING AUTHORITIES (CA) AND CONTRACTORS

Local authorities are responsible for collective wastewater treatment and for monitoring non-collective wastewater treatment (NCWT). Construction of such plants is therefore usually undertaken by town councils or groups of local councils (where they have shared requirements). These are called the contracting authorities.

The local authorities may request the help of specialist sewage contractors to assist them in designing, building, or upgrading a wastewater treatment plant. This assistance may take effect at the conclusion of the works or may involve management of the entire project.

The contractors in charge of designing the installations and their construction must implement procedures that satisfy existing treatment requirements and environmental standards. Their goal is to provide compliant installations for contracting authorities while anticipating potential malfunctions to ensure long-term reliability of the plants.

In some cases, assistance is provided to the contracting authority, facilitating the connection between it and the contractor, and providing support to the overall running of the project.

The design of the installations covers all the administrative and engineering that entail the construction of a WWTP with the overall objective of compliant effluent discharged into the environment.

It includes:
- The technical specifications,
- Design by the contractor,
- Preparation of applications for authorisation / Water Law,
- Site planning and organisation,
- Construction of the installations ,
- Testing and starting the WWTP,
- Delivery of a working WWTP

COMMISSIONING ENGINEERS

A specialised engineer oversees the commissioning of the WWTP and its different stages. Each component of the wastewater treatment plant is brought online in actual operating conditions. Wastewater is introduced into the tanks gradually, and operations are brought up to speed incrementally. Operators take the opportunity to familiarise themselves with the new plant's operating conditions.

OPERATORS

Once the work and the checks following commissioning are complete, wastewater can be treated in compliance with the stated objectives. Plant operators ensure that installations are functioning correctly, maintenance is performed, and that self-monitoring data is sent to monitoring bodies.

For municipal WWTPs, the operation of the plant can be undertaken by several types of players and in various forms:

- A local authority may operate a plant itself by means of a public company.

- Inter-authority federations may also be created to ensure public operation in an area that groups together various local authorities.

- Businesses specialised in sanitation (contractors) generally offer contracts to operate and maintain sites to the contracting authorities, for periods ranging from several months to decades.

2.2 OVERVIEW OF OPERATIONS IN A WASTEWATER TREATMENT SYSTEM

Water used by both households and industrial sites must pass through a wastewater treatment system in order to protect public health, the environment and water resources.

There are two major types of systems - combined sewer systems, in which rainwater and domestic wastewater are channelled through the same pipes, and separate sewer systems, which allow domestic water to be treated separately from rainwater.

Discharges of treated wastewater are subject to regulations to reduce their impact on the receiving waters and to significantly limit the risk of eutrophication *(see Chapter 1.4.3)*. Eutrophication is caused by the addition of high quantities of nutrients, which causes runaway algal growth, ultimately depleting oxygen levels in the water and even asphyxiating life in rivers.

Various chemical, physical, and biological levels are monitored, such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD). These indicators reflect the organic pollutant load in the water. Other levels such as suspended solids (SS) or total nitrogen (TN) may also be measured in sensitive areas. Phosphorous and total phosphorous (TP) may also be subject to specific monitoring in a sensitive area.

Organic pollutants may come from sources such as domestic (garbage, excrement), agricultural (slurry) or industrial (paper mills, dairies, abattoirs, tanneries, fish farms, etc.).

Wastewater treatment facilities are specially designed for each site, according to the sensitivity of the receiving water as well as other more specific factors (location, treatment process, number of inhabitants, etc.).

2.3 MAIN STAGES IN THE WASTEWATER TREATMENT PROCESS

In most cases, wastewater treatment operates as follows:

2.3.1 PRETREATMENT

The objective of pretreatment is to eliminate the largest elements through 3 principal steps:

→ Screening
Wastewater passes through a bar screen that retains the bulkiest objects. A sieving step can complete this phase of the pretreatment.

→ Grit Removal
Smaller solid particles (sand and gravel) settle on the bottom of grit chambers by sedimentation. The particles are subsequently collected by a pumping system.

→ Oil and Fat Removal
Oil and fat removal is performed by floatation. Air injected through the bottom of the tank causes fatty material to rise to the surface, where it is skimmed off.

2.3.2 PRIMARY TREATMENT

Primary treatment consists of water clarification via the removal of fine, suspended solids. In this stage, particles sediment due to physical forces, or through physicochemical interventions inducing coagulation or flocculation.
Impurities are slowly removed from the water. Suspended solids settle on the bottom of the tank, where they are scraped and collected as primary sludge (raw primary biosolids). Installing lamella clarifiers (or lamellar decanters) or adding flocculants can improve the results of this phase.

2.3.3 SECONDARY TREATMENT OR BIOLOGICAL TREATMENT

Secondary treatment involves the removal of matter held in solution in the water (organic matter, mineral substances, etc.) using processes similar to nutrient cycling observed in natural aquatic environments.

Biological treatment techniques harness the activity of bacteria to break down organic matter in the water being treated. Different procedures can be used to reduce carbon and nitrogen-based pollution depending on the nature and the volume of effluent to be treated as well as the receiving environment.

After this treatment, secondary clarification takes place in a dedicated tank to enable the collection of pollutants concentrated by the microorganism in the form of sludge. Generally, the now-purified water is discharged into the environment after secondary treatment.

2.3.4 TERTIARY TREATMENT

Complementary treatment can be performed for a more complete elimination of the nitrogen and phosphor in wastewater to meet effluent quality criteria in sensitive areas.

To ensure water purity, tertiary treatment uses biological processes with bacteria and physicochemical methods with the addition of reagents.

2.3.5 QUATERNARY TREATMENT

If effluent is to be discharged in an area where it is liable to affect public health, such as swimming areas or shellfish farming areas, a disinfection step may complete the treatment. Chlorination, UV treatment, or ozonation may thus be used to eliminate potential pathogens.

ELIMINATION OF MICROPOLLUTANTS
Ever-increasing amounts of chemical pollutants with potential health and environmental impacts are being found in wastewater: medicines, hormones, cosmetics, perfumes, metals, biocides, and so forth. New technologies are being developed to limit their impact, such as membrane-based techniques that ensure purity levels almost equivalent to drinking water. Because of the costs involved in their installation and running, this type of plant is still relatively rare.

2.3.6 SLUDGE TREATMENT

Depending on the type of wastewater treatment, the composition of ensuing sludge may vary. The treatment of the sludge depends on its intended usage. In general, the treatment reduces the volume of the sludge and stabilises its chemical composition. There are three principal outcomes for treated wastewater sludge:

- Agricultural use:
  - Spreading (fertiliser or compost)
  - Biogas production
- Incineration
- Disposal in landfills

2.4 "FIXED BED" INSTALLATIONS

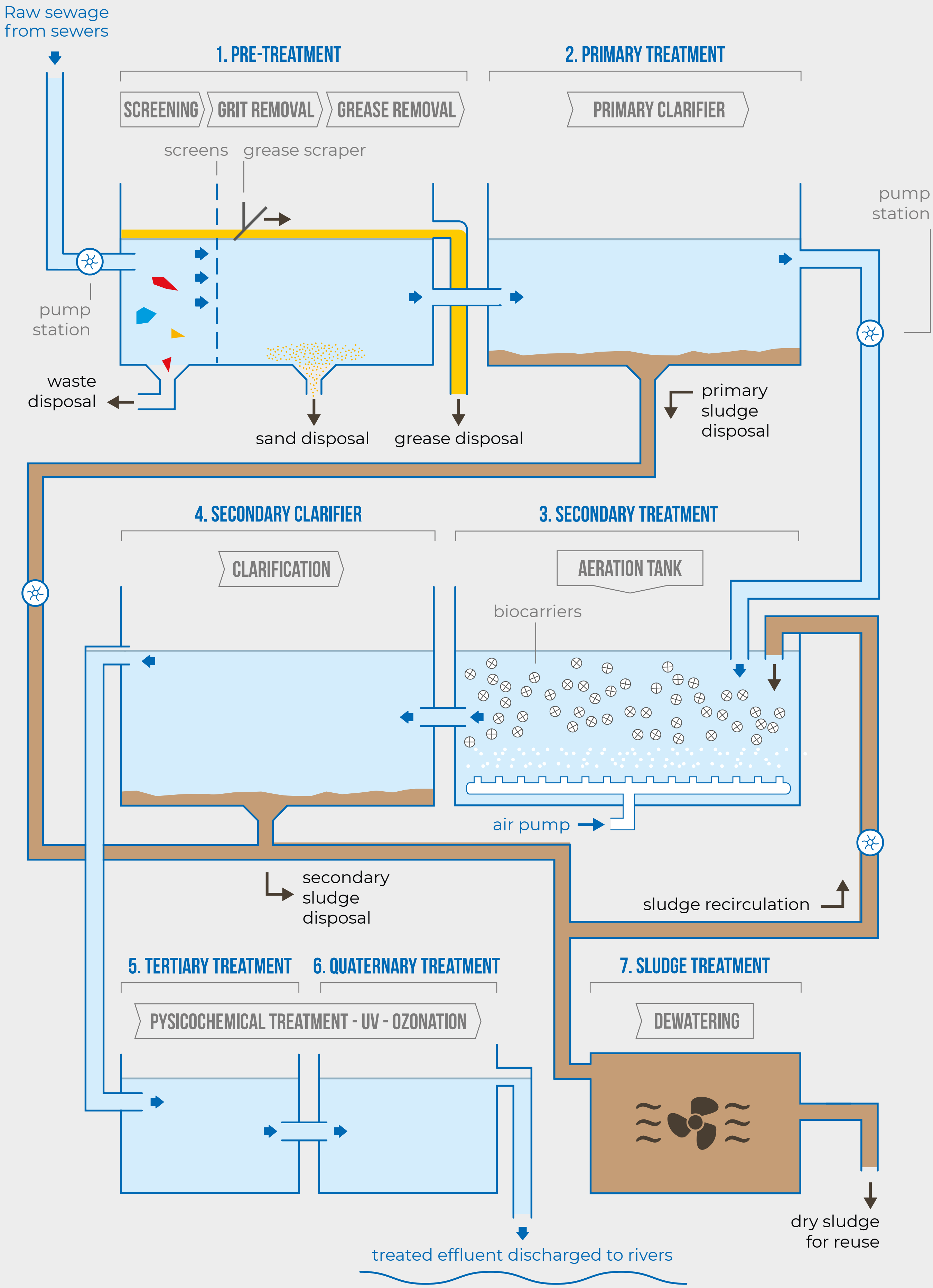
In fixed bed culture processes, the microorganisms (bacteria) used to break down the organic matter are grown on many types of carriers to create biofilms. Bacterial activity is highly dependent on the surface area between the biofilm and the effluent. The higher the surface area, the greater the treatment capacity. This surface area is generally indicated in m^2 of colonised surface / m^3 of support[7]. The carriers provided for the growth of microbial biomass (multicellular community) mean a higher number of cells can develop, thereby increasing the purification capacity of the installation. Fixed bacteria are usually more active than those in free cultures because of the protection provided by the supporting media. There are several solutions for optimising the surface of exchange between the biofilm and effluents, such as trickle filters, rotating biological contactors, biological filters, fluidised fixed bed reactors and mixed solutions.

Biomedia are used in fluidised fixed bed reactors *(see Chapter 3)*.

Figure 10 | ***Below*** | *Basin at České Budějovice, Czech Republic. © Martin Kníže*

Figure 11 | ***Right page*** | *Stages of a wastewater treatment plant. © Surfrider Foundation Europe*

Notes | ***7.*** *In activated sludge processes, the purifying micro-organisms are in a flocculated state (agglomerated in the form of flocs), reducing the exchange surface and therefore its efficiency.*



Raw sewage from sewers
1. PRE-TREATMENT
SCREENING
GRIT REMOVAL
GREASE REMOVAL
screens
grease scraper
pump station
waste disposal
sand disposal
grease disposal
2. PRIMARY TREATMENT
PRIMARY CLARIFIER
pump station
primary sludge disposal
4. SECONDARY CLARIFIER
CLARIFICATION
3. SECONDARY TREATMENT
AERATION TANK
biocarriers
air pump
secondary sludge disposal
sludge recirculation
5. TERTIARY TREATMENT
6. QUATERNARY TREATMENT
PYSICOCHEMICAL TREATMENT - UV - OZONATION
7. SLUDGE TREATMENT
DEWATERING
dry sludge for reuse
treated effluent discharged to rivers

3 FOCUS ON FLUIDISED BED INSTALLATIONS

Biological treatment using fluidised bed bioreactors has heralded a technological and economic revolution in the world of wastewater treatment. This process revolves around the use of biomedia, and here we look at the reasons for its development.

3.1 HISTORY

The MBBR (Moving Bed Biofilm Reactor), or fluidised bed system, was developed in 1989 by the Norwegian University of Science and Technology in Trondheim (NTNU) and the Foundation for Scientific and Industrial Research (SINTEF), commissioned by the company Kaldnes (Kaldnes Miljø-Teknologi - KMT).

The aim of this project was to create smaller treatment units and bioreactors that could more effectively treat the nitrogen load in wastewater. The weather conditions and extremely cold winters in Norway mean wastewater treatment plants there are generally covered, and so need to be more compact. Meanwhile, new, and stricter legislation was coming into force at the European level, requiring that many wastewater treatment structures be upgraded. Specialist wastewater treatment R&D company Anox AB adopted this procedure and developed it for different industrial sectors, such as the paper industry. The two companies quickly became market leaders in the field of high-performance biological wastewater treatment.

__Figure 12__ | __Above__ | Different models of biocarriers collected on a beach. © Surfrider Foundation Europe

In 2000, Anox AB and Kaldnes signed a cooperation agreement, which led to Kaldnes being bought by Anox two years later. Since 2007, AnoxKaldnes™ has been part of Veolia Water Solutions & Technologies, a subsidiary of Veolia Water. The benefits offered by this technology meant it was rapidly sold all over Europe, followed by worldwide success.

Today, many companies have developed their own moving bed biofilm reactor technologies, giving rise to a wide range of names, such as MBBR, R3F® and FBBR (Fluidized Bed Bio Reactor), to name just a few of the most recent additions.

3.2 PRINCIPLES

The aim of fluidised bed bioreactor systems is to provide the bacteria with an environment that will allow them to develop optimally in a compact space, in order to break down the pollutants in the water. This optimisation depends on two major factors – the carriers upon which the bacteria can develop, and access to nutrients.

The support is provided by the biomedia, which are made of plastic, either polyethylene (PE) or high-density polyethylene (HDPE). These are added to the biological treatment basins at a rate of 30 to 70% of the volume of the basin. This means there are hundreds of thousands or even millions of pieces of plastic in each reactor. Their honeycombed, colonisable structure and their density, which is similar to that of water (1 g/cm^3), make it easy to keep them moving within the tank.

This movement should be uniform, to ensure an optimal level of contact between the microorganisms and the effluent to be treated (nutrients). This process depends upon the type of support chosen and the rate at which the treatment basins are refilled.

Biomedia can be used in different phases of the biological treatment process – pretreatment, secondary treatment, and even in combination with activated sludge. This flexibility means this system can be a very attractive option for new wastewater treatment plants. Fluidised bed technology can also be implemented during renovations of older wastewater treatment plants, in stations with highly variable seasonal loads (tourism or agricultural areas), or in cold climates (mountains/ Nordic countries).

This makes it possible to increase plants' treatment capacity without the need to build any new basins – an approach that is often heavily driven by financial or space constraints. The parameters used to calculate the volume of biomedia needed for water treatment are incoming flow, discharge flow, and effluent temperature. Optimal performance of wastewater treatment infrastructure is therefore heavily dependent on this calculation, which impacts the whole plant's performance and ability to achieve its objectives .

3.3 ADVANTAGES

Both the scientific literature and our interviews with wastewater treatment specialists have underscored the many advantages of using the moving bed biofilm reactor system, with the following list highlighting just some of them.

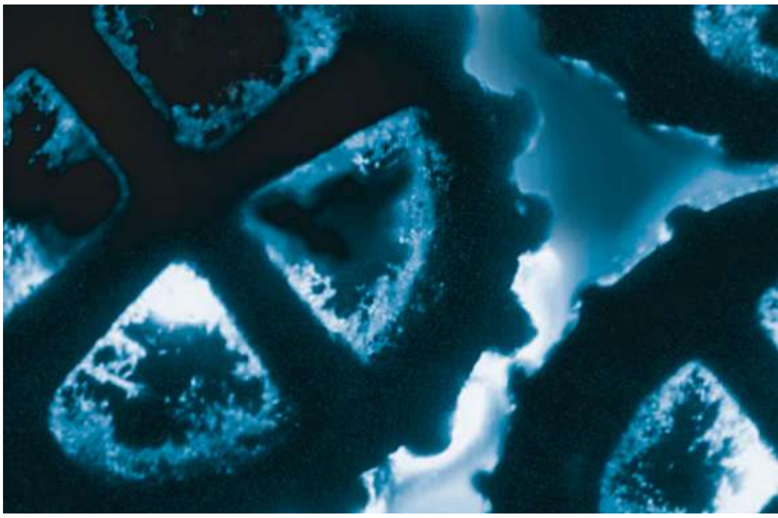
ADAPTABILITY

Moving bed biofilm reactors are very flexible because of their stable reaction to fluctuating influent concentrations. This means they can be adapted as required by varying the amount of biomedia depending on the load to be treated. The procedure enables rapid adaptation to seasonal variations in pollutant loads (BOD and COD) resulting, for example, from certain agricultural activities or the tourist.

HIGH CONCENTRATION OF AVAILABLE BIOMASS

The shape of the biomedia provides very good living conditions for bacteria, with a substantial surface for colonisation of between 200 and 1200 m^2/m^3, depending on the model. Living within this structure, the bacteria are protected from abrasion caused by the plastic pieces moving around inside the reactor. The large volume of biomedia placed in the tanks therefore enables the development of a very large concentration of biomass[8].

__Figure 13__ | __Below__ | Microscopic view of bacterial colonisation of biomedia



Notes | ***8.*** *Nicolella et al, 2000 ; Venu Vinod, 2005; Kargi, 1997.*

LENGTHY BIOMASS SURVIVAL TIME

The biomass remains in place for a long time, up to several weeks, which means a high concentration of nitrifying bacteria can be attained despite their slow growth rate and regardless of the influent rate[7].

IMPROVED MASS TRANSFER

The continuous agitation of the biomedia in the reactor enables the biofilm to remain in contact with the organic matter, thereby ensuring there are no areas of stagnation which reduce the rate of exchange. The high concentration of biomass and the large surface area of biofilm both contribute to improved contact between the different phases[10].

REDUCED WATER RETENTION TIME

This process is generally characterised by a retention time in the aeration tank of between 4 and 6 hours – compared with 8 to 50 hours in the case of activated sludge treatment[11].

EASE OF CLEANING

The media can be agitated either by aeration or the water can be moved with the help of rotors to ensure continuous mixing of the media. This agitation means there is no need to wash the supports, unlike in fixed bed processes using pozzolana or zeolite, in which the beds become clogged, leading to reduced capacity, poor mixing and lowered oxygen transfer. The dead bacteria fall away when the biomedia bump into each other. This results in a layer of sludge forming on the surface, which can be easily removed[12]. This 'self-cleaning' phenomenon means there is no need for secondary reactors to be used while the unit is being cleaned.

A COMPACT PROCEDURE

Plants using fluidised bed technology have a footprint 10 to 50% smaller than classic activated sludge systems with an equivalent capacity. This is because processes using moving beds do not need large aeration tanks.

The combination of these factors means fluidised beds are very easy to use, with better treatment capacity and lower construction costs than classic activated sludge systems. These many advantages help explain the widespread adoption of the process around the world.

3.4 LIMITATIONS AND DISADVANTAGES

While this process has some clear advantages, it also has inherent risks and constraints:

POOR BACTERIAL ACTIVITY AT LOW TEMPERATURES (<5°C)

The bacteria in the reactors are virtually inactive at temperatures below 5°C. The effectiveness of the process, whatever the type of wastewater treatment plant, is thus highly dependent on temperature and so subject to variations from season to season. Some plants, for example, in Norway or mountainous areas, are kept under cover to reduce these fluctuations.

AN ENERGY-HUNGRY AND COSTLY PROCESS

Energy consumption is an indirect environmental impact of the wastewater treatment process. The large volumes of biomedia used in this process must be kept in continuous movement through aeration or mechanical mixing, requiring significant energy usage and leading to non-negligible operation costs. This cost is even higher if the process is not functioning in an optimal manner[13].

The energy required to aerate the basins at an activated sludge plant accounts for 40 to 80% of the plant's total consumption.

If agitation is poor, the biomedia flow with the current and eventually end up clogging the effluent mesh, causing malfunctions. It is therefore of utmost importance that the tanks are kept sufficiently agitated, which requires considerable energy consumption.

This energy expenditure means plant developers are currently studying options to reduce the energy consumption of their processes.

SLOW COLONISATION OF BIOMEDIA BY BACTERIAL BIOFILMS

The slow colonisation of individual biomedia means the process requires an extended start-up time[14]. It is difficult to monitor the thickness of the biofilm, which is essential for the good functioning of the reactor, given the high volume of biocarriers and microscopic size of the bacteria. Moreover, a reduc-

Notes | ***9.*** *Nicolella, 2000.* ***Notes*** | ***10.*** *Nicolella & al, 2000; Jianping et al, 2003; Vinod & Reddy, 2005* ***Notes*** | ***11.*** *Kargi et Karapinar, 1997; Jianping et al, 2003.* ***Notes*** | ***12*** *Kargi & Karapinar, 1997* ***Notes*** | ***13.*** *Perret & Canler, 2012* ***Notes*** | ***14.*** *Nicolella et al., 2000* tion in effectiveness is observed when biomedia carry an excessive biofilm load, which obstructs their structural features and alters their density.

ACUTE OR DIFFUSE BIOMEDIA LOSS

The numerous incidents recorded across Europe *(see Chapter 7)* reveal the system's vulnerability when preventive and retention measures were inadequately applied. Depending on the amounts lost, the overall environmental impact can be disastrous.

Once in the environment, biomedia can be ingested by marine animals, increasing mortality rates and causing long-lasting harm to ecosystems. Biomedia have notably been found in the stomach contents of the northern fulmar[15] and loggerhead turtle, protected species used as indicators for marine litter in monitoring programs.

Whether biomedia losses occur acutely (in large amounts due to an exceptional accident) or diffusely (in small amounts, regularly), it constitutes yet another form of plastic pollution in the environment.

Biomedia loss also has financial implications, given that biomedia cost an estimated €500 per m³. Incidents could involve the loss of anything from a few thousand pieces up to several million, and so are not something that operators want to happen. Clean-up costs after an accidental spill can also be at their expense, as has been the case in France on the Gervanne River (Font Rome fish farm) or in Denmark (Atlantic Sapphire) *(see Chapter 7)*.

As we have seen, this technology offers some major benefits in terms of compact footprint, ease of use and construction costs. However, it also uses high amounts of energy, with consumption up to "50% higher than conventional activated sludge systems", as stated in a report by the agency responsible for ensuring French drinking water supplies (FNDAE). The other major disadvantage is the high risk of biomedia losses in the environment during WWTP operation. Operational parameters must be tightly controlled, and optimal functioning of the systems requires an adaptational period with expert support.
The shape of biomedia, bacterial colonisation, their concentration in tanks, and how they are mixed are the subjects of continuous innovation on behalf of various constructors.

Figure 14 *|* ***Below*** *| Biobeads on a beach in Cornwall in 2015 following heavy rain. © Rob Wells*

Notes | ***15.*** *Van Franeker, 2022.*

3.5 OTHER BACTERIAL CARRIERS

Besides the biocarriers mentioned in this report, numerous other types of physical support for bacterial proliferation used in wastewater treatment can cause pollution in the marine environment.

3.5.1 BIOBEADS

Plastic beads called "biobeads" resembling pre production plastic pellets regularly wash up on coasts in Cornwall (England), French coastlines of the English Channel, Belgium, and the Netherlands.[16]
These biobeads measure from 3.5 to 4 mm and are made of polyethylene (for the most part recycled). Unlike industrial plastic granules with a smooth and uniform shapes, biobeads are cylindrical but irregular in shape with ripples. Most biobeads found on beaches are black, however, they may also be blue, white, grey, green, or purple, for example.

Biobeads, or "BAFF (biological aerated flooded filter) media" are used to filter wastewater in treatment plants using activated sludge systems. Their shape enables improved and increased colonisable surfaces by bacteria. According to research by the Cornish Plastic Pollution Coalition[17], in 2018, 46 municipal wastewater treatment plants used biobeads and the BAFF system in England.
Since the 90s, BAFF has been used widely in installations where there was a need to increase treatment capacity and limited space to build new infrastructures. Maintenance of this type of system is expensive and complicated.

Biobeads are poured into biological treatment tanks in large numbers. 3 mm mesh steel grids are installed above the reactors to prevent biobeads from escaping. According to Cornish Plastic Pollution Coalition estimations, each bioreactor could contain up to 5 billion plastic beads. The Plympton wastewater treatment plant (Plympton, England), with a capacity of 85000 population equivalent (8 reactors), uses 43 billion biobeads[18].

Like biomedia, these floating plastic granules can escape from treatment systems and pollute aquatic environments. Once in the environment and on beaches, it is nearly impossible to collect them because of their small size and close resemblance to natural sediment. Pollution can be considerable (several cubic meters lost) and spread over large areas in the marine environment. Like all other microplastics, biobeads have a substantial environmental impact.

In France, biobeads have been regularly reported since 2009 by the Robins des Bois association. They were found from Contentin, Bay of the Seine, to the Bay of the Somme and the Calais Strait by the NGO "SOS Mal de Seine" when mandated by the French Environmental Ministry to perform the initial evaluation of pollution by plastic pellets. No biobeads were observed upstream in coastal rivers. A large accumulation was reported to the south of Boulogne-sur-Mer where 1 litre of sand was found to contain 75 g of biobeads.

Dr Van Franeker, a specialist of the Fulmar, a seabird strongly impacted by microplastic pollution, has observed them from Belgium to the island of Texel in the Netherlands.

3.5.2 POLYSTYRENE BEADS

Another process, called BIOSTYR™ , created by Veolia Water Technology uses expanded polystyrene (EPS) beads to treat wastewater.

This process is currently in use in numerous wastewater treatment plants in Europe for both urban and industrial wastewater. The utilisation of this type of beads is worrying, as losses of EPS have been recorded at treatment plants, and the beads are regularly found on French Mediterranean coasts.

Just like biocarriers, precautions must be taken to retain biobeads and polystyrene beads in their tanks to prevent environmental losses.

Figure 15 *| Polystyrene (EPS) beads. © Veolia*

Notes *|* ***16.*** *Bio-Bead pollution on our Beaches,2018, Cornish plastic pollution coalition.* ***Notes*** *|* ***17.*** *Cornish plastic pollution coalition is a group of 30 environmental NGOs, groups of people, and scientists that regularly do beach clean-ups to fight plastic pollution in Cornwall.* ***Notes*** *|* ***18.*** *Turner et al., 2019.*

4 USERS

Fluidised beds are now widely used for the treatment of effluents in municipal and industrial WWTPs, for individual systems, and even industrial and agricultural applications.

4.1 MUNICIPAL WASTEWATER TREATMENT

If a dwelling is connected to the local sewage network, this becomes part of the municipal mains wastewater treatment system – which is the most common system in urban areas.

The European Environment Agency (EEA) reports that, in 2023, 90% of urban wastewater is collected and treated at the European level according to European standards. However, wastewater treatment varies widely across the EU. Only four countries, Austria, Germany, Luxembourg, and the Netherlands, treat 100% of their wastewater, whereas ten others have reached levels above 90% (Source: European Environment Agency)[19].

Other countries, like Ireland, Bulgaria, Romania, Croatia, and Malta, have a harder time attaining targets set by European regulations, with levels under 50%. In France, the agency in charge of wastewater treatment reports:

"In 2021, France had 22,113 wastewater treatment centres with 22,613 WWTPs representing a total load of 78.5 million population equivalents (PE) for a capacity of 105.5 million PE. There are 3,852 municipalities of 2,000+ PE with 4,055 WWTPs (some municipalities having several plants). They represent a pollution load of 74.3 million PE[20]."

Figure 16 | *Above* | *Wastewater treatment plant in the town of Folschviller.* **

Notes | ***19.*** *https://water.europa.eu/freshwater/countries/uwwt*
Notes | ***20.*** *https://assainissement.developpement-durable.gouv.fr/pages/data/actu.php*

BIOMEDIA-USING MUNICIPAL TREATMENT PLANTS IN EUROPE

Municipal wastewater treatment usually uses MBBR processes to increase the capacity of existing stations or reduce the footprint of newer installations while improving their capacity *(see Chapter 3.4)*. Municipalities or conurbations using this type of process vary in size from several thousand population equivalents to tens or hundreds of thousands of population equivalents.

There are biomedia-using WWTPs in at least 12 Member States of the European Union, as well as in Switzerland, Norway, and Iceland (member states of the European Environment Agency). However, it remains difficult to make an exhaustive listing of them, as there are no obligations to list the type of technology used in national WWTP databases.

In 2023, Surfrider Foundation Europe lists 147 municipal plants that use MBBR technology with biocarriers in Europe, including 40 in France and 62 in Sweden. The two States have been working with SFE to catalogue the municipal wastewater treatment plants on their territory as part of an OSPAR convention workgroup.

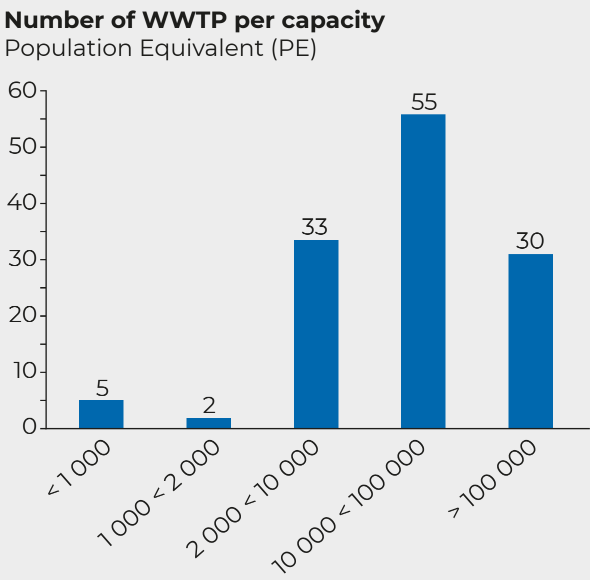


***Figure 17** | Known treatment plants using biomedia ranked by size, © Surfrider Foundation Europe.*

4.2 NON-MUNICIPAL WASTEWATER TREATMENT

Unlike mains wastewater systems, off-mains wastewater treatment, also called domestic or individual systems, are facilities that are not (directly) connected to the public network. In European legislations, this type of installation is called an IAS, for "Individual and other Appropriate Systems."

According to the UWWTD, urban settlements of 2,000 PE and above must collect and treat wastewater. Exceptionally, in urban areas and areas with low population densities, IAS can be used as alternatives when the installation of a collection network is not justifiable from a financial and/or environmental point of view and under the condition that the same level of treatment is reached as in surrounding urban areas[21].

This type of sanitation can be used in select scenarios:

- In urban areas > 2,000 PE (exceptions only).
- In urban areas < 2,000 PE with a collection network.
- In urban areas < 2,000 PE without a collection network.
- In small settlements and areas with low population densities
- For individual houses in rural areas

These independent facilities most often treat domestic effluents and are covered by specific regulation. They can treat volumes from dozens to several thousand PE and must be inspected regularly. In Europe, on average, less than 5% of wastewater from urban settlements is treated in non-municipal facilities.

There are many varieties of independent sanitation systems. The most frequent are compact stations that use biological treatment. Many companies on the market offer stations using MBBR technology. This type of installation is regulated and must meet national and European standards.

The development of off-main sanitation has enabled improvements in environmental quality in areas where collective networks would have been prohibitively expensive. However, there is a general lack of knowledge on how this equipment is

***Notes** | **21.** This Directive and its imposed limits are under revision at the time of writing.*

monitored and managed at the European level. In many cases, systems are prone to overflows and/or seeping due to inadequate use or maintenance[22].

Examples of off-main installations that use biomedia:

MICROPLANTS (1-50 PE)

Operating on the same principal as municipal wastewater treatment plants, they use biological systems for both primary and secondary treatment of effluent.

Among the various technologies, fluidised bed microplants use bacteria grown on physical carriers that move around in the tanks.

They are contained in concrete or plastic tanks, where the entire wastewater treatment processes take place. The tanks are divided up into compartments (settlement tank, reactor, clarifying tank) or sequential (one tank for each role). The biomedia inside these closed tanks are never replaced and are only cleaned in exceptional circumstances (to prevent any damage to the biofilm). The sludge is emptied out from the separate part of the settlement tank, so the biomedia are not affected during the process. It is essential for the biomedia to remain inside these microplants, and it seems very unlikely that they could escape except in the case of a major malfunction.

CONTAINERISED WASTEWATER PLANTS (50-1000 PE)

Containerised plants have been adapted from the processes used in microplants and are designed to meet similar needs, with treatment volumes of approximately 50 to 1000 PE. In order to cope with additional constraints in terms of the volumes to be treated or geographical isolation, these mobile treatment plants have been fitted inside shipping containers. These modulable and tough systems can be attached to different means of transport to be moved over long distances, making them easy to relocate. These containers use a variety of wastewater treatment techniques, adapted to the requirements of each situation. Fluidised bed systems also figure among the range of available solutions. These facilities are especially useful for temporary and mobile purposes (such as military or humanitarian operations), mining and oil industry work sites, construction sites, refugee camps, research stations, base camps on glaciers, in deserts and other places with extreme climates or in small spaces (ships).

***Figure 18** | **Top** | Installation of a micro purification Oxyfix® plant, ©Eloy Water (www.eloywater.fr)*
***Figure 19** | **Above** | Wastewaterbox containerised plant, ©Cohin environnement*

***Notes** | **22.** www.eureau.org/documents/drinking-water/briefing-note/5833-briefing-note-on-ias/file*

4.3 INDUSTRIAL WASTEWATER TREATMENT

Numerous industrial and agricultural activities generate wastewater, being water used in production processes, rinsing water for manufactured goods, workshop cleaning, raising livestock, etc. It is the industrial or agricultural operator's responsibility to provide suitable treatment equipment that meets European regulatory requirements.
Depending on the industry and type of effluents it produces, various sanitation systems can be used[23]:

· In-situ industrial wastewater treatment, if the wastewater generated contains high levels of pollutants requiring specific treatment and/or no nearby municipal network is available (A).

· Direct discharge into rivers if water quality is not adversely affected by the activity (B).

· Treatment by a public WWTP, if the industrial wastewater does not endanger the municipal wastewater treatment network. In rare cases, the wastewater can be further treated by an external, private WWTP (C).

When industrial wastewater flows into municipal collection networks, the effluent must be treated beforehand, to:

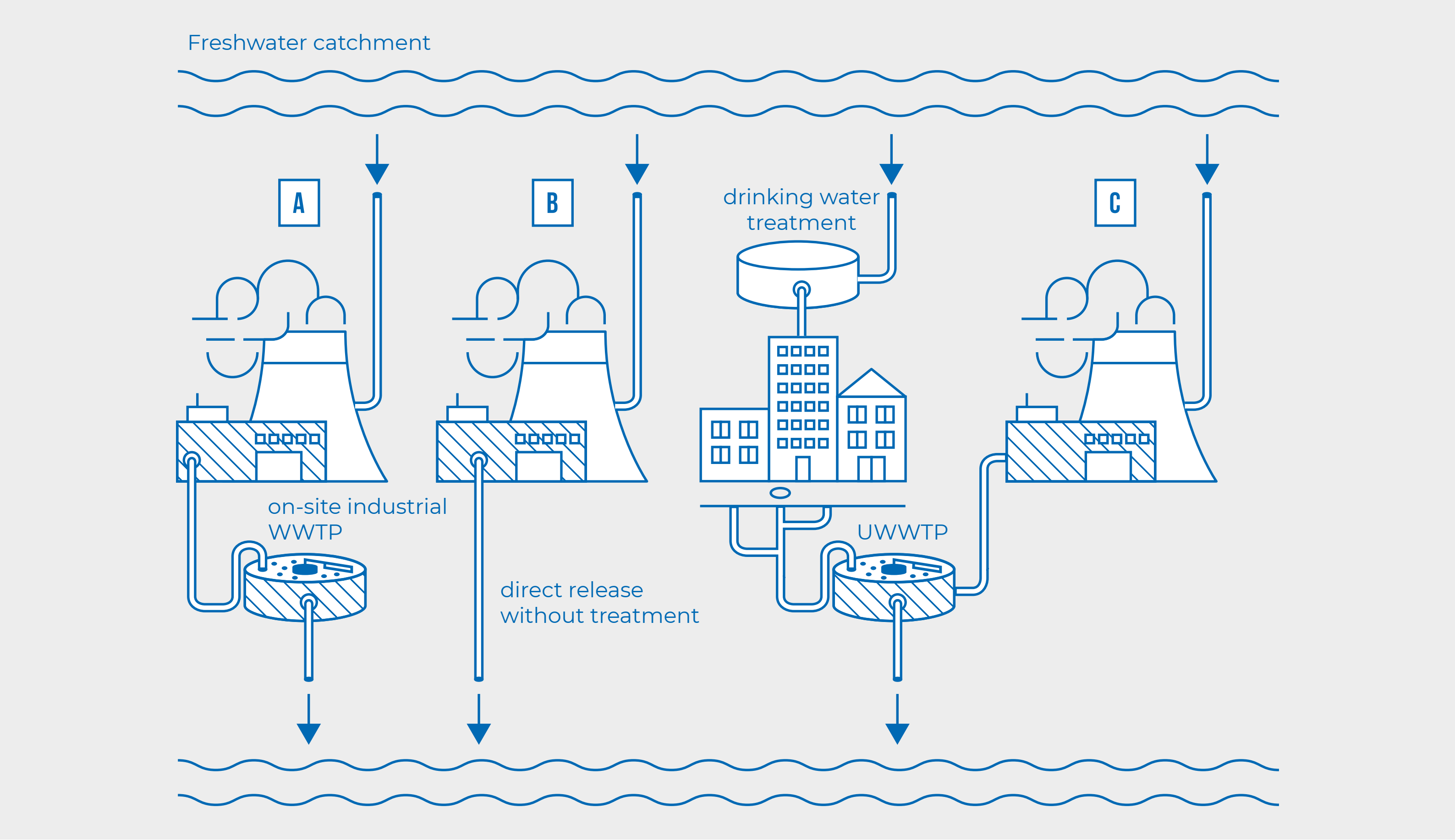
→ protect the health of employees working in collection networks and wastewater treatment plants,

→ ensure that collection networks, wastewater treatment plants, and equipment are not damaged,

→ avoid impairing the operation of the receiving wastewater treatment plant,

→ ensure that treatment plant discharges do not harm the environment or prevent receiving waters from complying with other Community directives,

Figure 20 | Illustration of the different types of industrial wastewater treatments (source: EEA)



Notes | 23. Industrial wastewater treatment – pressures on Europe's environment, 2018, EEA Report N°23

→ ensure the safe disposal of sludge in an environmentally acceptable manner.

DIFFERENT TYPES OF INDUSTRIAL EFFLUENT

Industrial wastewater is distinguishable from domestic effluent due to its higher and more uniform concentration of pollutants. Industrial and agricultural wastewater may contain high levels of heavy metals, pesticides, fertilizers, or other pollutants that are difficult to treat using municipal systems. In such cases, industrial effluent is not mixed with domestic wastewater until it is sufficiently treated to not compromise municipal collection networks or treatment systems.

Every industry has its own water usage and discharge patterns. The Industrial Emissions Directive *(see Chapter 1.4.3)* sets the Best Available Techniques (BATs) for each sector of activity. These are addressed in 32 BREFs (Best available techniques REFerence documents) covering 29 sectors of activity. These sector-specific documents aim to provide additional information to help reduce the impact of industrial activities on the environment (water, air, and soil).

Binding environmental protection obligations and the large volumes of water involved in processes are now driving companies to adopt methods to limit their water consumption and encourage its reuse.

In our observational work, we noted the biomedia usage for the treatment of industrial wastewater derived from the following activities:

· Pharmaceuticals and Hospitals

· Oil and gas extraction and processing

· Fish farming

· Food production (dairies, viticulture...)

· Paper production and transformation

· Leisure facilities

However, since no census has been made of the technologies used and the presence of biomedia in industrial wastewater treatment plants, it is virtually impossible to identify all the facilities that use them.

In France, more than 7,000 industrial sites classified as ICPE (Installations Classées pour la Protection de l'Environnement - Environmental Protection Priority Establishments) that could potentially be equipped with WWTPs are subject to the IED Directive.

NATURAL GAS AND PETROLEUM EXTRACTION WASTEWATER

As seen above, petroleum and natural gas production are among the industries that require wastewater treatment. New facilities using biomedia are being built to treat the water used for hydrocarbon extraction. These wastewater treatment facilities are installed directly on the seafloor next to drilling sights. The technology enables the treatment of high volumes of organic carbon as well as some chemical pollutants.

4.4 ONBOARD WASTEWATER TREATMENT

Cruise ships can, at times, have many thousands of passengers and crew on board, resulting in the production of large amounts of wastewater.
Over 120,000 litres of wastewater can require treatment each day in order to reduce a ship's environmental impact. Companies that specialise in wastewater treatment systems for ships and offshore activities have equipped some cruise ships with compact sewage treatment systems. These are specially designed to meet their requirements (limited space, large amounts of wastewater) using MBBR technology to optimise wastewater treatment performance. Examples of systems used include CleanSea® developed by Headworks and EcoOcean MBBR developed by Evac.

It is possible that biomedia could be lost from these kinds of systems, although this has never been directly observed.

4.5 UNREGULATED WASTEWATER TREATMENT SYSTEMS

Other domestic facilities operated by private individuals, such as swimming pools, natural lakes, and ornamental ponds also require regular water treatment. There are currently no discharge standards for this type of private amenity. Inspired by professional fish farms, many hobbyists use biomedia to filter the water in their ponds. This can be microplants purchased commercially, or home-made versions rigged up from plastic bins for example.
Unfortunately, the suppliers of these items often deliver them without any directions on how to use them, leaving the purchasers to work out how to install and use them on a trial-and-error basis.

5 SPREAD OF BIOMEDIA IN THE ENVIRONMENT

Biomedia spread through the environment if they escape from wastewater treatment plants, firstly through freshwater systems and then in the sea. Some of them will end up being washed up on the coast, sometimes thousands of kilometres from their source. To understand how they spread, it is essential to understand the environmental, weather, and water-related factors that interact with these items of floating debris.

5.1 LAND-BASED ORIGIN AND TRANSPORTATION IN WATERWAYS

Biomedia escaping water treatment plants can, like any exogenous element entering the environment, end up in the sea. They can be transported in freshwater systems over hundreds of kilometres from their point of discharge, just as a drop of water will also follow the same route through the water cycle. This also means they can be spread over vast distances along waterways.

Figure 21 | ***Above*** | *Biocarriers accumulated on river banks, Seine river France. © Renaud François*

THE UPSTREAM–DOWNSTREAM CONNECTION

An estimated 80% of the waste found on coastlines has a land-based source. The main vectors for the spread of pollution from inland areas to the oceans are rivers[24]. WWTPs generally discharge into water courses, and this is thus the principal means by which biomedia enter the environment. Rainfall impacts WWTP operations, water levels, and river flows. The ebb and flow between low and high water levels affects how a waterway transports the waste along its banks. When water levels rise significantly during heavy rains, this can remobilise waste, or lead to water reaching sensitive areas, for example from wastewater treatment plants or old rubbish dumps.

Once picked back up by the rivers, waste follows its route downstream. Estuaries mark an interface

Notes | **24.** *Jambeck et al., 2015 ; Gonzalez & Fernandez, 2021 ; Veiga et al., 2022* between the land and sea, and it is here, at river mouths, that waste reaches the oceans.

In many cases, it has been possible to identify the source of biomedia pollution by following it upriver or by inspecting rivers nearby polluted areas. Several cases of reported pollution *(see Chapter 7)* were possible to track upstream to identify sources of pollution:

· Seine River: Corbeil-Essonne WWTP

· Gervanne River: Font Rome fish farm at Beaufort-sur-Gervanne

· Serre-Poncon lake and Durance river: Vallouise-Pelvoux WWTP and Molines-en-Queyras / Saint Veran

5.2 BIOMEDIA TRANSPORT IN THE MARINE ENVIRONMENT

5.2.1 CURRENTS

The world's oceans are in a state of perpetual motion, due to the forces acting on water masses (winds, tides, Coriolis force) and their physicochemical properties.

Whether they are spilled at sea or entering the ocean through river systems, biomedia are carried on by surface currents. Once taken by these currents, they can be transported over several thousands of kilometres[25]. This is particularly true in the case of floating plastic waste, which faces few obstructions as it moves around in the marine environment.

5.2.2 STORMS

During storm events, it is frequent to observe large amounts of waste wash up on shorelines, pushed up by the wind or stirred up from the bottom by large swells.

In general, on the most exposed coasts (notably Western Atlantic coastlines), numerous biomedia are found after periods of stormy weather during beach clean-ups. The most recent example to date occurred in November 2023, near the Courant d'Huchet in the Landes department of France. After a period of storms, more than 40 individual biomedia of 8 different types were found in a single clean-up. Some were "endemic" models that had degraded only slightly, of the kind found on this coast for over ten years. These probably stem from old pollution events and are stirred up by stormy weather.

5.2.3 COMPUTER MODELLING FOR ENVIRONMENTAL CAUSES

Since 2015, Surfrider has partnered with oceanographic research institutes like the Mediterranean Institute of Oceanography (MIO) to improve understanding of biomedia dispersion at sea. Following pollution during the winter of 2019-2020 from the Bastia WWTP *(see Chapter 7)*, strandings of biomedia were reported on shorelines around much of the Western Mediterranean (France, Spain, Italy). Several questions arose:

→ How would it be possible to forecast sites where biomedia strandings might occur depending on weather conditions?

→ Is it possible to determine if biomedia washing ashore come from a predominant area?

→ How can massive arrivals of biomedia at sites close to the initial accident months after the event be explained?

Computer modelling produces simulations using large datasets, and it is possible to vary parameters according to numerous factors such as study sites, seasons (weather conditions), and intensity of particle emissions, for example. The models can be used to provide theoretical distributions to be compared with field observations performed throughout the year.

In an attempt to provide some initial answers to the above questions, backtracking simulations were carried out to identify the possible origins of strandings under different meteorological and seasonal conditions.

This study shows the relevance of such simulations, but the grids and choice of parameters to be varied must be improved for a more detailed analysis of dispersion patterns and stranding sites[26].

Notes | **25.** *Van Sebille et al., 2020, González-Fernández et al., 2020.* **Notes** | **26.** *Identification et corrélation des mesures de média filtrants avec des simulations numériques de transport, autour de la Corse. Elisa GRIMA*

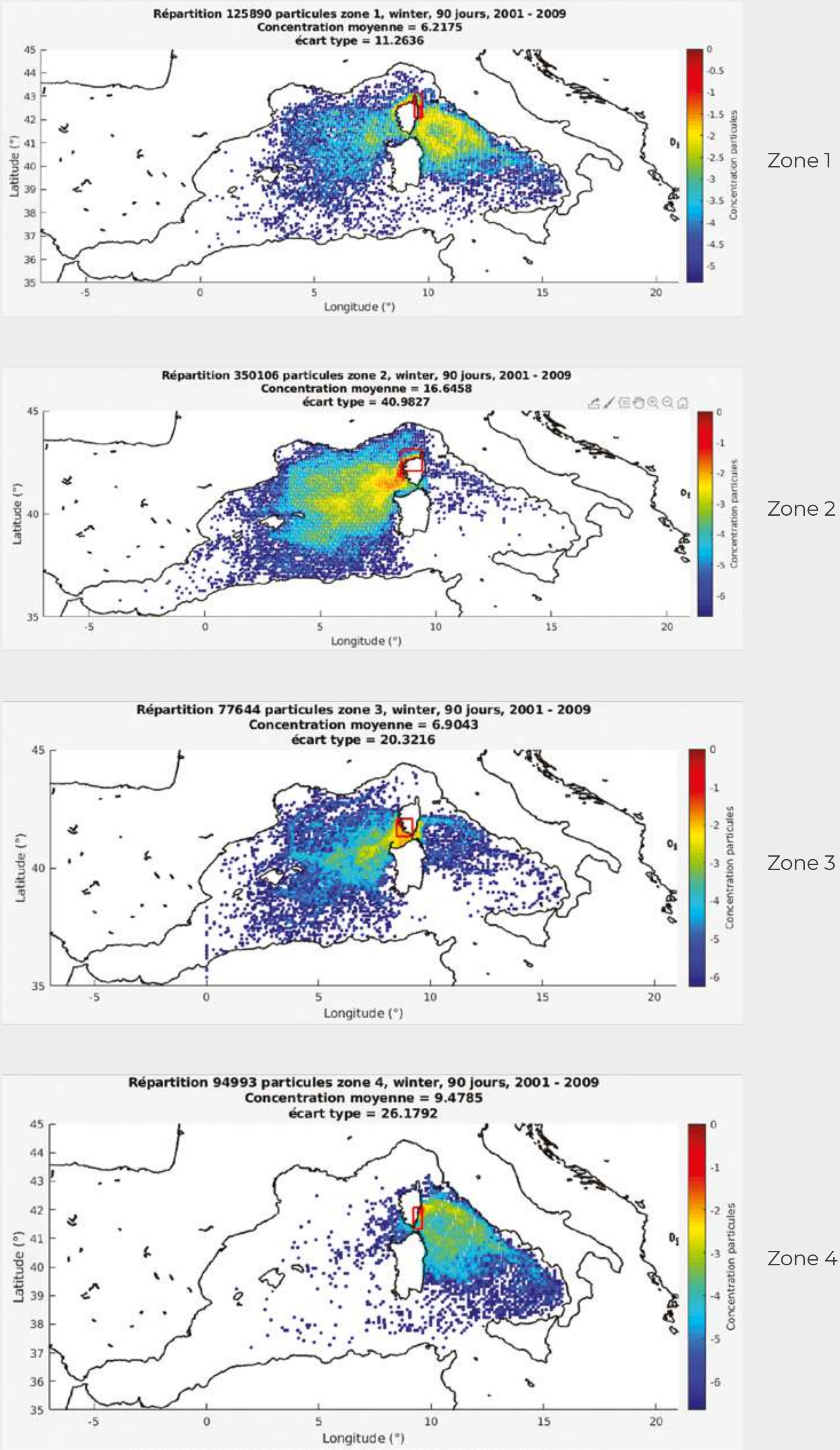


Figure 22* | *Above | *Possible origins of particles simulated over 3 winter months.Source: Elisa Grima, Université de Toulon - Mediterranean Institute of Oceanography (MIO)*

6 TRACKING OF BIOMEDIA POLLUTION

In 2009, a member of Surfrider Foundation Europe started to observe biomedia on the beaches of the French Basque Coast. Over the years, these plastic pieces started to turn up along all French and European coasts. Surfrider Foundation Europe has gained significant expertise and become the leading organisation working on this issue, thanks to its extensive network and the data collected by a network of external observers. Little by little, many data-collecting organisations have started to include the identification of biomedia in their protocols.

6.1 SURFRIDER'S MONITORING EFFORT

6.1.1 FIRST CITIZEN OBSERVATION

Biomedia were observed for the first time on the beaches of the French coast in 2009. Little was known about these small plastic wheels and what they were used for when the Surfrider volunteer group on the Basque coast started to report them. A few months later, the items were identified when a volunteer group visited a WWTP in Ajaccio, Corsica. The volunteers recognised the hitherto unidentified object, and by cross-checking, the link was established between water treatment stations and the little plastic wheels on beaches. Since then, many Surfrider volunteers and concerned citizens regularly report biomedia strandings across the entire European riverbanks and coastlines. Citizen observations are still one of the principal ways pollution events are reported. Surfrider's reputation and the ease of finding our educational material online means people quickly contact us when pollution occurs. Over the years, Surfrider has thus tried to standardise reporting.

***Figure 23** | **Above** | Biocarriers found on a beach in Corsica, France, 2018, © Mare Vivu*

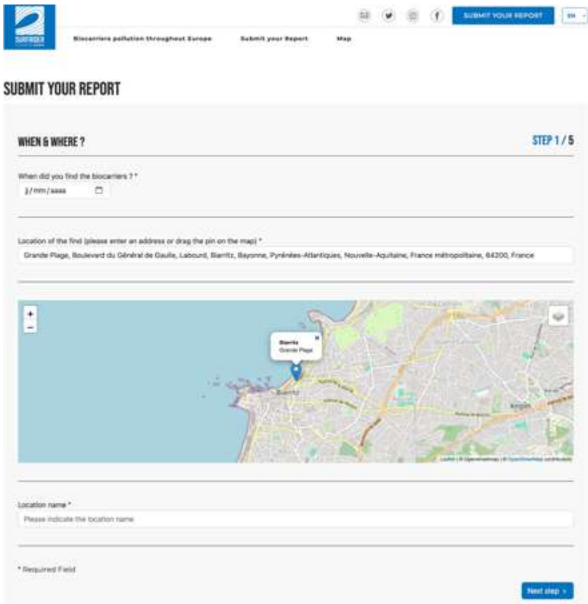


Figure 24 | Above | Extract from the Surfrider's biomedia pollution reporting website

We offer several tools to do so:

→ An online survey was created to enable easier citizen reporting of biomedia findings.

→ A guide categorising the types of biomedia found in the environment was also created to make the identification of biomedia easier. More than 30 models are represented. This identification guide, available in French, English, and Spanish, was included in the Ocean Initiative identification forms *(see 6.1.2.)* and distributed to other organisations

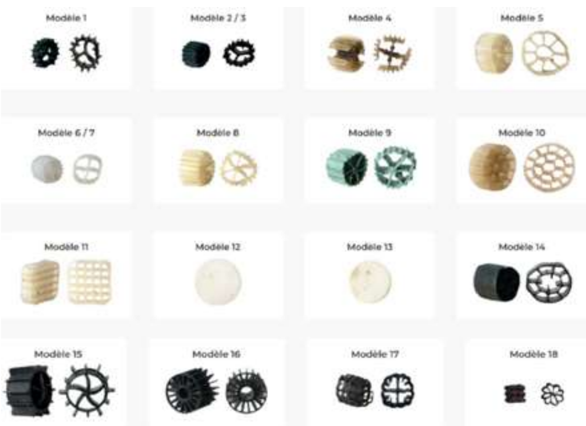


Figure 25 | Above | List of biomedia types, © Surfrider Foundation Europe

collecting data on marine litter across Europe.

6.1.2 OCEAN INITIATIVES

For over 30 years, Surfrider Foundation Europe has been developing the Ocean Initiatives programme, which aims to reduce marine litter and plastic pollution at the source by raising awareness and cleaning up waste in lakes, rivers, beaches and on the seabed. This Europe-wide programme allows us to gather essential information on plastic pollution using a participative science protocol. The organisers of these clean-ups are asked to categorise and count what they collect. Surfrider consolidates all

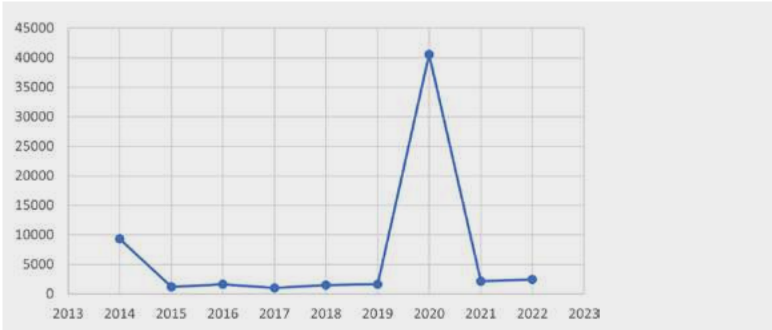


Figure 26 | Above | Number of biomedia reported during Ocean Initiatives, © Surfrider Foundation Europe.

these data, which are later shared and distributed to the wider public, media and public authorities[27]. Since 2013, Ocean Initiatives has included a specific section for reporting biomedia pollution stating the type, number, and density of biomedia found in aquatic environments, by means of an identification card.

It is primarily thanks to this standardised observation method and the wide network of Surfrider volunteers that we have been able to carry out this study. This constant monitoring is the primary means of discovering cases of pollution.

In 2023, out of 496 litter identification forms, 145 indicated the presence of biomedia. Almost one in three.

6.1.3 SCIENTIFIC QUANTIFICATION PROTOCOLS - OSPAR/MSFD

Stopping the proliferation of marine litter in the oceans requires a better understanding of the issue at a global level. National and European workgroups, assembling a wide variety of organisations

***Notes** | **27.** www.initiativesoceanes.org* collecting data on marine litter, are currently working to standardise protocols.

The European standard protocol is the "OSPAR/MSFD protocol for harmonised European guidance on monitoring of marine litter," which aims to identify and quantify marine litter washing up on beaches. The categorising of waste by type also enables the identification of the human activities at the root of the problem.

→ Since 2012, Surfrider has been a part of the "Réseau National de Surveillance des Macrodéchets sur le Littoral" (national OSPAR/MSFD beach litter monitoring network) in France and applies the OSPAR/MSFD protocol at 7 study sites on the Atlantic coast (in France and Spain). This helps gather data on litter washed up on coastlines on a European level, and to improve the foundations of common knowledge. In France, our study area includes the Maison des Douaniers Beach at Gefosse-Fontenay, Déolen in Locmaria-Plouzané, and Champs de Tir in Tarnos. In Spain, the beaches of Getxo, Mutriku, Donostia, and Getaria are are also monitored by Surfrider as part of the national monitoring program.

→ Starting in 2024, the same protocol will be followed in French overseas territories.

The waste is quantified and identified using a master list of more than 250 items categorised by material type and usage. The master list is updatable – if a type of waste is regularly found on a beach that is not listed on the datasheet, it can be included in later versions once approved by the relevant authorities. This system makes it possible to detect new types of waste being found on beaches. In this manner, biomedia were included on the OSPAR/MSFD protocol master list thanks to the identification and quantification work spearheaded by Surfrider. However, the litter identification data form chart does not enable reporting by model type[28].

This inclusion on the master list has helped collect standardised data from over 70 sites in Europe.

6.2 OTHER FORMS OF MONITORING

After various biomedia pollution reports and massive, concentrated strandings, "off protocol" observations were added to the data from the usual networks. Most of the time, these are independent organisations or local authorities that have taken action locally and alerted Surfrider.

These different sources of information have helped monitor the evolution of pollution events along rivers and European coasts. It has helped identify new sources of discharges in the environment and has improved data sets of ongoing studies.

6.2.1 ENGLISH CHANNEL OBSERVATION NETWORK

SOS MAL DE SEINE

SOS Mal de Seine has been conducting clean-ups along the banks of the river Seine since 2008, following the OSPAR protocol, which includes biomedia. The group monitored pollution from the river out to Normandy beaches after thousands of biomedia were lost into the Seine from the Corbeil Essonnes-Evry WWTP in 2010.

6.2.2 NORTH SEA OBSERVATION NETWORK

RINGKØBING-SKJERN (RKSK)

The community of Ringkøbing-Skjern was particularly active when, in March 2021, the neighbouring fjord was polluted by millions of biomedia. Numerous initiatives were undertaken, such as the publication of a dedicated website, the assembly of groups to speed up clean-up efforts, and news articles. During our investigations, the employees in charge of monitoring the pollution shared all the data collected. Some of their initiatives were also included in our good practice guide. *(Cf. Chapter 7).*

6.2.3 MEDITERRANEAN SEA OBSERVATION NETWORK

MARE VIVU

Since 2016, the Corsican organisation "Mare Vivu", specialised in Mediterranean plastic pollution, incorporated biomedia monitoring into its scientific monitoring programme. Their presence in the field makes it possible to rapidly raise the alarm in case of problems. In February 2020, incidents at Bastia Sud wastewater treatment plant led to the spillage of millions of biomedia into the sea. Upon the first signs of biomedia washing up on the beach of

__Notes__ | __28.__ The "master list" is the list of types of litter the most frequently found on beaches. It is developed and updated by the Technical Subgroup on Marine Litter and thanks to observations and results obtained on the field during surveys.

La Marana, they activated their local network, gathered 40,000 individual pieces, and warned the Bastia municipal government. Now, three years later, their monitoring efforts have enabled a detailed examination of the pollution's lasting effects.

CLEAN SEA LIFE
The LIFE programme, supported by the European Union and bringing together several Italian environmental protection groups like "Legambiente" played an important role in monitoring pollution caused by the Salerno wastewater treatment plant in 2018. Their efforts have enabled the mapping of the sites where the biomedia ended up, as well as the first legal proceedings for plastic (biomedia) pollution at sea in Italy. At the time of writing, the case is still in court.

OTHERS
· Port-Cros National Park (France)

· Camargue Nature Park (France)

· CESTMed (Mediterranean Seaturtle Study and Conservation Center) at Grau-du-Roi

· The Environment and Biology Commission of the Interregional Pyrenees-Mediterranean Committee of the Fédération Française d'études et de Sports Sous-Marins (French federation of underwater studies and sports)

· U Marinu CPIE Bastia Golo Méditerranée in Bastia

· Tragsatec

· Clean My Calanques

6.2.4 ATLANTIC OBSERVATION NETWORK

RIO MIÑO ENVIRONMENTAL GROUPS
Several organisations (Rio Miño fisheries association and ADEGA environmental association) alerted us to the presence of biomedia on the banks of the Rio Miño, on the border between Spain (Galicia) and Portugal. They have helped us in our investigations to pinpoint the sources of this pollution. Meanwhile, the conservation organisation ANABAM (Asociacion NAturalista del BAixo Miño) has conducted regular monitoring of this pollution event along the river and its impact on beaches. Acting as a regional relay, they attracted media coverage and contacted the local government in an attempt to identify the wastewater treatment plant that had spilt the biomedia into the river.

6.2.5 RIVERINE OBSERVATION NETWORK

CERTIFIED FISHING ASSOCIATIONS
The French Associations Agréées de Pêche et de Protection des Milieux Aquatiques (AAPPMA, Certified Fishing and Aquatic Environment Protection Associations) hold responsibility over riverbanks, waterways, and fishing resources in their areas, among others. Their members are fishers who know the environment well and spend many hours in it. They regularly share their observations with us. Several of them have raised the alarm about biomedia in rivers:

· The AAPPMA of the Nive River based out of Saint Jean Pied de Port, which monitors pollution in the Nive.

· The AAPPMA of the Gervanne River that became a part of the sharing of information following a pollution event caused by an incident in a fish farm[29].

(LPO) LIGUE POUR LA PROTECTION DES OISEAUX (BIRD PROTECTION LEAGUE)
In 2018, the Provence-Alpes-Côte d'Azur LPO, through its local Ecrin-Embrunais branch, was alarmed by a massive occurrence of biomedia in the Serre-Ponçon Lake caused by the WWTP of the towns of Vallouise and Molines-en-Queyras in its watershed. Since the beginning of their initiative, almost 100,000 individual biomedia have been collected. The members of the LPO also addressed the issue with the operators and government services in charge of monitoring the plants and pollution to ensure that necessary measures were being taken.

6.3 MAP OF OBSERVATIONS

Surfrider has developed an interactive map to visualise all reports of biomedia to us since 2014. While the map cannot be exhaustive using this data, it does give a good idea of the extent of this type of pollution. These observations have allowed us to show that this pollution now affects all European coastlines, that its dispersion in the ocean is rapid, and that it is becoming a worldwide problem[30].

Figure 27 | *Opposite* | *Location of biomedia observed in the environment, © Surfrider Foundation Europe*

Notes | ***29.*** *https://aappmagervanne.wordpress.com.* ***Notes*** | ***30.*** *https://biomedia.surfrider.eu/en/map*


Norge
Sverige
Suomi / Finland
Føroyar
Bergen
Oslo
Göteborg
Turku
Helsinki
Tallinn
Eesti
Latvija
Lietuva
Vilnius
København
Edinburgh
United Kingdom
Newcastle upon Tyne
Great Britain
Belfast
Isle of Man
Leeds
Éire / Ireland
Manchester
Sheffield
Birmingham
Cardiff
London
Guernsey
Lille
België / Belgique / Belgien
Luxembourg
Düsseldorf
Groningen
Hamburg
Berlin
Szczecin
Gdańsk
Bydgoszcz
Poznań
Warszawa
Polska
Magdeburg
Deutschland
Frankfurt am Main
Dresden
Wrocław
Kraków
Lublin
Nürnberg
Česko
Stuttgart
München
Linz
Wien
Österreich
Slovensko
Magyarország
Graz
Slovenija
France
Schweiz/ Suisse/Svizzera/ Svizra
Venezia
Torino
Genova
Bologna
Monaco
Hrvatska
Sarajevo
Србија
Timișoara
Cluj-Napoca
România
Craiova
Moldova
Oviedo / Uviéu
Vitoria
Andorra la Vella
Madrid
España
València
Portugal
Lisboa
Sevilla
Málaga
Gibraltar
Roma
Italia
Bari
Palermo
Malta
Constantine
Ελλάς
Αθήνα
Istanbul
Bursa
Izmir
Aydın
Leaflet | © Openstreetmap | © OpenStreetM
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7 BIOMEDIA POLLUTION

As reported in previous chapters, since 2009, there have been numerous cases of biomedia pollution along broad stretches of rivers and European coasts. Follow-up investigative work to identify its source has been conducted at some of the worst-affected sites. The list below is non-exhaustive but covers a large area and reflects the circumstances in which this type of pollution most commonly occurs.

A dozen instances of pollution occurring between 2010 and 2018 were documented in our report on biomedia published in 2018-2019. We will not cover those cases again, but you can consult the report on Surfrider's website: https://tinyurl.com/3x3mu9fa

In this new edition, we will present further cases illustrating the circumstances behind biomedia spillage affecting European coast-lines over the past five years.

Figure 28 | Above | Biocarriers collected on the shore of Serre-Poncon Lake, France, 2021. ©JP Coulomb

7.1 PRINCIPAL CASES (2019-2023)

7.1.1 HVIDE SAND – RINGKØBING-SKJERN (RKSK)

GENERAL INFORMATION
LOCATION: Denmark, Hvide Sand / Ringkøbing-Skjern
ACTIVITY TYPE: Fish farm, Atlantic Sapphire (salmon)
DISCHARGE LOCATION: Ringkøbing Fjord
DATE OF THE POLLUTION EVENT: March 2021

OBSERVATIONS

In March 2021, almost one million individual pieces of plastic biomedia were spilt into the Ringkobing Fjord. The biomedia were found all over the fjord and along the coastlines of the Baltic Sea at Hvide Sand. From there, they spread up the west coast of Sweden.

BIOMEDIA FOUND

RK Bioelements

DESCRIPTION OF THE INCIDENT

The fish farm was using a MBBR system to treat its wastewater. The discharge outlet for treated water was slightly above the surface of Ringkøbing fjord. A net had been installed at the outlet to contain biomedia that might escape in the event of an incident. One of the MBBRs was being repaired following an issue with its bottom plate. While the operation was underway, the large amount of biomedia in the tank blocked water flow, causing overflowing and the biomedia to escape. An investigation at the site showed that the retaining net was not in place when the problem occurred. During the winter, an accumulation of snow, combined with freeze and thaw cycles had weakened the net, and it had ended up tearing off. No one noticed it happening, as checking the retaining system was not part of routine monitoring. In turn, the absence of the net allowed the biomedia to spill into the fjord during the maintenance of the tank.

MEASURES IMPLEMENTED

Following the spill, Atlantic Sapphire (who did not comment about the incident) hired eight people to help clean the shorelines. They also contacted local authorities and the NGO's OMHU and CARE, who organised clean-up efforts on the coast.
The RKSK government did not lodge an official complaint. The company was required to submit a plan for cleaning up the biomedia, as well as implementing measures to prevent future issues. The collaboration between the fish farm and the other actors, transparency concerning the incidents, and the implication of the company in finding solutions and improvements were essential in resolving the issue. The local government also published a website to map the spread of the pollution and guide clean-up operations.

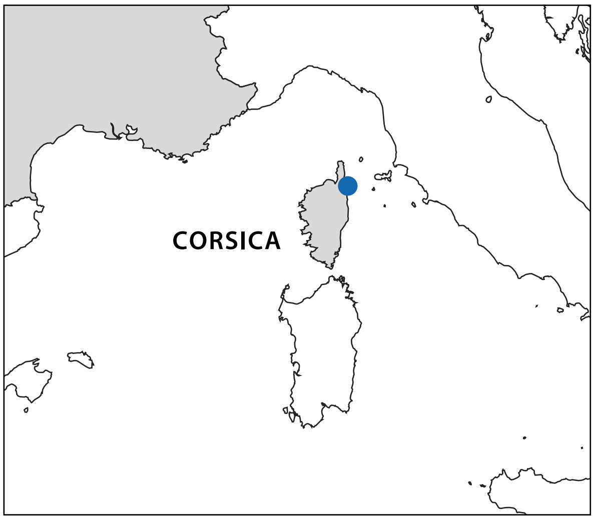
TECHNICAL IMPROVEMENTS:

→ Installation of grilles at the drain inlet.
→ Replacement and strengthening of the damaged net.
→ Daily monitoring of the grilles and nets to detect leaks and check their condition.

The study revealed that similar spills had also occurred in 2018 and 2019, with no communication on behalf of the fish farm.

Figure 29 | *Above* | *RK Bioelements from Atlantic Sapphire WWTP, © RKSK*

Figure 30 | *Above* | *RK Bioelements stranded on the beach after Atlantic Sapphire's pollution, © RKSK*



7.1.2 CORSICA (FRANCE), BASTIA

GENERAL INFORMATION
LOCATION: Bastia (Corsica, France)
ACTIVITY TYPE: South Bastia municipal WWTP
NOMINAL CAPACITY: 124,000 PE
DISCHARGE LOCATION: Mediterranean Sea
DATE OF THE POLLUTION EVENT: December 2020

BIOMEDIA FOUND
Anox Kaldnes - K5

OBSERVATIONS
At the beginning of January 2021, Surfrider received numerous accounts of huge amounts of biomedia on the beaches of the Marana area (Bastia - Corsica - France). The NGO Mare Vivu took the issue in hand and alerted the local government and the press about the scale of the pollution and the need for action. At the beginning of February, a clean-up operation coordinated by Mare Vivu brought together around 100 people and resulted in the collection of several tens of thousands of biomedia. The pollution event was of a scale never before seen in France.

Shortly afterwards, Acqua Publica - Bastia Water Commission began cooperating and publishing the results of investigations of the cause of the pollution at the WWTP.

Because of the sheer amount of filter media that escaped into the sea, they quickly started to be found across extended stretches of the Corsican coast. Several weeks later, they began to appear on Mediterranean shores of Italy, France, and Spain. At the same time, CESTMed published reports of ingestion of the biomedia by loggerhead turtles.

DESCRIPTION OF THE MALFUNCTION
At the end of 2020, following a period of heavy rain, several million biomedia escaped from the Bastia Sud wastewater treatment plant. After that, the operators attempted to estimate the losses. In total, from the initial implementation of MBBR processes in Bastia in 2014, almost 20 m^3 of biomedia had been involuntarily spilt into the sea, half of which stemmed from the latest incident.

The heavy rains had triggered an anomaly in the water level sensor, causing the water in the MBBR tank to rise. Several technical failures contributed to the biomedia escaping:
• No grille on the exhaust air return duct

• The presence of holes without grilles on the concrete sheaths on top of the equipment where the tanks connected with one another.

• The possibility of water and material reflux to the pumping station leading to the MBBRs.

MEASURES IMPLEMENTED
→ Collection of the stranded biomedia:
The Mare Vivu environmental conservation group, present in the area, noticed the pollution and organised several clean-ups. On February 7, 2021, over 40,000 pieces of plastic biomedia were collected with the help of volunteers over a stretch of less than 4 km. In all, almost 3 m^3 of biomedia were collected through their initiative, washed, and reintroduced into the wastewater treatment plant. Other clean-ups, coordinated by the Corsican environmental office, took place late 2021.

→ Technical improvements:
Following the incident, Acqua Publica, the operator of the WWTP, rapidly committed to transparency and technological upgrades. These plans were shared with local government and environmental protection groups. In turn, Surfrider collaborated extensively with the WWTP operator on the issue to consolidate expertise, share experience, and implement good practices.

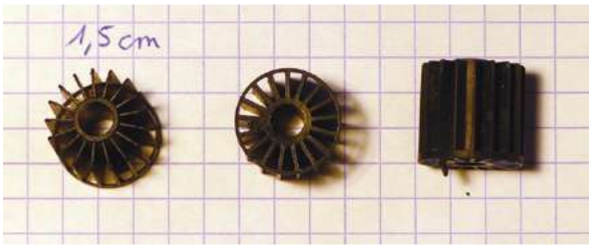
In the beginning of April 2021, Bastia, Furiani, Biguglia, and the Bastia communauté d'agglomération (conurbation) governments implemented an action plan for beach clean-ups.

→ Initiatives:
• Complete emptying of treatment lines (water and biomedia) in order to inspect the outlet filters on the reactors.
• Installation of strainers on the supply pipes to

prevent any backflow to the lift station.
• Installation of a supplementary water level sensor.
• Additional flat grilles on the contaminated air outlets on top of the tanks.
• Installation of a stainless-steel basket to collect biomedia arriving at the intermediate lifting station.

Discussions are underway with the plant designers to learn why such simple precautionary measures had not been taken. Making these design flaws known may improve future designs and help resolve who is responsible for what in the event of pollution.

Figure 31 | Opposite | Biomedia type K5 collected on the beach of La Marana after the incident at Bastia WWTP, © Claire Turgis



7.1.3 BEAUFORT-SUR-GERVANNE

GENERAL INFORMATION
LOCATION: France, Beaufort-sur-Gervanne,
ACTIVITY TYPE: Font Rome fish farm WWTP
DISCHARGE LOCATION: La Gervanne, then La Drôme, then Rhone River, then Mediterranean Sea
DATE OF THE POLLUTION EVENT: December 2022

BIOMEDIA FOUND: RK Bioelements

OBSERVATIONS
In December 2022, following minor flooding, high amounts of biomedia were found on the banks of the river Gervanne downstream from the Font Rome fish farm. A hiker counted up to 50 per square meter, a sign of close and recent pollution.

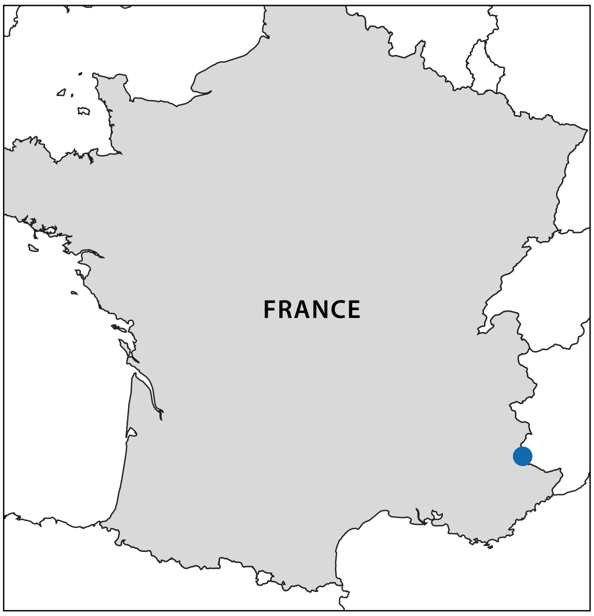
DESCRIPTION OF THE INCIDENT:
We were given only limited information regarding the specific causes of the incident. According to the information we did receive, the fish farm's wastewater treatment station did not comply with norms and declarations were not made after the facilities were expanded.

MEASURES IMPLEMENTED:
The residents of the area quickly contacted the water policy authorities. The "Direction Départementale de la Protection des Populations de la Drôme" (DDPP26) took up the issue.

DIFFERENT RESPONSES WERE INITIATED
→ Formal notice order for the collection of biomedia and request to inform the petitioner of the actions they have taken.

→ Obligatory monitoring and strengthened safety measures for biomedia retention at the facility.

Administrative action is still underway.



7.1.4 MOLINES-EN-QUEYRAS

GENERAL INFORMATION
LOCATION: France, Molines en Queyras and Saint Véran (Hautes Alpes)
ACTIVITY TYPE: Municipal WWTP
NOMINAL CAPACITY: 61,000 PE
DISCHARGE LOCATION: Le Guil river, then La Durance, then Le Rhône
DATE OF THE POLLUTION EVENT: July 2021

BIOMEDIA FOUND
Anox Kaldnes - Biochip M

OBSERVATIONS
At least two incidents, one in 2016 and another in 2021, led to the loss of biomedia from the Molines-en-Queyras/ St Veran facility. Thousands of biomedia were reported from the banks of the Guil (an affluent of the Durance River) all the way to Serre-Ponçon Lake, where they were being found in high numbers in clean-ups organised by the local LPO chapter.

DESCRIPTION OF THE MALFUNCTION
The first incident occurred in 2016 when a problem in an MBBR tank led to biomedia loss. The WWTP did not communicate about the event. Worried about finding increasing amounts of biomedia, citizens of the area alerted the municipality.

A second accident occurred in 2021, again without any communication on behalf of the treatment facilities. This time, it was fishermen who noticed high amounts of biomedia in the Guil (affluent of the Durance stream) and around the reservoir of the EDF (Electricité De France) dam at Maison du Roy. The yearly drainage of the dam in the spring of 2022 spread the biomedia downstream and led to their arrival in large numbers in the Serre-Poncon Lake.

MEASURES IMPLEMENTED
→ Nearly 100,000 biomedia have been collected by the Ecrins-Embrunais LPO since 2018. The NGO also called on the Office Français de la Biodiversité (OFB, French Biodiversity Office), responsible for enforcing water policy, to investigate.

→ Administrative procedures were initiated at the WWTP to prevent further accidents.

Late 2020, following a decision by the "Direction Départementale des Territoires des Hautes-Alpes " (DDT 05), an agreement was made to define a time period for the operators to find solutions and complete the necessary modifications to prevent further leakages.

A similar pollution event, originating from the Vallouise-Pelvoux WWTP, has also affected the Serre-Ponçon Lake since June 2017. Indeed two incidents at the Vallouise-Pelvoux WWTP also contributed to the pollution in Serre-Ponçon Lake since June 2017. After the local Ecrin-Embrunais LPO reported the pollution and an investigation by the DDT05, the plant's operators admitted to losing 2 m^3 of biomedia[31]. For further information, consult the map of accidents on Surfrider Europe's website.

Figure 32 | Above | Biomedia type Biochip collected on the shore of Serre-Ponçon lake after the incident at Molines-en-Queyras WWTP, © JP. Coulomb.

Notes | 31. Ballerini et al., 2022

7.1.5 NYKÖPING

GENERAL INFORMATION

LOCATION: Sweden, Nyköping
ACTIVITY TYPE: Municipal WWTP
NOMINAL CAPACITY: 50,000 PE
DISCHARGE LOCATION: Baltic Sea
DATE OF THE POLLUTION EVENT: January 2023

BIOMEDIA FOUND

Anox Kaldnes - K1

OBSERVATIONS

In midwinter, heavy rain and thawing caused flooding, which led to a significant pollution event at the Brandholmen-Nyköping facility. The plant operators promptly raised the alarm.

DESCRIPTION OF THE MALFUNCTION:

Rapid snowmelt caused a surge in flow rates at the station, increasing from 460 m³/h to 1600 m³/h. Water level sensors failed. Many of the biomedia were coated in an extracellular polymeric substance with a chalky appearance that disrupted bacterial biofilms. The high flow pushed biomedia against the side of the tank where they were blocked plugging the outlet and causing the water level to rise. The water level sensor malfunction prevented the automatic shut-off and resulted in the continuous operation of the pumps. The water in the tank overflowed and the biomedia along with it. Personnel were able to shut off one of the treatment lines, while the other continued to pump influent.

MEASURES IMPLEMENTED

The biomedia retained in the tertiary treatment tanks were collected and reintroduced into the MBBR. A bathymetric modelling company was hired to map out the potential areas of strandings to improve clean-up operations.

Since the accident, the development of bacterial films on the biomedia has been monitored more closely. Twice a week, photos are taken and archived. The monitoring of phosphate levels, identified as having contributed to the abnormal bacterial development, was also intensified. The personnel of the plant will be trained specifically for the MBBR system at Anox Kaldnes.

__Figure 33__ | __Below__ | Biomedia type K1 collected on the shore after the incident at Nyköping WWTP, © Pontus Stenberg/SVT

7.1.6 SALERNO

GENERAL INFORMATION

LOCATION: Italy, Salerno, Capaccio Paestum
ACTIVITY TYPE: Municipal WWTP
NOMINAL CAPACITY: 50,000 PE
DISCHARGE LOCATION: Sele River, then Mediterranean Sea
DATE OF THE POLLUTION EVENT: February 2018

BIOMEDIA FOUND

Anox Kaldnes - Biochip M

OBSERVATION

The harbour master's office and the coastguard sounded the alarm and discovered the origin of the pollution. More than 126 million pieces of plastic biomedia had escaped from the Capaccio Paestum WWTP. The biomedia then flowed into the river Sele, just a few kilometres from its mouth and very quickly found their way into the Mediterranean Sea and onto the Italian coast.

In June 2018, CESTMed reported cases of ingestion by sea turtles (presence in excrement).

DESCRIPTION OF THE INCIDENT

The loss of the biomedia happened in February 2018. In the Capaccio Paestum WWTP, one of the treatment lines malfunctioned due to bad weather and the breakage of a retaining grille.

MEASURES IMPLEMENTED

Members of the Italy-based CleanSea Life Project rapidly took up the issue and began field initiatives to raise awareness about the biomedia incident, map reports of the biomedia, and organise clean-ups. This data is being used in legal action. A total of more than 260,000 biomedia were collected on the shorelines of Italy, France, Tunisia, Spain, and even Malta.

Under the impetus of local NGOs, local authorities held investigations to determine the pollution's origin and identify those responsible. Eight people are facing charges for illegally dumping plastic waste into the sea.

At the time of writing, the case is still pending, and the verdict has not yet been announced.

__Figure 34__ | __Above__ | Biomedia type Biochip collected on the shore after the incident at Salerno WWTP, © Guardia Costiera.

__Figure 35__ | __Opposite__ | Map of sites where biomedia from Salerno have been found, ©CleanSeaLIFE

7.2 EVALUATION OF OBSERVED POLLUTION EVENTS

Since the start of Surfrider's investigations, we have examined over 40 incidents of pollution. At least 12 European countries have been directly affected by biomedia pollution: Switzerland, Denmark, France, Germany, Iceland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, and the United Kingdom.

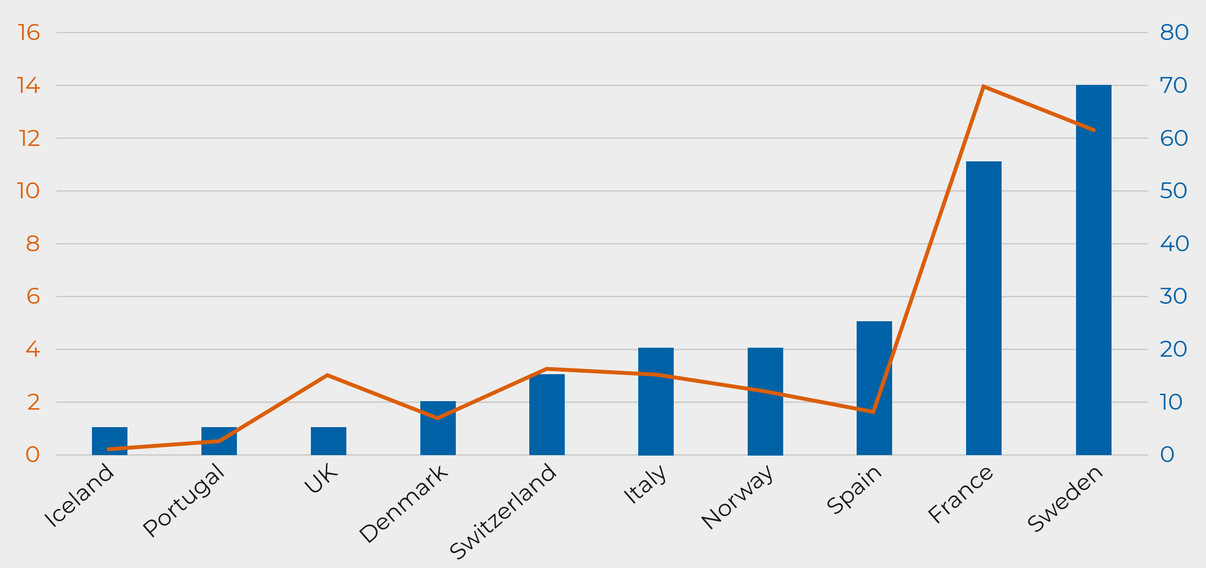
Beyond clearly identified pollution events, other cases of chronic, diffuse environmental leakage have also been recorded. However, the lack of information regarding WWTP use, and particularly in industrial WWTPs, makes identifying the sources of pollution difficult.

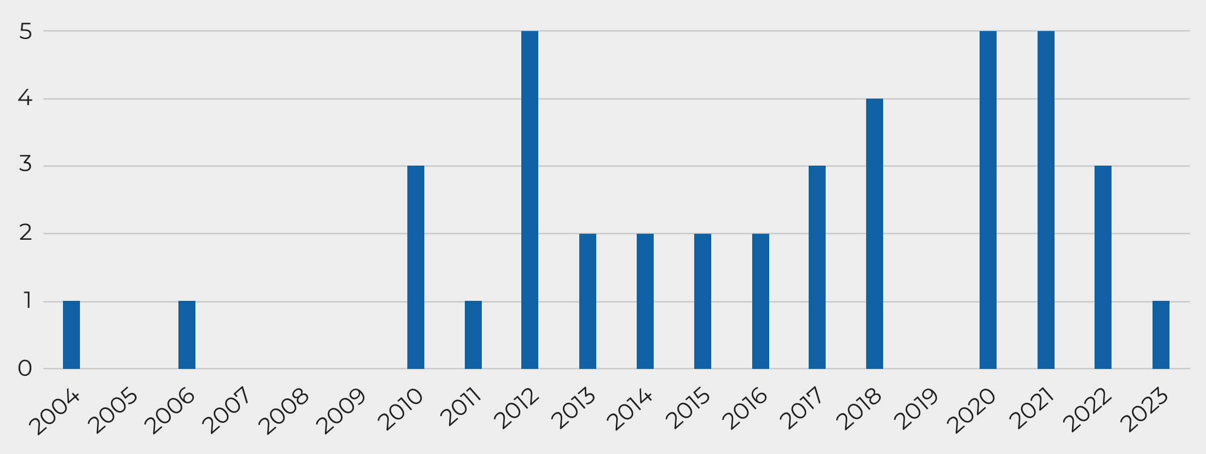
In most cases, biomedia that reach aquatic environments are never recovered, contributing to the global issue of plastic pollution.

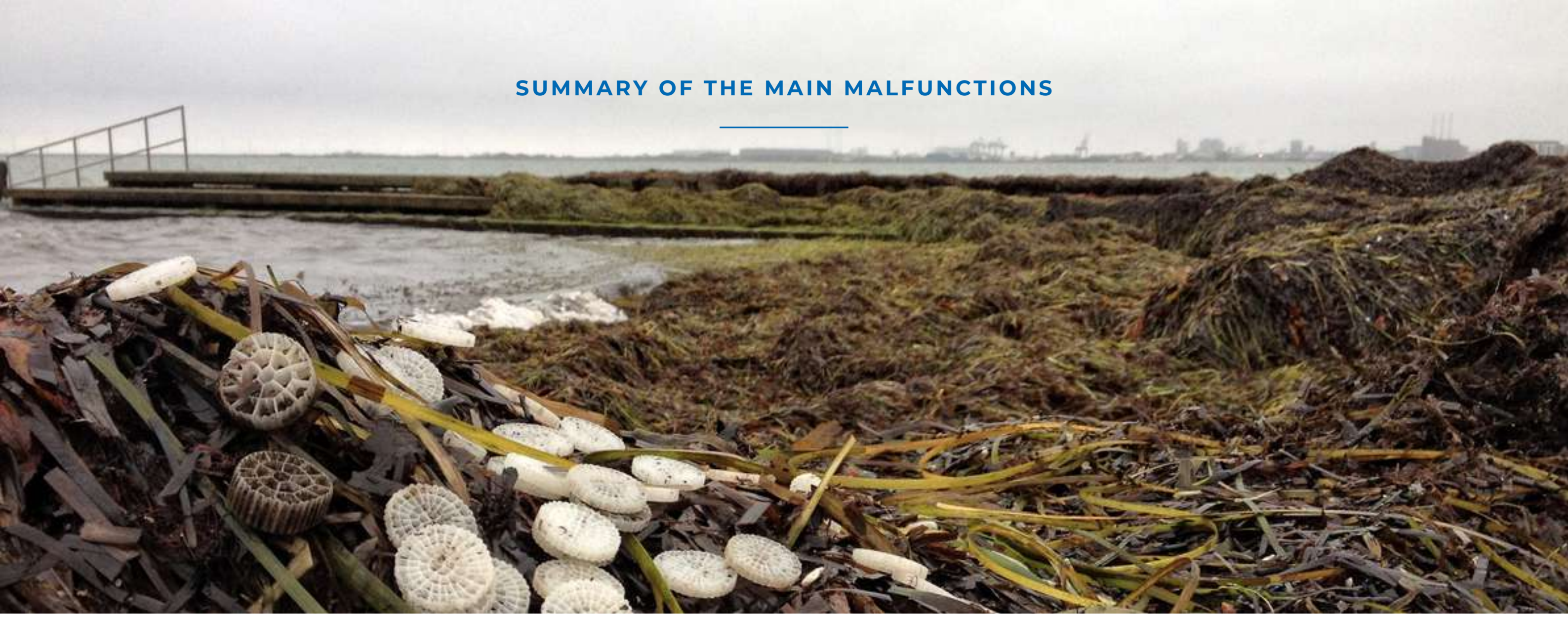
To learn more about the pollution events studied and the sites where biomedia have been found, consult our dedicated website: https://biomedia.surfrider.eu/en/map

The study of pollution events that caused biomedia to reach the natural environment demonstrates the vulnerability of wastewater treatment facilities. Generally, the incidents resulted from a series of failures, either of equipment or human error. Several periods proved particularly sensitive, such as episodes of heavy rainfall and flooding, as well as the commissioning phases of the new MBBR stations, during which numerous accidents occurred. Increases in the frequency, intensity, and impact of extreme weather events are likely to considerably increase the risk of accidents and, consequently, pollution.

***Figure 36** | **Below** | Number of treatment plants using biomedia per country (blue) / Number of cases of pollution per country (orange). **Figure 37** | **Bottom** | Number of incidents causing biomedia loss per year.*







8 SUMMARY OF THE MAIN MALFUNCTIONS

The various pollution incidents compiled by Surfrider underscore how vulnerable these installations are.

We analysed the 40 pollution events reported over the past 13 years to record the main types of malfunction implicated and draw up technical recommendations to reduce the risk of environmental biomedia loss. For the recommendations, our observations were supplemented with interviews with a representative panel of stakeholders involved in WWTP operation.
The interviews allowed wastewater treatment professionals to share their experience and were intended to help define the symptoms of non-obvious malfunctions as exhaustively as possible and the measures to reduce spillage risk throughout biomedia lifecycles.

In the following, we will summarize the main types of malfunction reported at each stage of the biomedia life cycle.

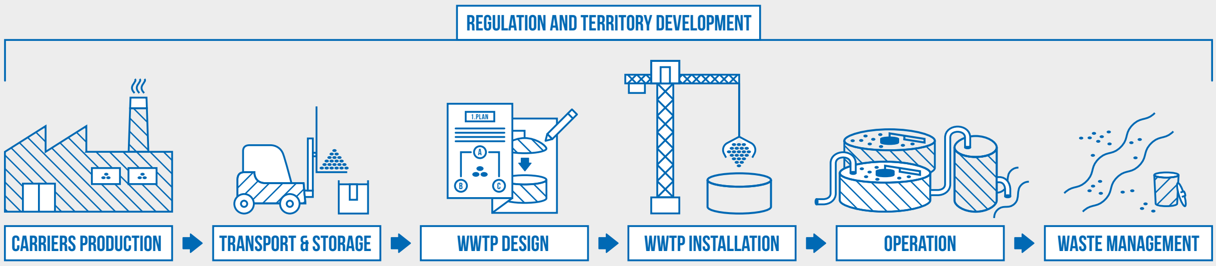


***Figure 38** | **Top** | K5 models stranded in Charlottenlund, Denmark, © Plastic Change*

***Figure 39** | **Above** | Biomedia life chain, from design to disposal, © Surfrider Europe*

8.1 REGULATION

Regulations are an essential means of action, enabling local, regional, national, or European authorities to determine standards and control requirements: discharge thresholds, technical documents for risk assessment and emergency procedures, and specific equipment.

To guarantee effective treatment of sewage before discharge in the receiving environment, all urban wastewater from built-up areas of 2000 population-equivalents (PE) or more, as well as all industrial wastewater, must conform to European and national regulations *(see Chapter 1.4)*. The Urban Wastewater Treatment Directive requires an authorisation for discharge into the environment when creating or improving a wastewater treatment system. Relevant government agencies must be contacted for these authorisations. Depending on the installation size and type, different agencies with local, regional, or national scope are responsible for oversight. The ongoing review of the UWWTD is an opportunity that Surfrider seized to alert decision-makers and push for regulation.

In some countries, like Sweden, Norway, or France, a risk and reliability assessment of proposed WWTPs is required as part of the authorisation procedure. This evaluation is intended to evaluate the risks related to the system itself, but all the potential risks regarding MBBR procedures are not covered.

At the time of writing, there is no obligation to declare the usage of plastic carriers for biofilm growth during biological treatment, and therefore, there is little information readily available on biological treatment systems used. Only general information is available to authorities (effluent type, treatment type, treatment capacity). Data on the type and volume of biomedia used is not generally reported. According to the interviews, the authorities responsible for the approval of wastewater treatment plants are not always sufficiently trained to analyse the technical specifications and characteristics of the wastewater treatment systems to be installed. The lack of data and technical knowledge on behalf of public authorities explains the poor understanding of the number of facilities using the technology and their location, making it difficult to plan inspections or respond to pollution incidents.

8.2 PRODUCTION, TRANSPORT, AND STORAGE

The measures to reduce and eliminate biomedia loss from production sites during transport and storage are either preventative or corrective. The emphasis should be on taking preventative measures to reduce risks, such as preventing leaks and containing spillage, as it is more challenging to collect biomedia once it has escaped from production or storage sites.

Reducing leaks at this stage relies heavily on common sense. For example, on several occasions, outdoor storage without monitoring was identified as the cause of biomedia loss into the natural environment. Improperly secured surface water drainage systems can also result in the escape of biomedia.

8.3 FACILITY DESIGN

Urban wastewater treatment consists of a series of physical, biological, and chemical treatments to collect wastewater effluent, store it, and eliminate and/or reduce eventual pollutants before reuse or discharge of the treated effluent. Biomedia are used during the secondary treatment phase. While designing the facility, two sets of parameters are crucial to consider to avoid biomedia leaks:

→ Maintaining the appropriate physical and chemical conditions for activated sludge;

→ Ensuring the reliability of the installations, procedures, and equipment needed to keep biomedia in tanks.

When these conditions are not respected, it can create a disequilibrium in the biological reactor and lead to diverse malfunctions like foaming[32] or overflowing. Station reliability depends on the presence of appropriate equipment (pumps, check valves,...), captor coverage, and regular maintenance. However, these conditions are not always fulfilled, which can result in failures. Overlooking biomedia spillage risk at the design stage can lead to a lack of equipment and increase the risk of malfunction without backup plans in place.

8.4 WWTP START-UP PHASE

Notes | ***32.*** *Collivignarelli et al., 2020*

The start-up phase for wastewater treatment plants is particularly critical as it is when many pollution events occur. During the start-up phase, the wastewater treatment plant begins operation in real conditions and the load is increased until optimal performance levels are achieved. Biomedia are added into the tanks at this step, and time must be allowed for bacterial biofilms to develop. Plant operators are also just familiarising themselves with their new equipment. The system may be particularly vulnerable to variations in the load and high water input during rainy weather.

In order to prevent these failures, contractors/wastewater treatment plant designers typically provide comprehensive guidelines covering all aspects of the operation. However, the many sub-contractors involved in the construction of a WWTP makes communicating the most relevant information difficult. This, in turn, leads to operating instructions not being followed, even when good practice guides are available.

External constraints (political pressure, architectural obligations, contractual deadlines, etc.) can also disrupt the flow of the start-up process.

8.5 WWTP OPERATION

Under normal operating conditions, the main objectives of operators should be to guarantee that bacterial biofilms are developing correctly in the WWTP. Some factors can influence biological treatment parameters. For example, in the case of heavy rain, and particularly for unitary wastewater treatment systems, there are wide swings in water levels and variations in effluent parameters (oxygenation, suspended solids, chemical or biological pollutants, etc.). Other factors like seasonal tourism or variations in industrial output can also impact the nature of the effluent.

Changes in parameters can affect the way biomedia reacts in the tank. A malfunction can lead to problems like the development of filamentous bacteria that disrupt the settling properties of the sludge and compromise treated water quality. Training operators about the particularities regarding biomedia is important to keep the facilities running reliably.

WWTP reliability depends on system maintenance and security. This necessarily includes maintenance of the equipment intended to retain biomedia filters. Regular checks, by both internal teams and external agencies are essential for the long-term performance of treatment facilities. Training operators in the specificities regarding biomedia is therefore crucial for keeping facilities running safely.

8.6 WASTE MANAGEMENT

Maintenance of the tanks sometimes requires a total emptying and collection of biomedia. If unsuited material is used for this purpose, it can create a spillage risk during the pumping, storage, or handling of collected biomedia before elimination or re-use.

Therefore, hiring a specialised company with secure operating protocols is essential for ensuring that biomedia are collected and stored safely. Once removed, biomedia are sent to an appropriate waste treatment centre.

8.7 PLANNING OF EMERGENCY MANOEUVRES IN CASE OF LEAKS OR ACCIDENTAL SPILLAGE

In its broadest sense, an emergency is a present or imminent situation that requires rapid, coordinated action to protect human health and safety or limit damage to property or the environment.

An emergency plan must be made for every new WWTP. Every operator is required to design, implement, and maintain an emergency management plan covering a wide range of situations, from bad weather to infrastructure failures. Given the rapid spread of biomedia in the environment, they must be considered an environmental risk and therefore included in emergency plans to anticipate response measures and means of intervention.

However, emergency plans generally do not include biomedia-related concerns. As a result, no specific organisational measures or equipment are ready in the event of a spill within the facility or into the environment, and those in charge of operations are generally unaware of the danger. That is particularly problematic because the person in charge of operations at the WWTP is generally the person of reference in the event of an accident, and their knowledge of the impact of a biomedia leak on the environment is essential for an appropriate response.

9 RECOMMENDATIONS

The failure to consider the risks associated with biomedia use in the conception of WWTPs has been made evident by the inadequate retaining equipment installed in tanks or insufficient monitoring and maintenance systems.

Furthermore, in the event of an incident, very few stations implement suitable warning systems, and when incidents are reported, it is done so far too late. Spread in aquatic environments is therefore rapid. Reducing risk is the main objective of our recommendations. In total, the best practice guide contains more than 150 recommendations deriving from our observations, literature reviews, and interviews with stakeholders involved in the various stages of the biomedia life cycle.

For more detail, consult the Plastic Biocarriers, Recommendations for the use in wastewater treatment plants.

The good practices can be regulatory, administrative, technical, or operational. Some recommendations are common sense and very easy to implement to quick effect. Others, such as regulatory measures or those involved in the design of the WWTPs themselves, can be longer to implement and more costly.

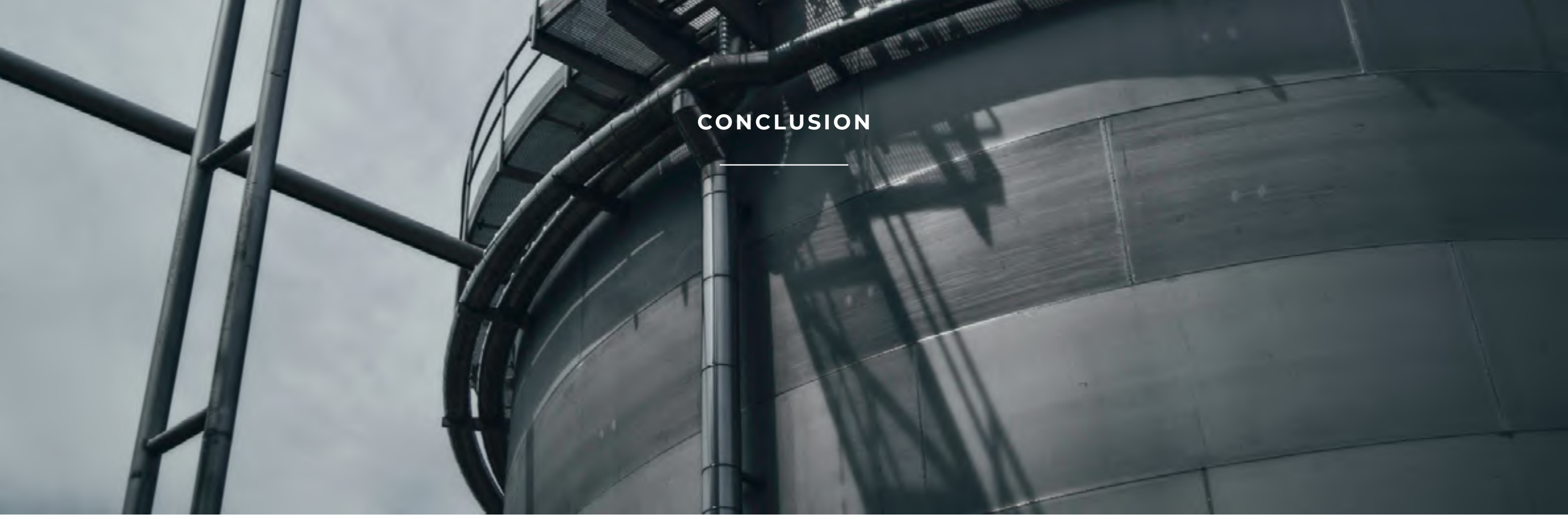
Figure 40 *| **Top** | Biomedia collected on a beach in the Basque Country, © Surfrider Côte Basque*

Figure 41 *| **above** | Cover of the Good Practice Guide written by Surfrider, 2023.*

As seen in the previous chapter, it is essential to implement measures throughout the biomedia life cycle to prevent and reduce biomedia leakage and the associated environmental pollution.

The following table summarises the proposed measures and rates them according to priority.

STAGE	MEASURE	COST	EFFECTIVENESS / IMPACT	EASY TO SET UP	RATING
Regulation	Training in environmental agencies	+	++	+++	1
	Adding requirements for the authorisation procedure concerning process declaration and retention measures	+	++++	++	1
	Application for a HIRA	+	++	++	1
Production / Transport / Storage	Improved storage conditions	+	+	++++	1
	Limited and safer handling	+	+	+++++	1
	Employee training	+	+	+++++	1
	Adaptation of the Emergency Plan	++	+	++	3
	Monitoring the implementation of prevention measures	++	+	++	2
Engineering	Improvement of general conditions (geological and building design)	+++++	+	+	3
	Improving stormwater management and the collection network	+++++	++++	+	1
	Improvement of basin/tank construction	++++	++	+	3
	Improvement of aeration /mixing equipment	+++	+++	++	3
	Improved grille design	++	+++++	++	2
Operation	Quality control	+	+	+	2
	On-site storage	+	+++++	+++++	1
	Test phase security	+++	+++++	++	1
	Effluent management	+	+++	+++	2
	Maintenance	+++	+++++	+++	1
	Operator training	+	+++	+++++	1
Self-monitoring	Implementation of a CMMS	++++	+++	++	3
	Setting up a biocarrier monitoring system	++	++	++	2
Supervision	National Data Base	+	++++	++++	1
	Specific control plan	++	++	++	3
Crisis Management	Adapting the crisis management plan and integrating containment and clean-up resources	++	++	++	3
	Improving information resources in the event of a crisis	+	+	+++++	2
	Develop the inspection / maintenance plan	+	+	+	2



10 CONCLUSION

Biomedia can be used to treat both domestic and industrial wastewater. Currently, a wide variety of technologies enable the treatment of low volumes (individual households) to very high volumes of several hundreds of thousands of PE. Almost every industrial sector uses the technology: fish farming, paper production and processing, oil & gas extraction, food processing...

Since 2009, Surfrider has been in the field recording reports of biomedia strandings, quantifying them, analysing major pollution events, and investigating their causes. This work has enabled us to list over 250 facilities that use biomedia across Europe and study 40 individual pollution events.

A diverse group of individuals and organisations, including citizens, NGOs, wastewater treatment professionals, and government agencies, have contributed to enhance understanding of the causes of plastic biomedia pollution on coastlines. It is clear that there are shortcomings throughout the entire chain of biomedia use, from the authorisation procedure and the design of biomedia-using facilities to accident response.
In 2023, Surfrider's work over more than 15 years culminated in the publishing of a good practice guide for biomedia usage in WWTPs, providing numerous solutions to reduce pollution risk.

The guide includes over 150 recommendations relevant over the entire biomedia usage process.

Until measures to limit biomedia loss are implemented, the risk of accidents will remain high. We at Surfrider will continue providing our expertise, conducting investigations, and lobbying for legislative measures and the "polluter pays" principle in the case of an accident.

Surfrider is also counting on citizen support to continue their observations in the field, without whom, none of this would be possible. We will continue to raise awareness to pursue this successful, multi-year collaborative effort.

Moving forward, we expect significant progress over the next few years with the introduction of best practice guidance and training for wastewater treatment plants. Regulation changes (notably the review of the UWWTD) should also improve the consideration of risks involved with biomedia use in WWTP monitoring.

***Figure 42** | **above** | Basin at České Budějovice, Czech Republic. © Martin Kníže*

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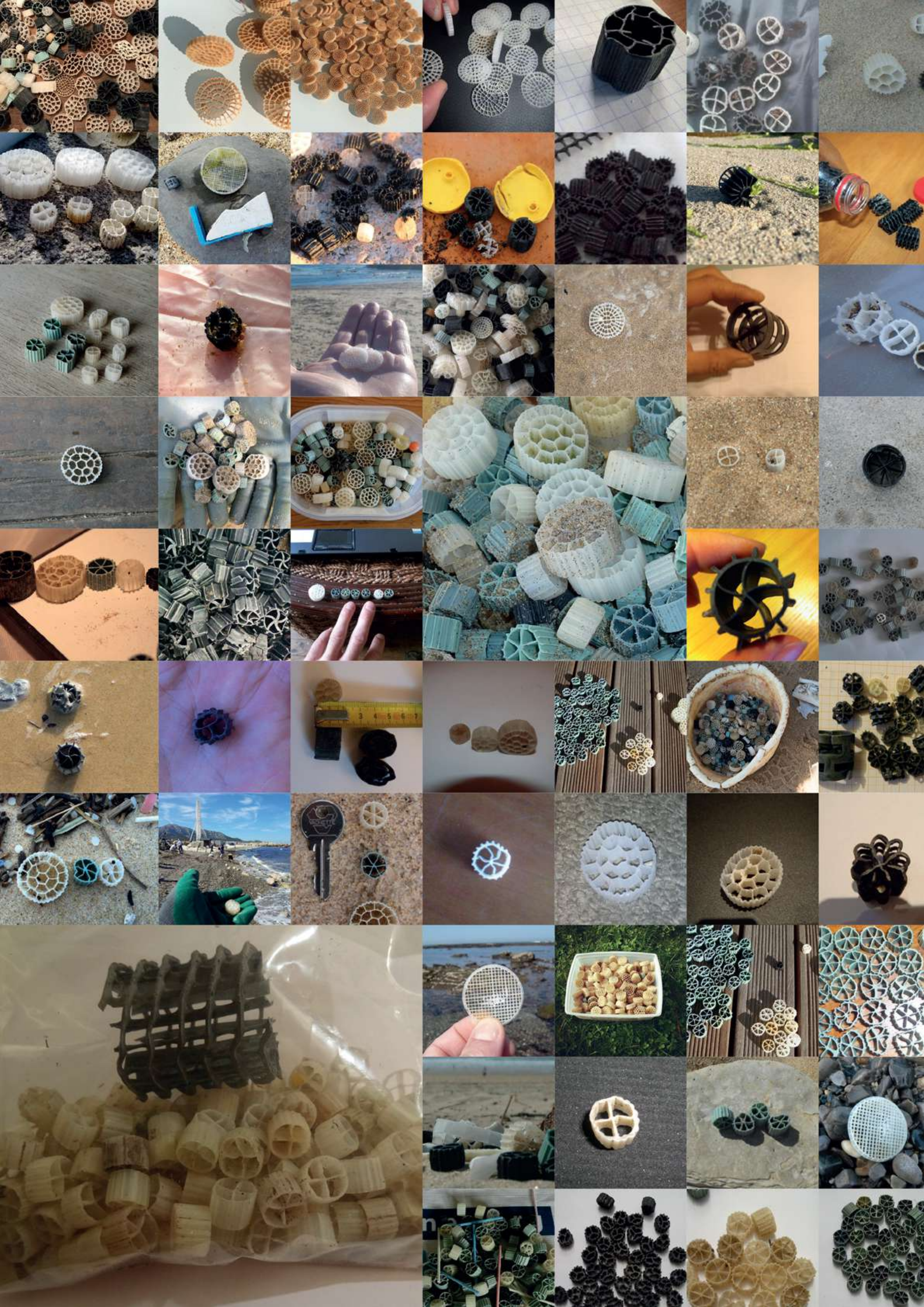

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