



(ARTICLE)

## Microplastic Pollution in Surface Water: Identification of Contamination Sources and Evaluation of Low-Cost Filtration as a Mitigation Strategy

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### تلوث الميكروبلستيك في المياه السطحية: تحديد مصادر التلوث وتقييم الترشيح منخفض التكلفة كاستراتيجية للتخفيف

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#### Abstract:

Microplastic pollution is now recorded in rivers, lakes, estuaries, and treated wastewater. Surface water is important because it connects land-based sources with drinking-water intakes, aquatic life, and coastal seas. This paper identifies common contamination sources and evaluates low-cost filtration as a practical mitigation route. The study uses a secondary data design based on public monitoring studies and published filtration experiments. Monitoring evidence was drawn from the River Thames, Mississippi River, Pearl River, Yangtze River Basin, and wastewater treatment studies. Source evidence was assessed using reported particle shape, polymer type, land use, and transport pathway. The synthesis shows that fibers, fragments, films, rubber-like particles, and pellets point to different sources. Likely sources include synthetic textiles, tyre wear, packaging waste, urban dust, wastewater effluent, and stormwater runoff. Reported surface-water abundance varied widely, from below one particle per liter to many particles per liter. This spread reflects true local pressure and different sampling methods. Filtration evidence shows that sand filtration, biochar, membrane bioreactors, and chitin-cellulose foam can remove high particle shares. Reported removal often exceeded 90 percent under tested conditions. Low-cost treatment is strongest when coarse screening, settling, sand filtration, and biochar are combined. The paper proposes a source-to-filter management framework for urban surface water. It also stresses quality control, safe handling of spent filter media, and source reduction. Filtration can lower exposure, but it cannot replace plastic prevention at source.

**Keywords:** : microplastics; surface water; rivers; source identification; sand filtration; biochar; wastewater; stormwater; low-cost treatment.

#### المخلص

يتم الآن تسجيل تلوث الميكروبلستيك في الأنهار، والبحيرات، والمصبات، والمياه المعالجة. تُعد المياه السطحية مهمة لأنها تربط المصادر البرية بمصادر المياه الصالحة للشرب، والحياة المائية، والبحار الساحلية. يهدف هذا البحث إلى تحديد مصادر التلوث الشائعة وتقييم الترشيح منخفض التكلفة كطريق عملي للتخفيف. يعتمد البحث على تصميم بيانات ثانوية استناداً إلى دراسات المراقبة العامة والتجارب المنشورة للترشيح. تم جمع الأدلة من دراسات المراقبة على نهر التايمز، ونهر المسيسيبي، ونهر اللؤلؤ، وحوض نهر اليانغتسي، ودراسات معالجة مياه الصرف الصحي. تم تقييم أدلة المصدر باستخدام نوع الجسيمات المبلغ عنها، ونوع البوليمر، واستخدامات الأراضي، ومسار النقل. أظهرت النتائج أن الألياف، القطع، الأفلام، الجسيمات المطاطية، والكريات تشير إلى مصادر مختلفة. تشمل المصادر المحتملة المنسوجات الاصطناعية، وتآكل الإطارات، ونفايات التعبئة والتغليف، والغبار الحضري، وفضلات مياه الصرف الصحي، والجريان السطحي للمياه العادمة. تراوحت وفرة الجسيمات في المياه السطحية المُبلغ عنها من أقل من جزيء واحد لكل لتر إلى العديد من الجزيئات لكل لتر. يعكس هذا التباين الضغط المحلي الفعلي وطرق أخذ العينات المختلفة. أظهرت الأدلة على الترشيح أن الترشيح بالرمل، والفحم النباتي، والمفاعلات الحيوية الغشائية، ورجوة الكيتين-السليولوز يمكن أن تزيل حصصاً عالية من الجسيمات. غالباً ما تجاوزت نسبة الإزالة المبلغ عنها 90% تحت الظروف المختبرة. يكون العلاج منخفض التكلفة أقوى عندما يتم دمج الفحص الخشن، والاستقرار، والترشيح بالرمل، والفحم النباتي. يقترح البحث إطار إدارة من المصدر إلى الفلتر لمياه السطح الحضرية. كما يركز على مراقبة الجودة، والتعامل الآمن مع وسائط الترشيح المستهلكة، وتقليل المصدر. يمكن للترشيح أن يقلل من التعرض، لكنه لا يمكن أن يحل محل الوقاية من البلاستيك في المصدر.

**الكلمات المفتاحية:** الميكروبلستيك؛ المياه السطحية؛ الأنهار؛ تحديد المصادر؛ الترشيح بالرمل؛ الفحم النباتي؛ مياه الصرف الصحي؛ مياه العواصف؛ العلاج منخفض التكلفة.

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## 1. Introduction

Plastic materials are light, cheap, and durable. These same qualities make them persistent pollutants. Small plastic particles now occur in many surface-water systems. These particles are called microplastics when they are below 5 mm. They can be primary particles made small by design. They can also be secondary fragments formed by breakdown. Weathering, sunlight, abrasion, and water movement can produce many small pieces. (Andrady, 2011;Lamma,2021) described this breakdown as a key process in aquatic plastic pollution.

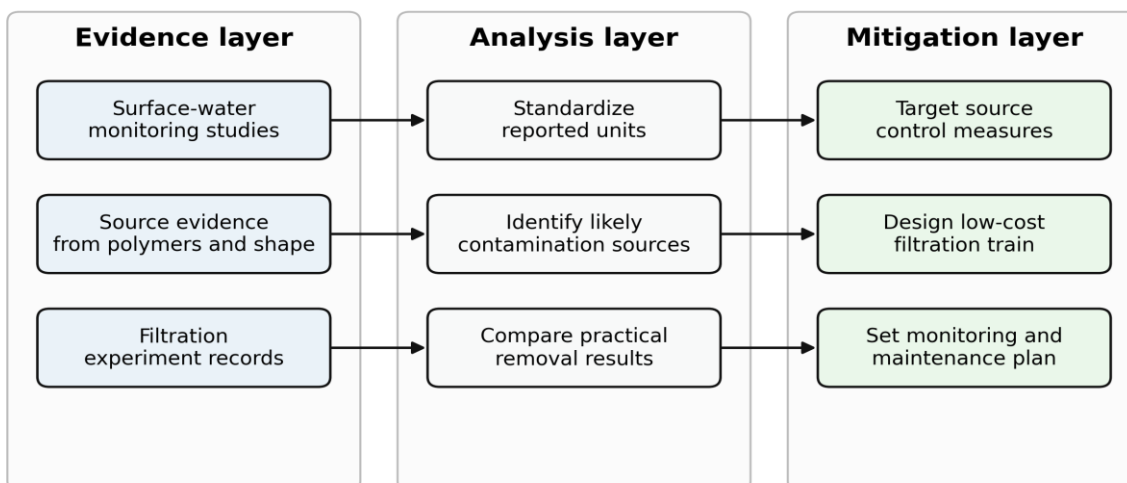
Surface water is a major exposure pathway. Rivers receive plastic from streets, drains, sewage systems, industry, tourism, and waste sites. Lakes can hold particles for long periods. Estuaries receive particles from both rivers and coastal waters. These settings connect land activities with aquatic organisms and drinking-water systems. (Lebreton et al., 2017) showed that rivers are important routes for plastic movement to the sea. (Meijer et al., 2021) later showed a wider river-source pattern. Their model found that more than 1000 rivers account for much of global river plastic emissions.

Microplastics in surface water are not only a litter issue. They can be ingested by small organisms. They can also carry additives and other pollutants. Their surface can support microbial biofilms. Their risk depends on particle size, polymer, shape, weathering, and exposure time. A single count value cannot describe all risk. (Koelmans et al., 2019) noted that freshwater and drinking-water studies need stronger methods. Clear methods are needed before firm health risk conclusions can be made.

This paper focuses on two practical questions. The first question is source identification. Managers need to know whether particles come from textiles, tyre wear, packaging, pellets, or wastewater. The second question is filtration. Many places cannot install advanced treatment systems quickly. Low-cost filtration may reduce particle loads at selected points. Sand, gravel, cloth, biochar, and biomass foam are examples of lower-cost options. Their value depends on performance, maintenance, cost, and safe disposal of captured particles.(Lamma et al.,2021)

The paper uses a data-based synthesis. It does not claim to be a new field sampling campaign. It uses real monitoring results and real filtration experiments. The aim is to build a stronger applied research paper from available evidence. This design is useful when new local data are not available. It also makes the work transparent and reproducible.

### Research design used in this paper



**Figure 1** Research design used in this paper

## 1. Research Problem and Objectives

The research problem is the increasing presence of microplastics in surface water. The problem is made harder by many source pathways. The same river can receive fibers from wastewater and rubber particles

from roads. It can also receive fragments from packaging and pellets from industry. A filter placed at one outlet may not address every source. A correct response must start with source identification.

The selected domain is surface-water pollution. This includes rivers, urban streams, lakes, estuaries, and treated water outlets. The chosen mitigation domain is low-cost filtration. Low-cost does not mean weak science. It means using available media and simple hydraulic designs. It also means choosing solutions that small communities can maintain. (Lamma & Swamy, 2015)

The paper has four objectives. The first objective is to describe major sources and pathways. The second objective is to compare selected surface-water monitoring results. The third objective is to evaluate published filtration experiments. The fourth objective is to propose a practical treatment framework. The framework combines source control, monitoring, and low-cost filtration. (Lamma, 2021)

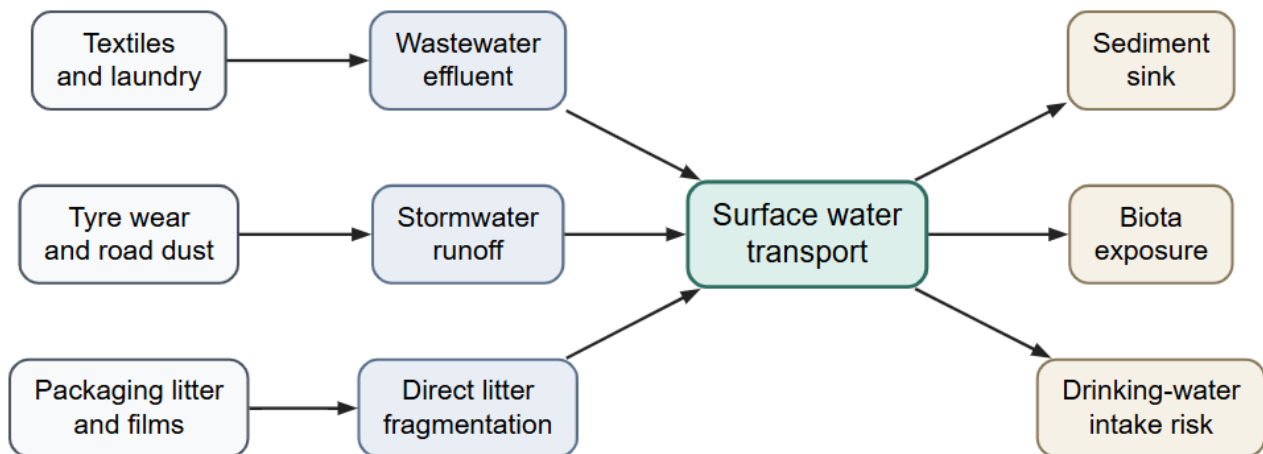
## 2. Literature Review

### 2.1. Formation and Transport of Microplastics

Microplastics enter water in several ways. Some are released as small particles. Others form when larger plastic waste breaks apart. Sunlight can weaken polymer bonds. Physical abrasion can create smaller fragments. River turbulence can move particles downstream. Low-density polymers can float near the surface. Dense particles and biofouled particles can settle into sediment.

(Geyer et al., 2017) estimated that humans had produced 8300 million metric tons of virgin plastics by 2015. They also found that large amounts became waste. This history matters for surface water. Old plastic waste can keep fragmenting for years. (Jambeck et al., 2015) linked land-based plastic waste with ocean inputs. Their work showed why waste management matters for aquatic pollution.

Rivers are important because they combine source pressure and transport. (Lebreton et al. 2017) estimated that rivers carry large plastic loads to the ocean. (Meijer et al., 2021) improved the spatial view. They found that many small and medium urban rivers matter. This means mitigation should not target only the largest rivers. Small urban drains can also be priority sites.



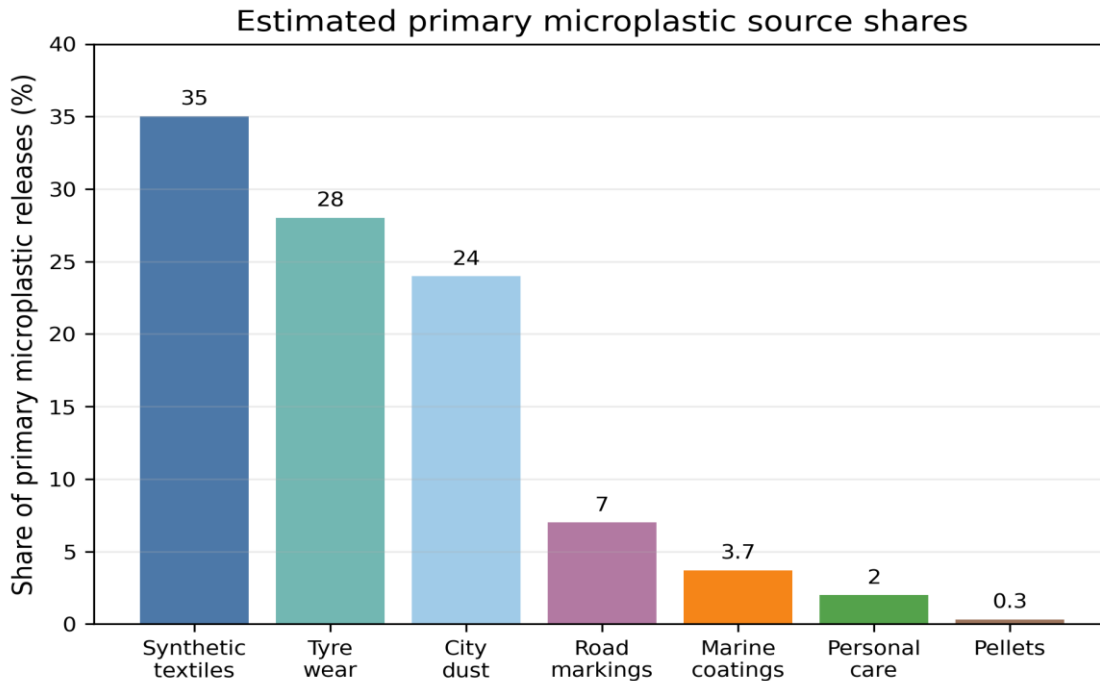
**Figure 2** Source-to-surface-water pathway for microplastics.

### 2.2. Major Sources in Surface Water

Microplastic sources are often divided into primary and secondary sources. Primary microplastics enter the environment as small particles. Secondary microplastics form from larger plastics after release. (Boucher and Friot, 2017) estimated source shares for primary microplastics entering oceans. Synthetic textiles and tyre wear were among the leading categories. These categories also matter for surface water. Laundry water and road runoff both reach rivers through drainage systems.

Textile fibers are common in water samples. They can come from washing synthetic clothes. They can also come from sewer overflow and wastewater effluent. Tyre wear particles are linked to roads. Rainfall

can wash them into drains. Packaging waste often appears as films and fragments. Industrial pellets may show pellet loss or poor handling. These source clues are useful, but they are not proof. Chemical confirmation is needed. Visual sorting alone can misclassify natural fibers.



**Figure 3** Estimated source shares for primary microplastics. Source (Boucher and Friot, 2017: IUCN report)

### 2.3. Monitoring Challenges

Microplastic monitoring is not simple. Different studies use different mesh sizes. Some use manta nets. Others use grab samples or pumps. Smaller mesh sizes capture more particles. Chemical analysis also differs. Some studies use FTIR. Others use Raman spectroscopy. Some studies first sort particles by sight. These method choices change reported abundance.

(Koelmans et al., 2019) emphasized quality assurance in freshwater studies. Good studies need field blanks and laboratory blanks. They also need clean equipment. Plastic tools should be avoided when possible. ITRC guidance also recommends careful sampling volumes and strict contamination control. This matters because airborne fibers can enter samples during handling.

### 2.4. Filtration as a Mitigation Strategy

Filtration is one of the most direct treatment routes. It can capture particles before discharge. Conventional sand filtration is already used in water treatment. Tertiary filters can polish wastewater effluent. Biochar can add rough surfaces and pores. Biomass foams can add adsorption sites. Membranes can remove smaller particles, but they cost more and need more maintenance.

Talvitie et al. (2017) tested advanced treatment technologies for wastewater effluent. They reported strong removal by rapid sand filtration, dissolved air flotation, disc filtration, and membrane bioreactors. Wolff et al. (2021) studied downstream sand filters at municipal and industrial plants. Their sand filtration stage removed about 99 percent of microplastics in tested systems. (Wang et al., 2020; Alhadad, 2022) showed that biochar columns removed more than 95 percent of 10 µm microplastic spheres. These studies support low-cost media as part of a treatment train.

**Table 1** Key terms used in this paper

Term	Meaning in this paper	Management importance
Microplastic	Plastic particle below 5 mm.	Defines the main contaminant class.
Primary microplastic	Particle released at small size.	Points to product and process controls.
Secondary microplastic	Fragment formed after larger plastic breaks down.	Points to litter and waste control.
Fiber	Long thin particle or filament.	Often linked with textiles and wastewater.
Fragment	Irregular broken particle.	Often linked with packaging and plastic litter.
Film	Thin sheet-like particle.	Often linked with bags, wraps, and packaging.
Pellet	Small industrial raw material particle.	Can indicate industrial handling losses.

### 3. Materials and Methods

#### 3.1. Study Design

This study used a secondary-data synthesis. The data came from peer-reviewed papers, public reports, and open thesis material. The paper focused on surface water and treatment experiments. It did not include marine beach litter as the main evidence. It also did not include only sediment studies. Sediment evidence is important, but the title focuses on surface water.

The research design had three layers. The first layer collected monitoring evidence. The second layer identified sources from particle and context information. The third layer evaluated filtration as mitigation. The design followed a practical management logic. It asks what is present, where it likely comes from, and how it can be reduced.

#### 3.2. Data Sources

Monitoring evidence was selected from river and surface-water studies. These included the River Thames, Mississippi River, Yangtze River Basin, and Pearl River systems. These studies were chosen because they report particle abundance and particle characteristics. Filtration evidence was selected from studies on sand filtration, biochar, membrane bioreactors, and biomass foams. All cited values were taken from available publications or public abstracts.

**Table 2** Public and published data sources used for the synthesis

Source type	Examples used	Purpose
Global plastic context	Geyer et al. (2017), OECD (2022), UNEP (2021)	Explain the scale of plastic waste and leakage.
River transport evidence	Lebreton et al. (2017), Meijer et al. (2021)	Support the role of rivers and urban drains.
Surface-water monitoring	Devereux et al. (2023), Dizack (2024), Gao et al. (2022)	Compare abundance and source clues.
Filtration experiments	Talvitie et al. (2017), Wang et al. (2020), Wolff et al. (2021)	Evaluate removal performance.
Monitoring guidance	Koelmans et al. (2019), ITRC guidance	Define good sampling and QA practice.

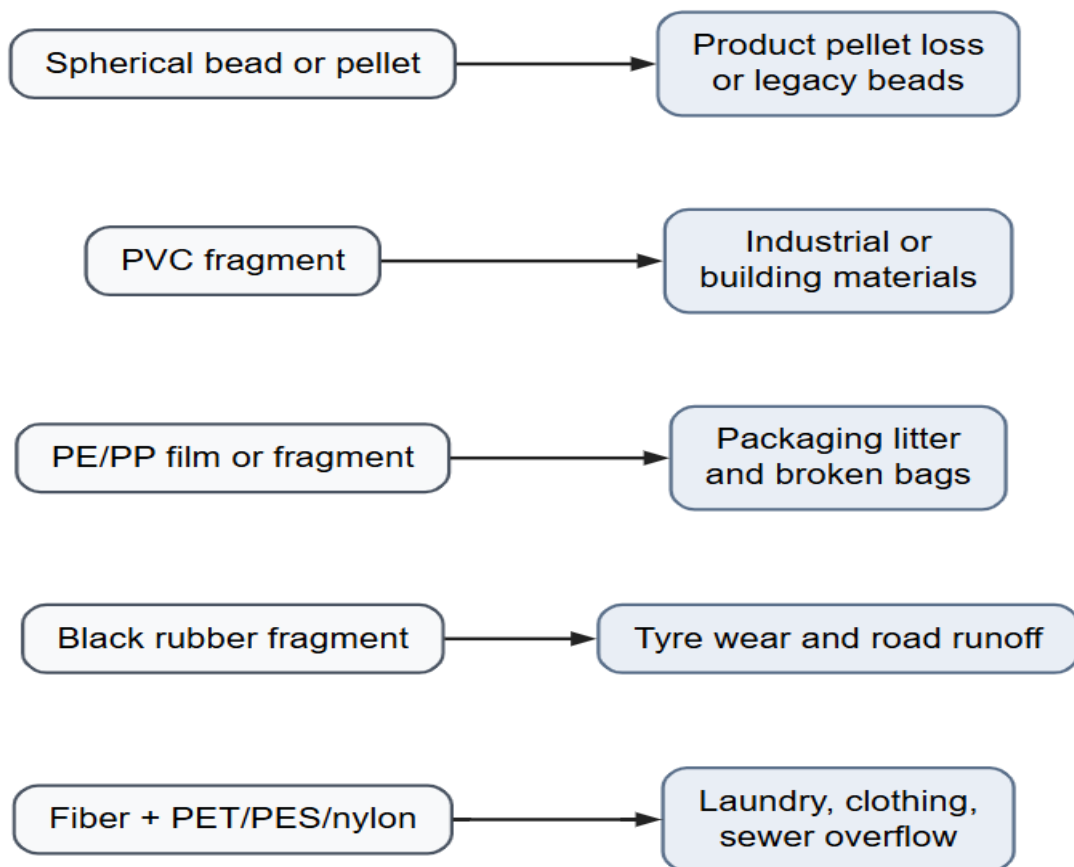
#### 3.3. Data Standardization

Reported abundance values were converted to particles per liter when possible. Items per cubic meter were divided by 1000. Studies with only a range were treated as range evidence. When a chart used one value, the midpoint was used only for visualization. This choice was stated in the caption and table notes.

The paper did not pool all data into one global mean. A pooled mean would be misleading. Studies use different particle size limits and different instruments. A study that detects 30 um particles will report more particles than a study that detects only larger pieces. The synthesis therefore compares patterns with caution.

### 3.4. Source Identification Method

Source identification used four evidence types. The first type was morphology. Fibers, films, fragments, and pellets can suggest different sources. The second type was polymer chemistry. PET and polyester fibers can suggest textiles. Rubber-like fragments can suggest tyre wear. PE and PP can suggest packaging, containers, and bags. PVC can suggest industrial or construction materials. The third type was land use. Urban roads, industries, and wastewater outlets can raise source pressure. The fourth type was season and flow. Rain can increase stormwater transport.

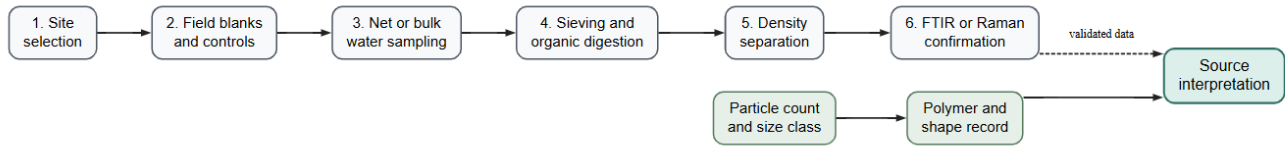


**Figure 4** Source identification cues used for surface-water microplastics.

### 3.5. Filtration Evaluation Method

Filtration studies were evaluated using reported removal efficiency. The basic formula was used in all cases. Removal efficiency equals influent count minus effluent count, divided by influent count, multiplied by 100. Some studies reported the value directly. Other studies reported before-and-after counts. For this paper, directly reported efficiencies were used where available.

The evaluation also considered practicality. A low-cost filter must be easy to build and maintain. It should not create a hidden waste problem. Captured microplastics must be handled safely. Spent sand, sludge, or biochar should not be returned to soil or waterways. Incineration, secure landfill, or controlled regeneration may be needed, depending on local rules.



**Figure 5** Recommended monitoring workflow for surface-water microplastics. Source: (Koelmans et al., 2019)

**Table 3** Quality-control steps for microplastic monitoring

Step	Minimum practice	Reason
Field sampling	Use metal or glass where possible.	Reduces contamination from tools.
Blanks	Include field and laboratory blanks.	Detects airborne and handling contamination.
Clothing	Avoid synthetic lab coats when possible.	Limits fiber shedding into samples.
Digestion	Use controlled chemical digestion.	Removes organic matter without damaging polymers.
Density separation	Use a solution suited to target polymers.	Improves particle recovery.
Identification	Confirm particles by FTIR or Raman.	Prevents false positives from visual sorting.
Reporting	Report size limit and volume filtered.	Allows comparison between studies.

## 4. Results

### 4.1. Evidence of Surface-Water Contamination

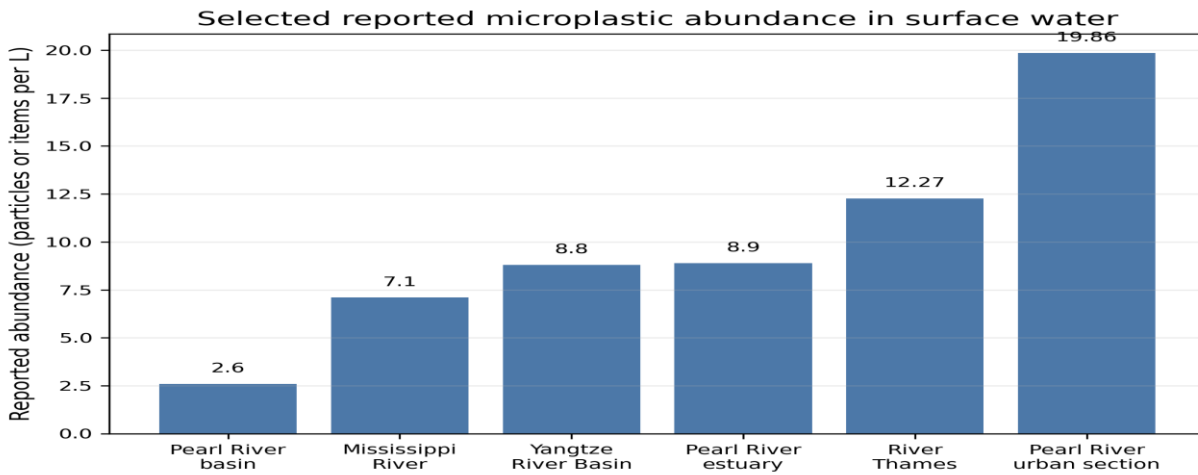
The selected studies show that surface water often contains microplastics. The River Thames study found 6401 microplastic pieces from monthly sampling. The average abundance was 12.27 pieces per liter. The study used visual classification and FTIR testing for selected pieces. It also found variation between sites and months. Devereux et al. (2023) reported these results for the tidal Thames.

The Mississippi River thesis found suspected microplastics at every sampled site. The average count was 7.1 plus or minus 3.1 particles per liter. Fibers were the main form and made up 97 percent of particles. Raman spectroscopy on a subset showed that many particles were human-made. (Dizack, 2024) also linked higher counts with population density. This result supports the role of urban pressure.

A Mississippi River System study during flash drought found much higher counts. It reported average concentrations from 16 to 381 microplastics per liter across seven sites. PET, resin, and PE were among the most common polymers. The authors also found that drought affected polymer composition. This shows that climate and flow conditions can affect particle profiles.

The Yangtze River Basin also shows a broad contamination pattern. A 2025 basin study reported an average abundance of 8797 items per cubic meter. This equals about 8.8 items per liter. The study found that polypropylene and fragments were dominant. Results such as these show that rivers with large urban and industrial pressure need high-resolution monitoring.

The Pearl River evidence shows strong spatial variation. (Gao et al., 2022) found seasonal and site differences in the Pearl River Delta. Other Pearl River studies reported high abundance in urban sections and lower abundance in estuary areas. This pattern supports a source gradient. Urban tributaries can act as both input zones and temporary retention zones.



Values are not strictly comparable because mesh size and identification methods differ.

**Figure 6** Selected reported microplastic abundance in surface water. Source: (Devereux et al., 2023; Dizack ,2024), Yangtze River Basin data, and Pearl River studies.

**Table 4** Selected surface-water monitoring evidence used in this paper

System	Reported value	Dominant information	Citation
River Thames, UK	Mean 12.27 pieces/L	6401 pieces found; FTIR used for selected pieces.	Devereux et al. (2023)
Mississippi River, USA	Mean 7.1 +/- 3.1 particles/L	Fibers made up 97 percent of particles.	Dizack (2024)
Mississippi River System, USA	16 to 381 MPs/L across seven sites	PET, resin, and PE were common polymers.	Cizdziel et al. (2024)
Yangtze River Basin, China	8797 +/- 12,281 items/m <sup>3</sup>	Polypropylene and fragments dominated.	Yangtze Basin study (2025)
Pearl River Delta, China	Seasonal and site differences	Rainy season and urban sites showed higher burden.	Gao et al. (2022)
Pearl River urban section	19,860 items/m <sup>3</sup>	Urban section higher than estuary.	Pearl River study (2018)

#### 4.2. Source Signals

The monitoring evidence points to mixed sources. Fibers strongly suggest textiles, wastewater, and sewer overflow. The Mississippi River thesis found a dominant fiber signal. That signal is consistent with textile release from laundry and wastewater. The IUCN source estimate also identifies synthetic textiles as a major primary microplastic source. (Boucher and Friot, 2017) support this interpretation.

Fragments and films are often linked with plastic packaging. Urban litter can break into pieces near drains and riverbanks. High fragment shares may also occur when old waste is exposed to sunlight and abrasion. Polyethylene and polypropylene are common in packaging. They are also common in floating surface-water particles. This makes source proof difficult without site context.

Road runoff is another important pathway. Tyre wear particles are not always counted in older microplastic studies. They can be black, rubber-like, and dense. Many can settle or bind to road dust. Rainfall moves road dust into drains. This source is important for small urban rivers. (Meijer et al., 2021) highlighted the importance of small urban rivers in plastic emissions.

Industrial pellet loss can be identified when pellets or uniform beads are present. Such particles are common near manufacturing and handling areas. Personal care microbeads are now restricted in many countries. Still, legacy particles may remain. Their importance is lower than textiles and tyres in global estimates. Yet local sources can still produce strong spikes.

**Table 5** Source interpretation matrix

Particle clue	Possible source	Main pathway	Confidence note
Clear or colored fibers	Synthetic textiles	Laundry wastewater and sewer overflow	High when PET or polyester is confirmed.
Black rubber-like fragments	Tyre wear	Road runoff and storm drains	Needs chemical testing for rubber markers.
PE or PP films	Packaging and bags	Litter fragmentation and drains	Common polymers need local context.
Uniform pellets	Industrial handling loss	Industrial drains and spills	High when found near plastic facilities.
PVC fragments	Construction or industrial materials	Industry and urban runoff	Useful if PVC is confirmed.
High count after rainfall	Road dust and washed litter	Stormwater	Needs rainfall and flow records.

### 4.3. Filtration Evidence

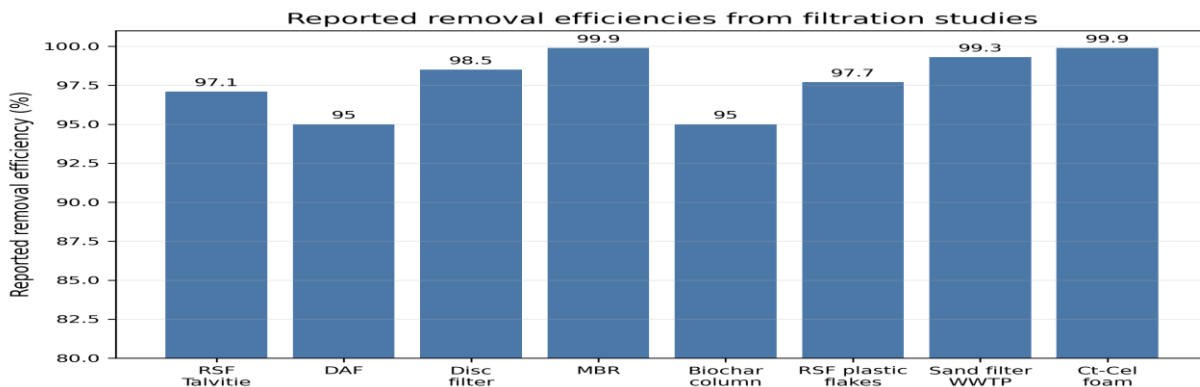
The filtration evidence is strong but varied. (Talvitie et al., 2017) reported high removal by tertiary wastewater technologies. Rapid sand filtration removed about 97.1 percent. Dissolved air flotation removed about 95.0 percent. Membrane bioreactor treatment reached 99.9 percent. Disc filtration reached up to 98.5 percent. These results show that final treatment can reduce microplastic discharge.

(Wolff et al., 2021) studied downstream sand filters in Germany. They found 99.2 percent and 99.4 percent removal in two municipal wastewater plants. They also found 99.2 to 99.9 percent removal at a PVC manufacturer. Their method used Raman microspectroscopy and strict blank control. This makes the evidence useful for practical filtration design.

(Sembiring et al., 2021; Alhadad, 2018) tested rapid sand filtration for artificial microplastics. They found high removal for plastic flakes. Smaller effective sand size improved removal. Their study also showed that tyre flakes were more difficult than some plastic flakes. This result matters for urban runoff. Tyre-wear particles may need pretreatment and careful filter design.

Biochar is promising because it is porous and can be made from waste biomass. (Wang et al., 2020) tested biochar columns for 10 µm spheres. They reported more than 95 percent removal for tested biochars. The mechanism was not only simple sieving. Particles were stuck, trapped, and entangled in biochar structures. This supports a hybrid sand-biochar system.

Recent biomass foams also show high removal. A chitin-cellulose fibrous foam reached up to about 99.9 percent removal in reported tests. It also remained effective after repeated cycles. This material is promising, but field scale testing is still needed. It may be better for polishing than for heavy sediment loads.



Efficiencies depend on particle size, matrix, pretreatment, and detection method.

**Figure 7** Reported removal efficiencies from filtration studies. Source: (Talvitie et al., 2017; Wang et al., 2020; Wolff et al., 2021; Sembiring et al., 2021; Wu et al., 2024).

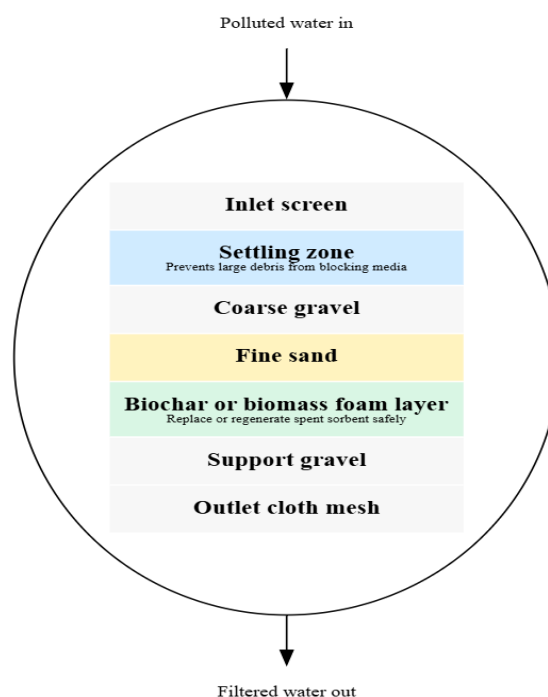
**Table 6** Filtration studies and practical performance evidence

Treatment	Reported performance	Important condition	Citation
Rapid sand filtration	97.1 percent removal	Tertiary treatment of wastewater effluent	Talvitie et al. (2017)
Dissolved air flotation	95.0 percent removal	Advanced wastewater treatment	Talvitie et al. (2017)
Disc filter	Up to 98.5 percent removal	20 um pore size in study	Talvitie et al. (2017)
Membrane bioreactor	99.9 percent removal	Higher cost and maintenance	Talvitie et al. (2017)
Downstream sand filters	99.2 to 99.9 percent removal	Municipal and PVC process wastewater	Wolff et al. (2021)
Rapid sand filter	97.7 percent for plastic flakes	Artificial particles; media size mattered	Sembling et al. (2021)
Biochar column	Above 95 percent for 10 um spheres	Corn straw and hardwood biochars	Wang et al. (2020)
Chitin-cellulose foam	Up to about 99.9 percent	Bench and natural-water tests	Wu et al. (2024)

### 5. Proposed Low-Cost Filtration Strategy

The best low-cost strategy is not a single media layer. Surface water contains leaves, sand, silt, organic matter, and plastics. A filter that receives all material at once will clog quickly. A treatment train is better. The train should first remove large debris. It should then settle heavy solids. After that, fine sand and biochar can capture smaller particles. A final cloth or cartridge can polish the flow.

The proposed train is designed for urban drains and small community channels. It can also fit pilot studies near wastewater outlets. The first section is a trash screen. The second section is a settling chamber. The third section is a gravel and sand bed. The fourth section is a biochar or biomass foam layer. The final section is a protected outlet. Flow should be slow enough to increase contact time. The unit should also allow backwashing or media replacement.

**Figure 8** Low-cost filtration train for polluted surface water.

**Table 7** Suggested pilot design for a low-cost microplastic filter

Component	Suggested role	Practical design point
Inlet screen	Stops leaves and large litter.	Use removable metal mesh.
Settling chamber	Removes sand and dense particles.	Clean before every major rain season.
Coarse gravel	Spreads flow and supports media.	Avoid short circuiting.
Fine sand	Captures larger particles and flocs.	Select media size after jar testing.
Biochar layer	Adds adsorption and trapping sites.	Use washed, stable, low-ash biochar.
Outlet cloth or cartridge	Polishes final flow.	Replace when head loss rises.
Spent media plan	Prevents re-release of particles.	Bag, label, and dispose under local rules.

The pilot should be monitored before and after the filter. Samples should be taken at the same flow condition. A blank sample should be included. Inlet and outlet particles should be counted and confirmed by FTIR or Raman. Turbidity and total suspended solids should also be measured. These cheaper indicators can help track filter clogging. (Wolff et al., 2021) found a relationship between suspended solids and microplastic concentration in wastewater samples. That link may help field operation.

The filter should be tested under dry weather and after rain. Dry weather results can show baseline wastewater or local discharge. Rain events can show stormwater and road runoff effects. If rain increases black fragments and fibers, source controls should target drains and textile pathways. If pellets appear, industrial handling should be investigated. This links treatment with source identification.

## 6. Discussion

### 6.1. What the Evidence Means for Source Control

The evidence shows that surface water receives particles from many sources. No single source explains all cases. Fibers can dominate one river. Fragments can dominate another. Urban runoff can add tyre wear. Wastewater can add textile fibers. Industrial areas can add pellets or PVC. This means local monitoring is essential.

Source control should come before filtration. Textile fiber capture can reduce loads from laundry. Better road sweeping and stormwater treatment can reduce road dust. Good waste collection can reduce packaging fragments. Pellet handling rules can reduce industrial losses. These steps reduce the load before particles reach water. Filtration is then used as a second barrier.

The source evidence also shows the value of polymer data. Particle shape alone is not enough. A natural cellulose fiber can look like a textile fiber. A dark mineral grain can look like a rubber particle. Chemical confirmation reduces this uncertainty. FTIR and Raman methods are therefore central to strong research.

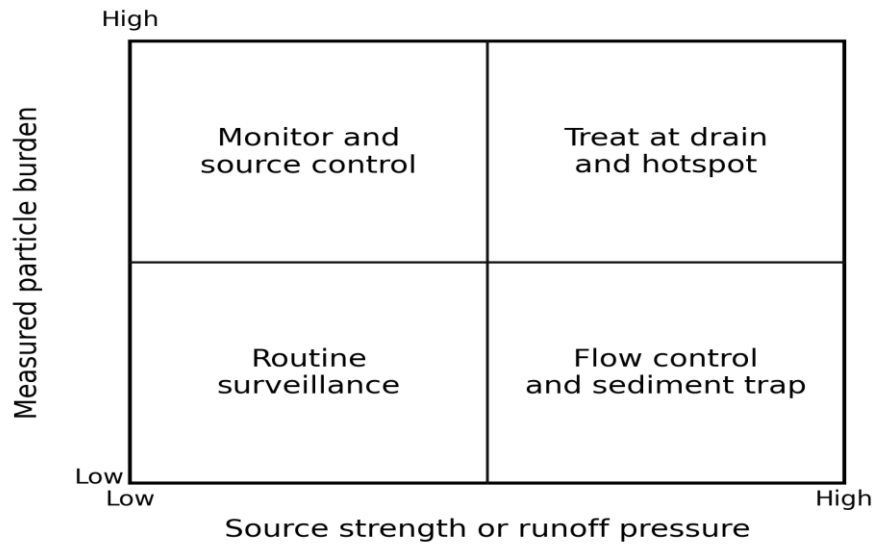
### 6.2. Why Low-Cost Filtration Is Useful

Low-cost filtration is useful because many cities need immediate action. Advanced membranes work well but may be too expensive. They also require pumps, cleaning, energy, and skilled staff. Sand and gravel are more available. Biochar can be made from agricultural residues. Biomass foams may become useful if production can scale.

The strongest approach combines physical capture and particle adhesion. Sand removes larger particles by straining. Biochar can trap particles in pores and rough surfaces. Biomass foam can bind particles through surface interactions. Coagulation can create larger flocs before filtration. This combined logic can raise removal and reduce clogging.

However, filtration has limits. Very small particles and nanoplastics are harder to capture. High sediment loads can block filters. Flood flows can bypass systems. Captured particles can be released if media is disturbed. A filter also creates a waste stream. This waste stream must be managed safely.

**Decision matrix for placing filtration controls**



**Figure 9** Decision matrix for placing filtration controls.

**6.3. Comparing Sand, Biochar, and Biomass Foam**

Sand filtration is the most established option. It is already used in drinking-water and wastewater treatment. It is simple and widely understood. Its main weakness is limited capture of very small particles. It also needs backwashing or media cleaning. (Sembiring et al., 2021) showed that media size and particle size affect performance.

Biochar is attractive because it can use local biomass. (Wang et al., 2020) showed strong removal of small spheres. Biochar can also be mixed with sand. This may improve performance without a full membrane system. Yet biochar quality varies. Poor biochar can leach color, ash, or dissolved organic matter. It must be washed and tested before use.

Biomass foam is promising but newer. Chitin-cellulose foam shows high removal in reported studies. It may work as a polishing layer. It also may be useful for household or small outlet filters. Yet it needs more field evidence. Its performance during muddy stormwater events is still uncertain.

**Table 8** Practical comparison of low-cost filtration options

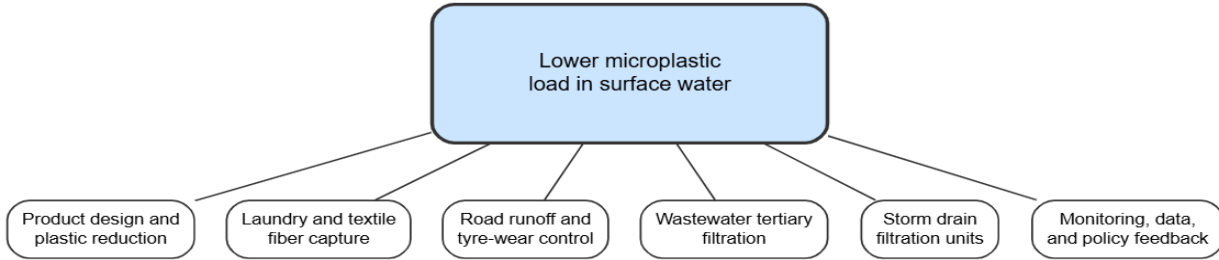
Option	Strength	Weakness	Best use
Sand filter	Cheap, known, durable	Can miss small particles	Tertiary polishing and storm drains
Gravel and settling	Prevents clogging	Does not remove fine particles alone	First barrier in drains
Biochar layer	Low-cost sorbent; rough pores	Quality varies by feedstock	Polishing after sand
Cloth or cartridge	Simple final barrier	Needs frequent replacement	Small pilot systems
Biomass foam	High reported removal	Needs more field testing	Polishing and modular units
Membrane	Very high removal	Higher cost and energy	Advanced treatment plants

**6.4. Environmental and Public Health Meaning**

The health risk of microplastics is still being studied. It would be wrong to claim full certainty. It would also be wrong to ignore exposure. Microplastics occur in surface water, food, air, and drinking water. They

may carry additives and sorbed pollutants. They can also interact with organisms. (UNEP, 2021) described plastic pollution as an ecosystem and health concern.

The best public health action is exposure reduction. This means less plastic leakage, better drains, better wastewater polishing, and better monitoring. Filtration can help at local points. It cannot solve plastic overproduction. (OECD, 2022) reported that global plastic waste grew strongly from 2000 to 2019. This broader waste trend drives future aquatic pollution.



**Figure 10** Integrated mitigation framework.

### 7. Management Implications

The first implication is that cities should map microplastic sources. Mapping does not need to begin with a large budget. A city can start with wastewater outfalls, storm drains, road crossings, markets, and industrial zones. Sampling should then confirm particle types and polymers. This creates a local source profile.

The second implication is that filtration should be placed near sources. A filter at a storm drain can intercept particles before dilution. A filter near a laundry outlet can target fibers. A filter near industrial drainage can reveal pellets or PVC fragments. This targeted approach is cheaper than treating a whole river.

The third implication is that filter waste must be controlled. Captured particles should not be washed back to the river. Spent biochar and sludge can become secondary pollution. Safe handling is part of the treatment process. A treatment system without waste control is incomplete.

The fourth implication is that monitoring results should be reported clearly. Each report should state sample volume, mesh size, blank correction, and identification method. Without these details, comparisons are weak. Strong reporting also helps future meta-analyses.

**Table 9** Recommended actions for municipalities and researchers

Action	Reason	Expected result
Monitor key drains and outfalls	Sources are spatially uneven.	Hotspots can be located.
Use blanks and chemical confirmation	Contamination and false positives are common.	Data quality improves.
Install pilot filters at source points	Dilution makes river-wide treatment harder.	Particles are captured earlier.
Combine settling, sand, and biochar	Single media can clog or miss particles.	Removal becomes more stable.
Track spent media disposal	Captured particles remain pollutants.	Re-release risk falls.
Reduce plastic leakage at source	Filtration cannot stop all future inputs.	Long-term load decreases.

### 8. Limitations

This paper has limits. It uses published data from different studies. Those studies used different sampling and identification methods. Therefore, reported abundance values are not fully comparable. The concentration chart should be read as a pattern summary, not a global ranking.

The paper also evaluates filtration using published experiments. Many experiments use controlled particles and clean water. Real stormwater contains mud, leaves, oils, and organic matter. These materials can reduce filter life. Field pilots are needed before large implementation.

Another limit is the lack of a single global standard. Some studies count only particles above 300  $\mu\text{m}$ . Others count smaller particles. Smaller particles are often more numerous. This can make one river look more polluted only because the method detects smaller material. Future work should follow consistent monitoring protocols.

The paper also does not quantify nanoplastics. Nanoplastics are harder to sample and identify. Some filtration systems may miss them. Future studies should test smaller particles using advanced instruments.

## 9. Future Research

Future research should include local field sampling. The best study would sample dry weather, first flush rain, and post-rain conditions. It should sample both upstream and downstream of drains. It should also test inlet and outlet water from a pilot filter.

Future experiments should compare sand-only, sand-biochar, and sand-biomass foam columns. The same inlet water should be used for all columns. The study should measure particles, turbidity, head loss, and flow rate. It should also record how often media must be changed.

More source markers are also needed. Tyre wear particles need better identification. Textile fibers need polymer and dye analysis. Packaging fragments need polymer and weathering data. These details can improve source control.

## 10. Conclusion

Microplastic pollution in surface water is a real and growing problem. Rivers and urban streams receive particles from wastewater, stormwater, litter, roads, and industry. Published monitoring studies show wide concentration ranges. They also show many particle types and polymers. This confirms the need for local source identification.

The evidence supports low-cost filtration as a useful mitigation tool. Sand filtration, biochar columns, and biomass foams can remove large particle shares in tested systems. Strong results were often above 90 percent. Yet filtration is not a complete solution. It must be combined with source reduction, monitoring, maintenance, and safe waste handling.

The most practical response is a layered strategy. Cities should reduce plastic leakage first. They should then monitor priority drains and outlets. After that, they should install pilot filters at high-risk points. A train with screening, settling, sand, and biochar can be tested locally. This approach is realistic, lower cost, and scientifically defensible.

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