A Global Analysis of Microplastics Research: Mapping strategic funding, national research capacity, scientific, priorities, and policy frameworks

18,863 articles · 158 countries · 428 experts · 2004 –2024

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Research Output Tracks National Investment, Not Pollution Burden

- **A pervasive contaminant**

  Microplastics (<5 mm) reach from the deepest oceans to Arctic ice —and, since 2021–2022, into the human placenta and bloodstream.

- **A skewed knowledge base**

  Output concentrates in high- and middle-income nations, while regions with severe plastic pollution often cannot generate local data.

- **Research question**

  What shapes the global microplastics research landscape—and what policy framework follows from that evidence?

- **Why it matters**

  Closing these gaps is an equity imperative—and a prerequisite for globally coordinated solutions.

This study — an integrated three-pillar assessment

1. **Bibliometric analysis**—18,863 WoS articles, 2004–2024
2. **Socioeconomic indicators**—GDP per capita; R&D % of GDP (World Bank)
3. **Global expert survey**—428 respondents, 32 countries

Five aims: map the publication landscape; test how investment and economic strength drive output; capture community consensus on priorities; identify knowledge and methodological gaps; propose a policy framework for mitigation.

Three Data Pillars: 18,863 Articles, Two Indicators, 428 Experts

① BIBLIOMETRIC CORPUS

Web of Science Core Collection; TS = "Microplastic(s)" OR "Micro-plastic(s)", searched May 2024.

29,928 records → 25,111 (2004–2024) → 20,151 (articles) → **18,863 (SCI-E & SSCI)**

② MACROECONOMIC INDICATORS

World Bank Open Data, 2004–2024: GDP per capita (current US$) and R&D expenditure (% of GDP).

Matched to publications by country and year; incomplete series excluded for a **balanced panel**

③ GLOBAL EXPERT SURVEY

Mixed-methods online questionnaire (Google Forms + WeChat), closed-ended with branching logic, anonymous.

428 responses, 32 countries; descriptive statistics + inductive thematic analysis.

- **Reproducible spec**

  R · Bibliometrix + Biblioshiny · tidyverse (merge) · QGIS (maps) | corpus n = 18,863 | survey n = 428

A 428-Expert Survey Complements the Bibliometric Record

Design & dissemination

- **Instrument:** mixed-methods, cross-sectional questionnaire; closed-ended items with contingency branching (Dillman et al., 2014).
- **Reach:** Google Forms worldwide + WeChat in China; academic networks, mailing lists, and research consortia; fully anonymous.
- **Sample:** 428 respondents across 32 countries — China 211, US 58, Germany 36; country-level analysis limited to these three.
- **Analysis:** descriptive statistics for closed items; inductive thematic analysis for open-ended responses (Braun & Clarke, 2006).

Thematic domains covered

Professional profile—demographics, discipline, and geographic location of respondents

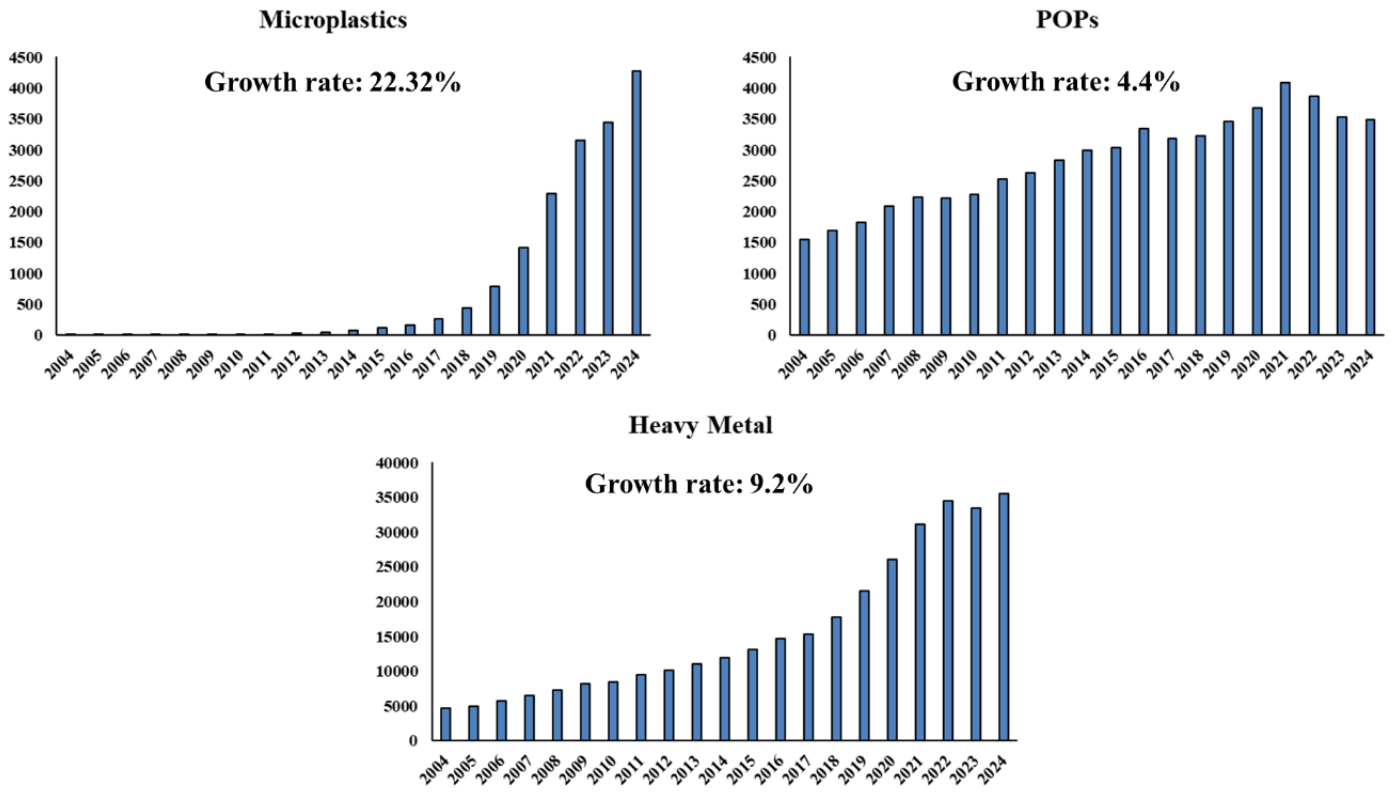
Research focus—environmental monitoring, human-health toxicology, remediation, modelling, instrumentation

Future directions & challenges—pressing issues, technical barriers, effective approaches

Barriers to entry—for non-active researchers: funding, technical hurdles, data access

Microplastics Research Grows at 22.3% CAGR—Far Above Legacy Pollutants

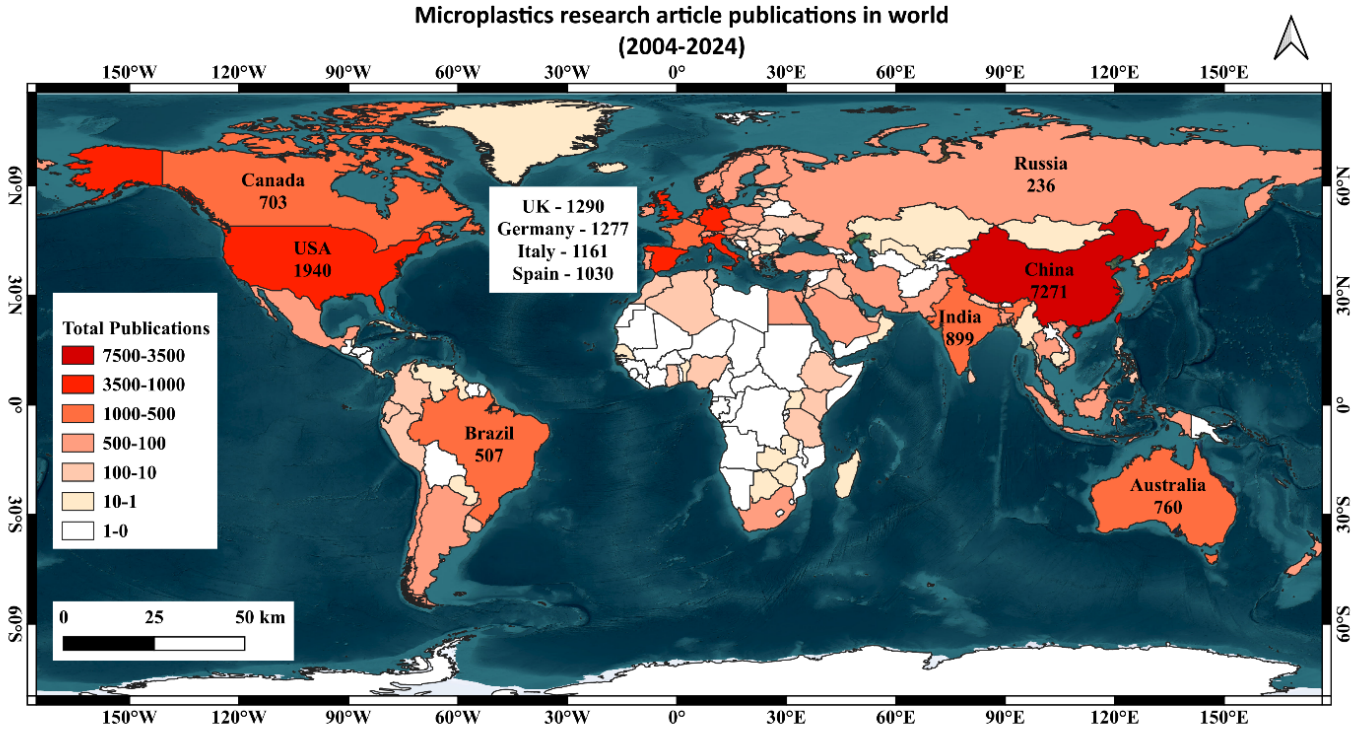
- **7 articles in 2004 → 4,266 in 2024**; 35,472 documents in total (WoS).
- Legacy pollutants grow steadily: POPs at **4.4%** and heavy metals at **9.2%** CAGR.
- **Acceleration ≈ 2014:** UNEA Resolution 1/6 on marine plastic debris and microplastics.
- **Second surge 2018–19:** Basel Convention plastic-waste amendment; first detection of microplastics in human stool.



Annual publication counts, WoS 2004–2024 (Fig. 4)

China Produces 26.7% of Global Output; High-Burden Regions Stay Invisible

- **China: 7,271 articles (26.73%)**—nearly 4× the US (1,940); field-high h-index 567.
- **16 of the 20 most productive institutions are Chinese**; the Chinese Academy of Sciences leads with 505 articles.
- Asia (44.28%) and Europe (35.54%) hold **79.82%** of output; Africa 2.46%, South America 3.63%.
- Pollution hotspots barely register: **Indonesia 155** articles, **Philippines 41**.



Article counts by country, WoS 2004–2024 (Fig. 2)

Volume Sits in China; Per-Paper Impact Sits in Western Europe

Country	Articles	Citations	h-index	ACPP	Strategic model
China	**7,271**	**322,213**	**567**	47.09	High-volume output under targeted state funding
United States	1,940	—	284	77.23	Balanced volume and per-paper influence
United Kingdom	1,290	—	—	**115.28**	High-impact model; foundational contributions
Netherlands	—	—	—	**131.88**	Smaller system, exceptional citation efficiency
India	899	—	—	30.49	Emerging capacity, rising volume
South Korea	836	—	—	43.99	Emerging capacity, rising volume

- **Institutions:** 16 of the global top 20 are Chinese; the Chinese Academy of Sciences leads with 505 articles, 38,094 citations, and h-index 104. University of Toronto posts the second-highest institutional ACPP (87.10).
- **Authors:** Huahong Shi leads productivity metrics (66 articles, h-index 48); Richard C. Thompson exemplifies the high-influence model with an unmatched ACPP of 336.14.

A Young Field: Highly Collaborative, Highly Cited, Global in Reach

47,826	**authors** contributed to the corpus — on average 6.1 co-authors per article, with 28.63% of publications involving international co-authorship.
53.22	**average citations per article** — a citation impact well above typical environmental-science fields, reflecting the urgency of the topic.
29,527	**author keywords** (plus 13,273 system-generated) — a vocabulary spanning environmental fate, ecology, chemistry, and human toxicology.
158	**countries** contribute publications — a globally networked endeavor, yet with output concentrated in a small group of nations (next slides).

Basis: 18,863 original research articles, Web of Science Core Collection, 2004–2024.

Engagement Needs Sustained R&D Above ~0.5% of GDP—Not a Large Economy

Country / region	Articles	GDPpc (US$)	R&D (% GDP)	Pattern
China	**7,271**	8,244	1.66	Targeted state funding → volume leadership (NSFC: 4,471 articles)
United States	1,940	60,546	2.46	High capacity, modest share —the policy paradox
Japan	538	—	2.60	High investment, different national priorities
Malaysia	262	—	0.48	Near the threshold; relatively strong output
Indonesia	155	—	0.11	Severe pollution, minimal research engagement
Philippines	41	—	<0.1	Severe pollution, minimal research engagement
Africa (all)	688	—	0.07	Below the threshold across the region

- **Threshold effect:** average R&D below 0.5% of GDP → consistently minimal engagement, regardless of pollution burden.

Funding mirror: China's NSFC supported 4,471 articles; Africa (R&D 0.07%) and South America (0.24%) barely register.

Regulatory Coherence, Not GDP, Best Predicts Research Output

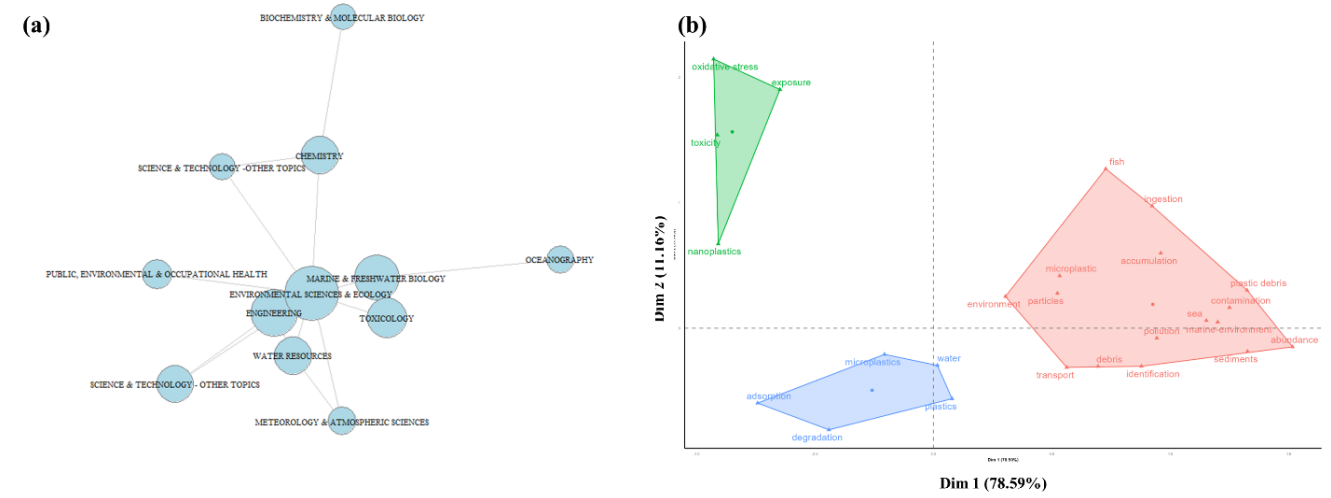
Four national policy regimes

- **Europe—the coordinated model:** the Single-Use Plastics Directive and EU Horizon 2020 funding align regulation with research investment; output 35.54% of the global total.
- **United States—the policy paradox:** the largest economy (GDPpc $60,546; R&D 2.46%) delivers only 10.68% of output, under fragmented federal plastic regulation.
- **China—the top-down model:** microplastics embedded in the national "Ecological Civilization" strategy; middle-income GDP, field-leading volume.
- **Emerging movers:** Saudi Arabia's Vision 2030 and Türkiye's EU-aligned reforms are beginning to mobilize research; Southeast Asia still lacks policy and funding.

- The ongoing UN plastics treaty negotiations (UNEA 5/14, 2022) could redirect global research focus and funding toward today's gaps.

Three Keyword Clusters Track the Pivot from Fate to Human Health

- **Cluster 1 · Material properties & fate:** degradation, adsorption — baseline particle behavior in aquatic systems.
- **Cluster 2 · Occurrence & ecological pathways:** the largest cluster — sediments, ingestion, fish; monitoring meets exposure.
- **Cluster 3 · Toxicology & health risks:** nanoplastics, oxidative stress — the mechanistic, health-facing frontier.
- **Citation trajectory:** Geyer et al. (2017), 11,309 citations → microplastics in placenta (2021), 371 cites/yr → in blood (2022), **515 cites/yr** — the field's fastest-moving front.



(a) Research-area network; (b) keyword factorial map (Fig. 3)

The Field Pivot Is Visible in Citations: Placenta 371/yr, Blood 515/yr

① SCALE OF THE CRISIS

Geyer et al. (2017)—production, use, and fate of all plastics ever made.

11,309 citations—the field's most-cited paper.

→

② ECOLOGICAL EFFECTS

The **"Plastisphere"** and organismal uptake studies map biological interaction across the food web.

Amaral-Zettler et al. (2020); Lusher et al. (2013).

→

③ HUMAN HEALTH CRISIS

Microplastics in **placenta** (Ragusa et al., 2021) and **blood** (Leslie et al., 2022).

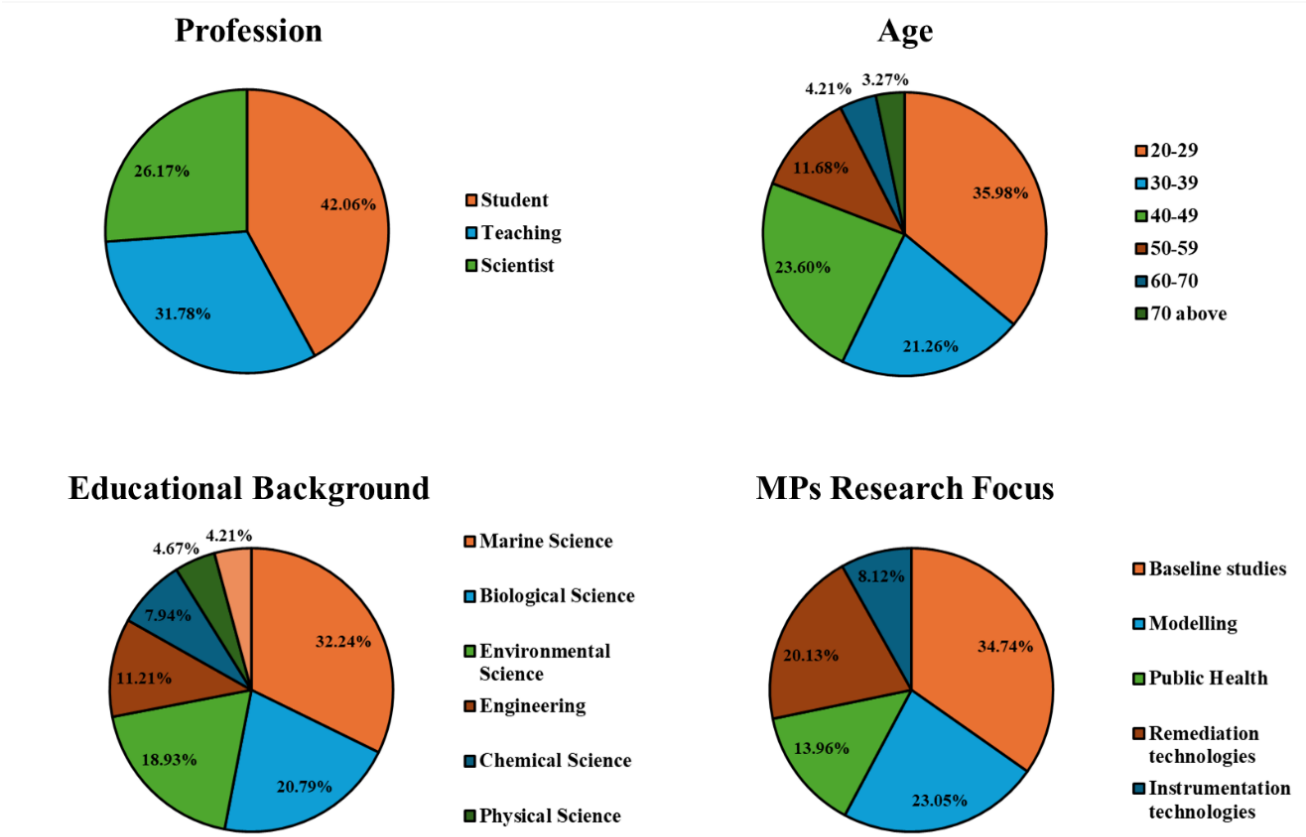
371 and 515 citations/year—the fastest-moving front.

- The citation record reads as one narrative: from documenting environmental contamination to quantifying human exposure—defining the field's maturation and its current urgency.

- **Where the knowledge is published:** Science of the Total Environment carries the largest volume; Environmental Science & Technology shows the highest per-article impact (ACPP 155.08), alongside Water Research and Environment International. High impact factors correlate strongly with high ACPP.

A Young, Student-Led Community, Anchored in Marine Science

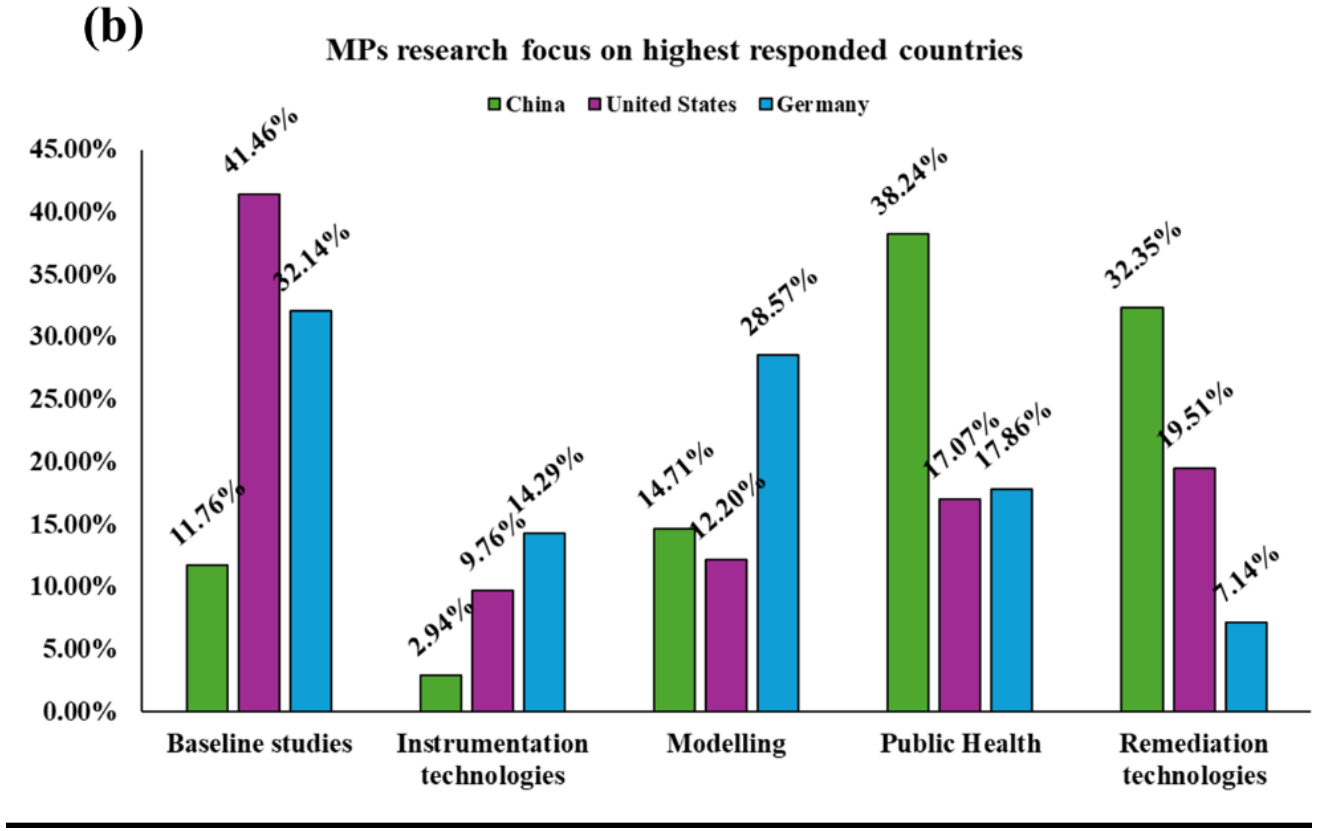
- **428 respondents, 32 countries** China 211, US 58, Germany 36; Thailand 18, Bangladesh 17, India 14.
- Age: **20–29 leads at 36.0%** 40–49 at 23.6%; 30–39 at 21.3%.
- Profession: **students 42.1%** teaching staff 31.8%, scientists 26.2%.
- Discipline: **marine science 32.2%** biological science 20.8%, environmental science 18.9%.
- Current work: baseline studies 34.7%; modelling 23.1%; remediation 20.1%; public health 14.0%; instrumentation 8.1%.



Survey demographics and research focus (Fig. 5)

A De Facto Division of Labor: Baseline Pioneers vs. Technology Developers

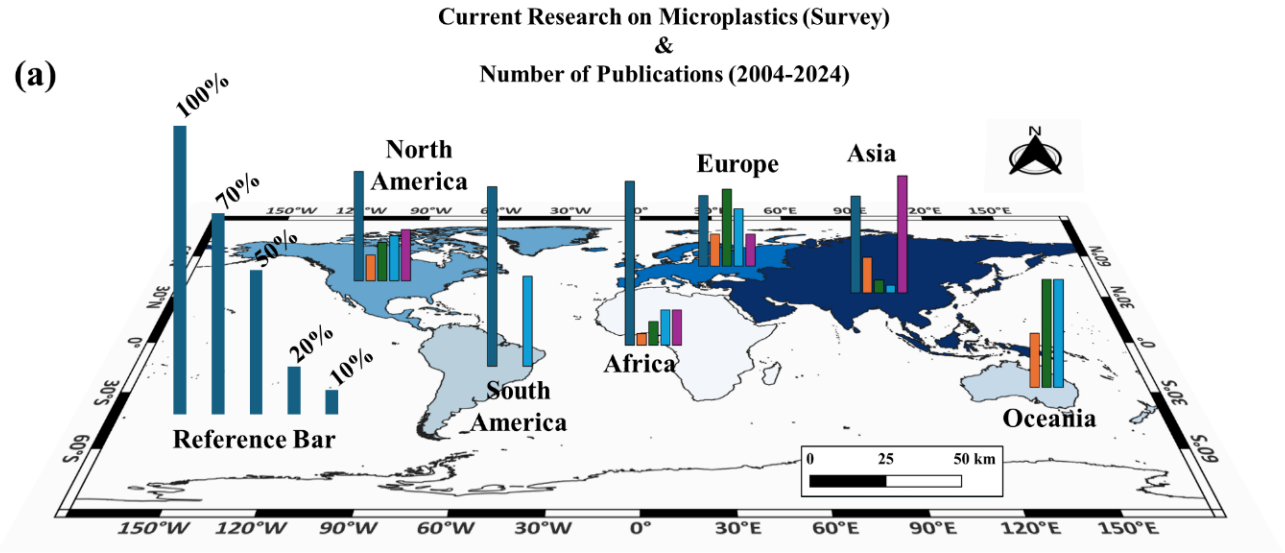
- Survey: **428 respondents, 32 countries**; students 42.1%, aged 20–29 36.0%; marine science 32.2%.
- Current work worldwide: **baseline studies 34.7%**, modelling 23.1%, remediation 20.1%, public health 14.0%.
- Africa (60.9%) and South America (66.7%) work mainly on **baseline monitoring**.
- China leads remediation (32.4%) & public health (38.2%); Germany leads modelling (28.6%).



Research focus in the three highest-responding countries (Fig. 6b)

Without China, Asia's Focus Shifts Back to Baseline Monitoring

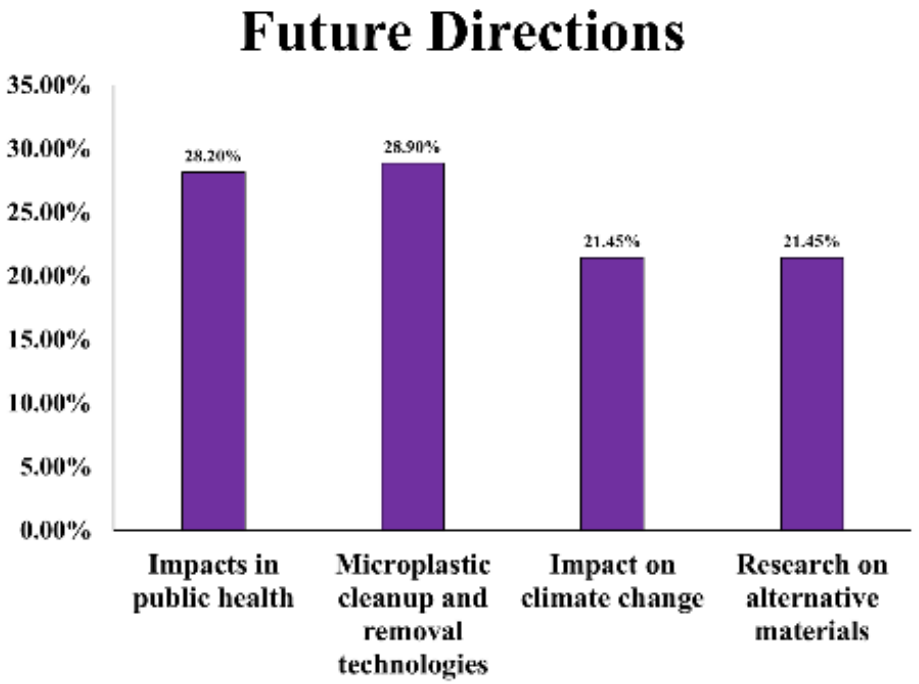
- Asia contributes **44.28%** of global publications—but China alone accounts for **60.38%** of Asia's share.
- Excluding China, Asia's focus reverts to **baseline studies (~63%)**—mirroring Africa (60.87%) and South America (66.67%).
- Oceania shows the opposite extreme: activity only in **instrumentation, modelling, and public health**
- Continental profiles are **national priorities in disguise**—the case for targeted capacity-building in the Global South.



Current research focus (survey) vs. publication counts by continent (Fig. 6a)

Consensus Priorities: Cleanup Technology (28.9%) and Human Health (28.2%)

- Top technical barriers: **identifying & quantifying microplastics (31.2%)** lack of standardized methods (26.5%).
- Preferred solutions: **biodegradable alternatives (32.3%)** improved recycling systems (31.1%).
- National accents differ —US: public health; China: alternative materials; Germany: cleanup & climate links.
- Yet all agendas converge on **health, cleanup, and climate interactions**.



Future research directions, global responses (Fig. 7a)

The Community's Agenda: Fix Waste Management, Standardize Methods

- **Most pressing concerns (global)**
- **Ineffective waste management—36.2%**
- **Marine accumulation—31.7%**
- Health impacts —17.6%
- Limited public awareness—14.5%

National accents: German (39.7%) and US (39.5%) experts prioritize waste management—reflecting advanced policy frameworks —while Chinese respondents emphasize public awareness (27.6%) and health effects (26.2%).

- **Perceived effective solutions (global)**
- **Biodegradable alternatives—41.1%**
- **Enhanced recycling—30.8%**
- Public awareness campaigns; singleuse bans follow

National accents: Germany strongly prefers biodegradables (48.0%); China emphasizes recycling (31.4%) and awareness campaigns (27.6%).

- **Key barriers:**identification & quantification challenges (29.9%) and lack of standardized methods (27.8%)—the technical bottleneck that Tier 3 of the policy framework addresses.

Without Common Methods, Risk Assessment Rests on Incomparable Data

Methodological gaps in the field

- **Sampling:** gear and volumes differ (100 L to >1,000 L), so concentrations in particles/m^3 are not comparable.
- **Identification:** FTIR / Raman give particle detail but invite operator bias; Pyro-GC/MS gives mass data but destroys particles; reference libraries are not harmonized.
- **Exposure:** most fish studies sample gut and gills — tissues rarely eaten; edible-flesh (fillet) evidence remains scarce.
- **Risk assessment:** no formal frameworks exist for human exposure or terrestrial ecosystems; HC5 values from SSDs are unreliable.

Limitations of this study

- **Database coverage:** WoS underrepresents Global South journals — the geographic disparities reported here are therefore **lower-bound estimates**.
- **Survey skew:** 211 of 428 respondents (≈50%) are from China. Findings are interpreted jointly with the bibliometric data, and country-level responses are reported separately.
- **Scope:** review articles excluded; sentiment and gray-literature dimensions remain for future work.

Gut-and-Gill Studies Overstate the Dietary Exposure Pathway

The exposure-evidence gap

- **What is measured:** most fish studies analyze the **gastrointestinal tract and gills**, where microplastics primarily accumulate.
- **What is eaten:** these organs are **almost universally discarded** in culinary preparation and rarely consumed.
- **The weak link:** translocation to edible muscle (fillet) is reported, but studies are **scarce and concentrations very low**.
- **The consequence:** extrapolating gut/gill data to human dietary exposure is **scientifically tenuous** and risks overstating the immediate public-health concern.

The measured-to-consumed mismatch

Measured — microplastics accumulate in fish gastrointestinal tract and gills

↓

Discarded — gut and gills are removed during culinary preparation, rarely consumed

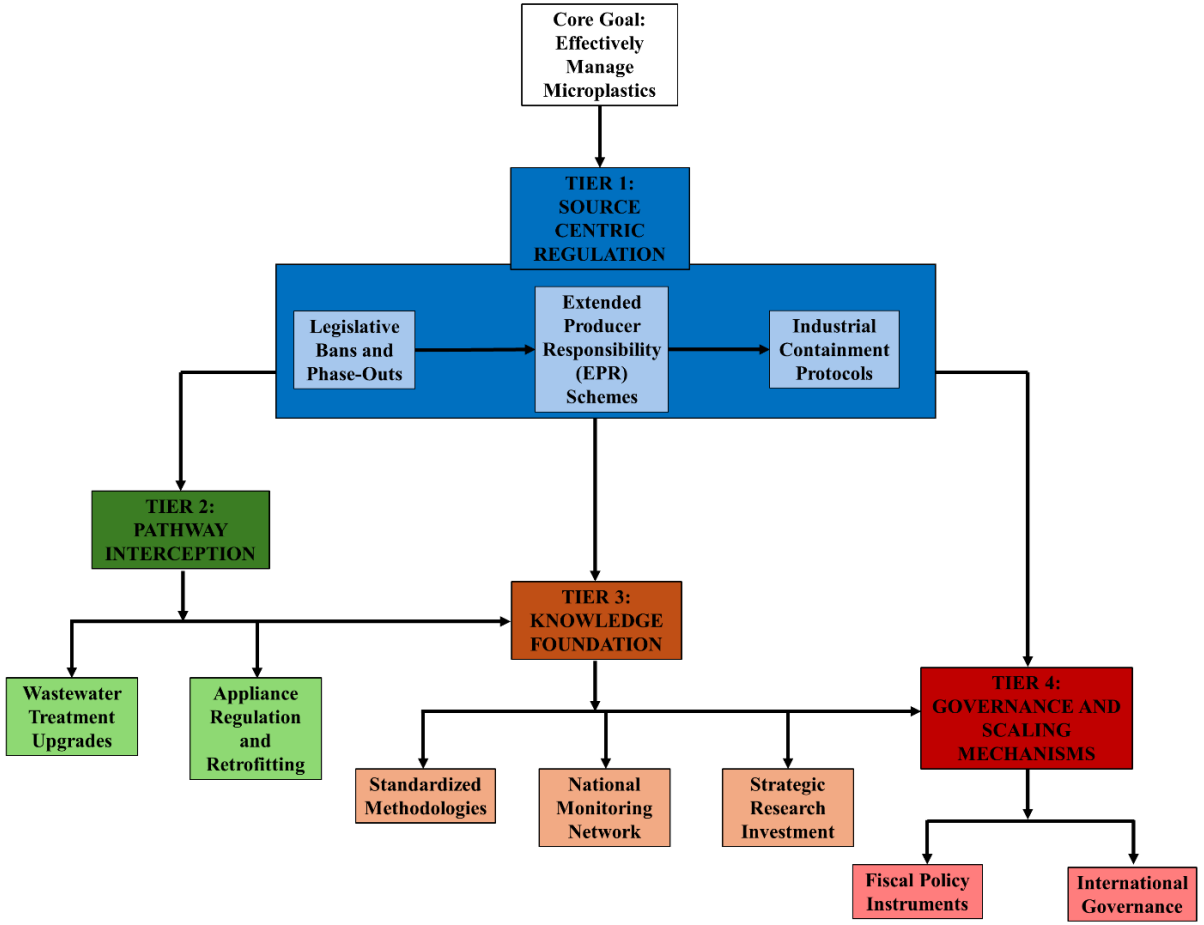
↓

Actually eaten — edible fillet; translocation evidence scarce, concentrations very low

The way forward: standardized analysis of microplastics in the **edible flesh (fillet)** of commonly consumed fish species — a realistic measure of potential human exposure.

A Four-Tier Framework Moves Policy Upstream—Source to Governance

- **T1 · Source-centric regulation:** bans on intentionally added microplastics; extended producer responsibility; industrial containment —upstream prevention is the neglected research domain.
- **T2 · Pathway interception:** advanced wastewater treatment; washing-machine microfiber filters —answers the top perceived challenges (waste management, marine accumulation).
- **T3 · Knowledge foundations:** standardized methods, national monitoring, targeted R&D —answers the top technical barrier (no standard methods).
- **T4 · Governance & scaling:** virgin-polymer tax; binding treaty targets —regulatory coherence, not GDP, predicts output.



A four-tiered policy framework for microplastics mitigation (Fig. 8)

A Tripartite Shift: Equity, Standards, and Aligned Agendas

To harness the field's momentum, three strategic shifts are essential

1. **Correct geographic inequity**

   Targeted capacity-building and equitable partnerships that prioritize research where the pollution burden is highest—Southeast Asia, Africa, South America.

2. **Establish universal methodological standards**

   Harmonized sampling, analysis, and reporting protocols to generate reliable, comparable, policy-relevant data worldwide.

3. **Align global agendas with consensus priorities**

   Human-health risk assessment, affordable remediation technologies, and sustainable material design.

The microplastics crisis is a quintessential Anthropocene challenge—demanding a response as interconnected as the pollutant itself, built on equity, rigor, and mission-driven collaboration.

Conclusions: Fund Capacity Where the Burden Is, Standardize Measurement

1. Microplastics research is in **hypergrowth (22.3% CAGR)** and has pivoted decisively toward human health.

2. Research geography mirrors **investment and policy coherence—not pollution burden** (≈0.5% R&D-of-GDP threshold).

3. A global division of labor: the Global South monitors baselines; the Global North builds health and remediation science.

4. The community agrees on priorities —**cleanup technology, human health, climate links**—and on the standardization barrier.

Open questions (2)

- How can funding and partnerships build research capacity in high-burden, low-income regions — Southeast Asia and Africa above all?

- Can the UN global plastics treaty lock in binding monitoring standards and microplastic reduction targets?

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