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Characteristics of microplastic particles that influence atmospheric deposition in remote regions

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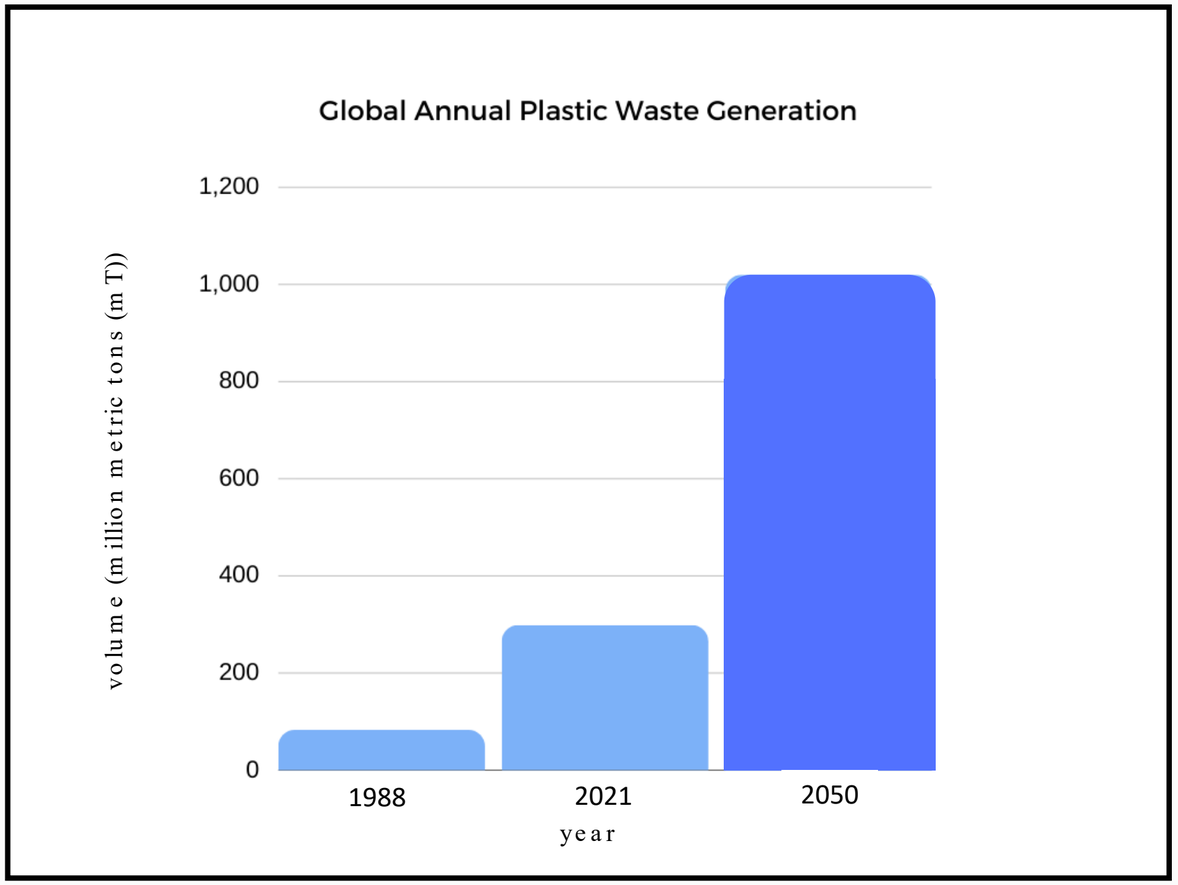
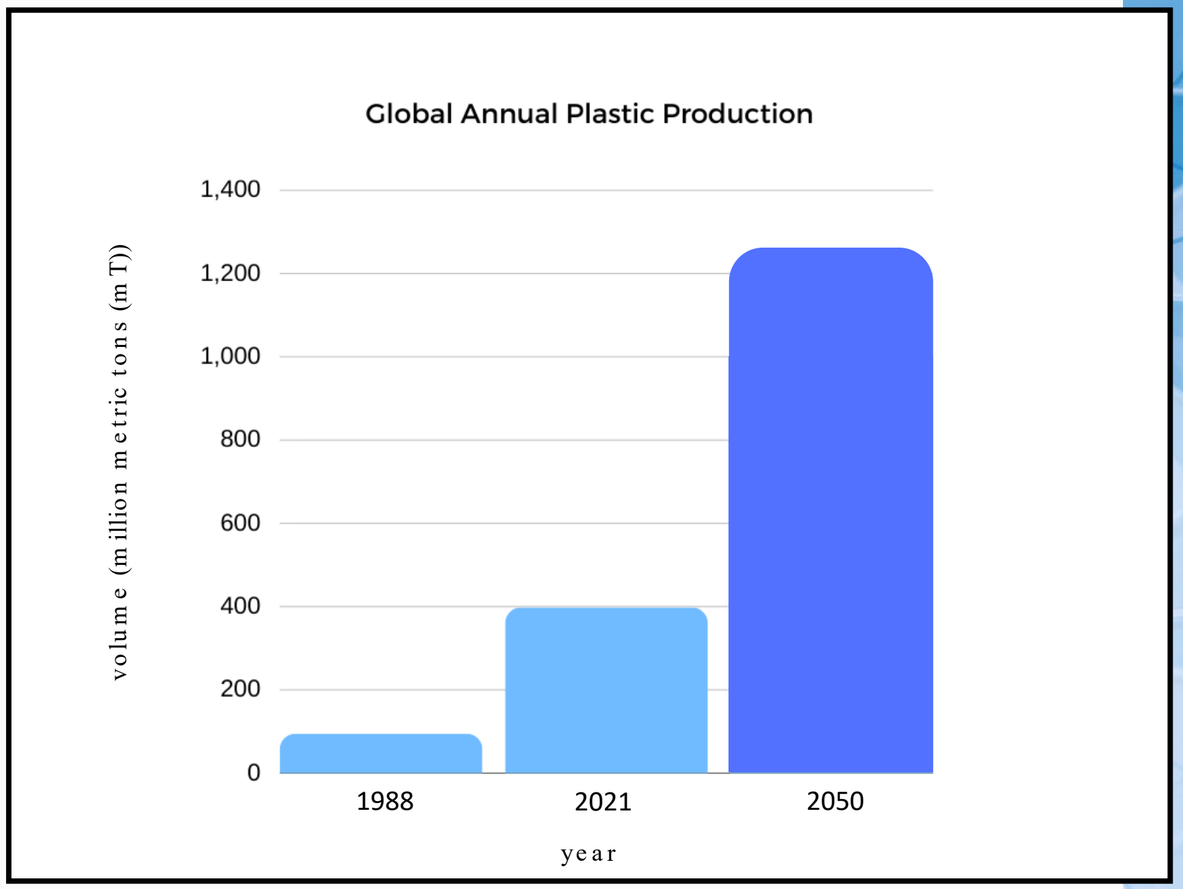
Rapid Increase in Plastic Production



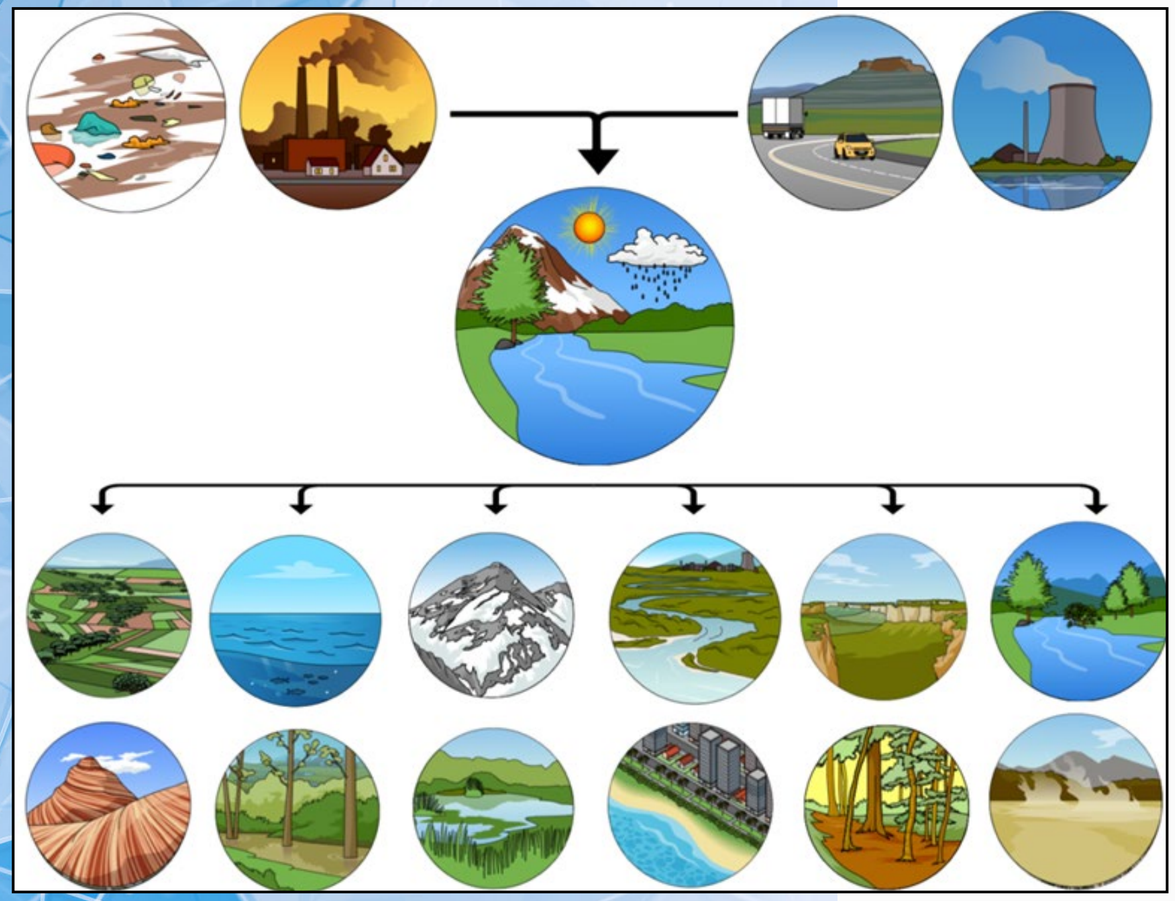


Annual average by 2050: 846 million mT

Annual average by 2050: 1.007 billion mT

Addor, John & Wiah, Eric & Alao, Felix. (2022). An Improved Two-states Cyclical Dynamic Model for Plastic Waste Management. Asian Research Journal of Mathematics. 52-68. 10.9734/arjom/2022/v18i530378.

Ubiquity and Environmental Threats



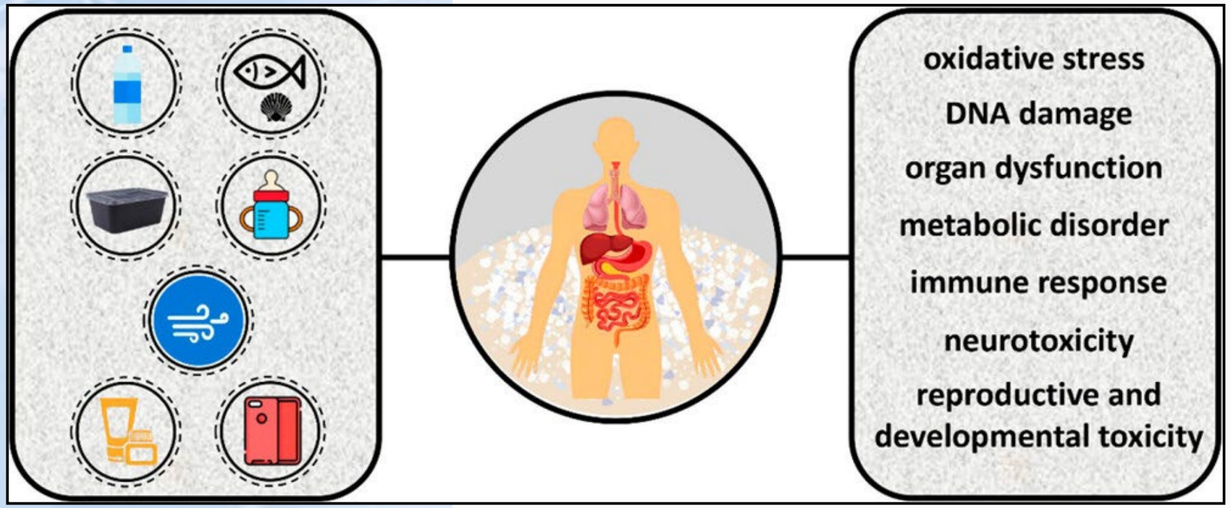
The extent of ecosystems which plastic pollutants (sourced from urban areas or anthropogenic activity) can enter via atmospheric deposition and other long - range transport pathways.

- Most plastics disintegrate over time, forming microplastics (1 -5000 µm) and nanoplastics (<1µm) that can be transported over large distances.

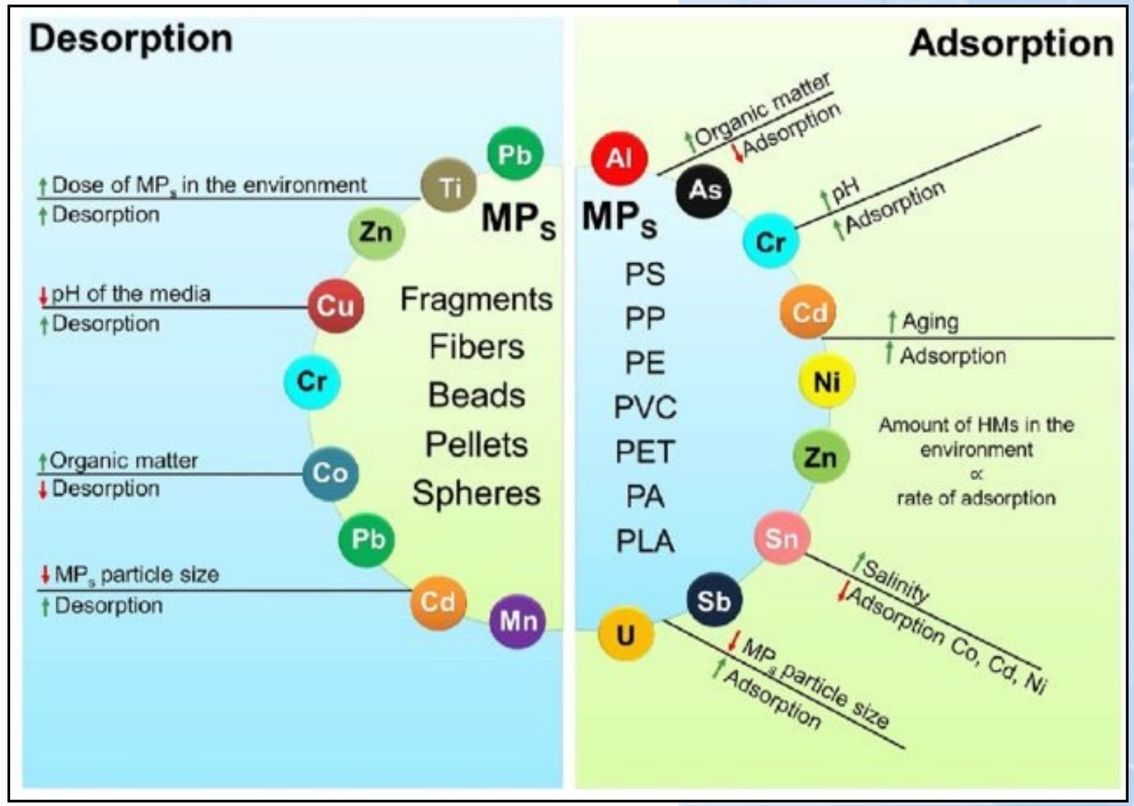
- Microplastic particles (MPs) are found ubiquitously, even in remote areas, indicating widespread environmental pollution.

- MPs interfere with natural processes, posing significant threats to ecosystems and exacerbating the climate crisis.

Human Health Impacts



Exposure pathways and toxicity of MPs in the human body.
(Li et al., 2023)

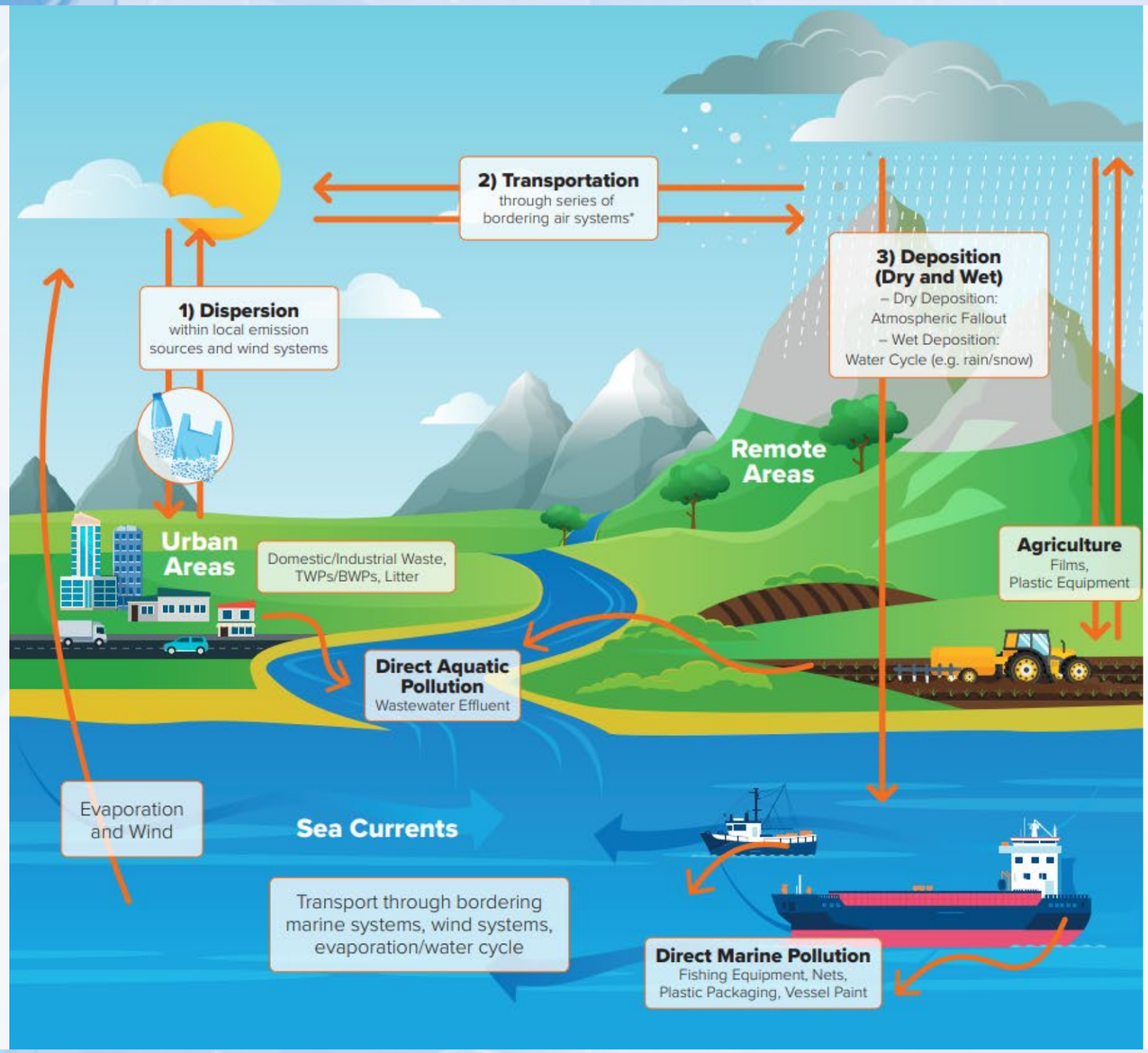


Factors affecting the mechanisms of adsorption and desorption of heavy metals on MPs. (Khalid et al., 2021)

Li Y, Tao L, Wang Q, Wang F, Li G, Song M. Potential Health Impact of Microplastics: A Review of Environmental Distribution, Human Exposure, and Toxic Effects. Environ Health. 2023;1(4):249 -257. doi:10.1021/envhealth.3c00052y.

Khalid, Noreen & Aqeel, Muhammad & Noman, Ali & Khan, Shujaul & Akhter, Noreen. (2021). Interactions and effects of microplastics with heavy metals in aquatic and terrestrial environments. Environmental Pollution. 290. 118104. 10.1016/j.envpol.2021.118104.

Sources and Transport Mechanisms



An illustration of atmospheric transport of microplastics (MP) and other transport pathways.

Research Objectives

RO1: Determine if there is a significant difference in the observed characteristics of MP pollutants in remote/urban areas versus expected

RO2: Identify outliers in the absolute difference of remote/urban MP pollutants' physical characteristics (shape, polymer composition, color)

Research Methods

Systematic Review

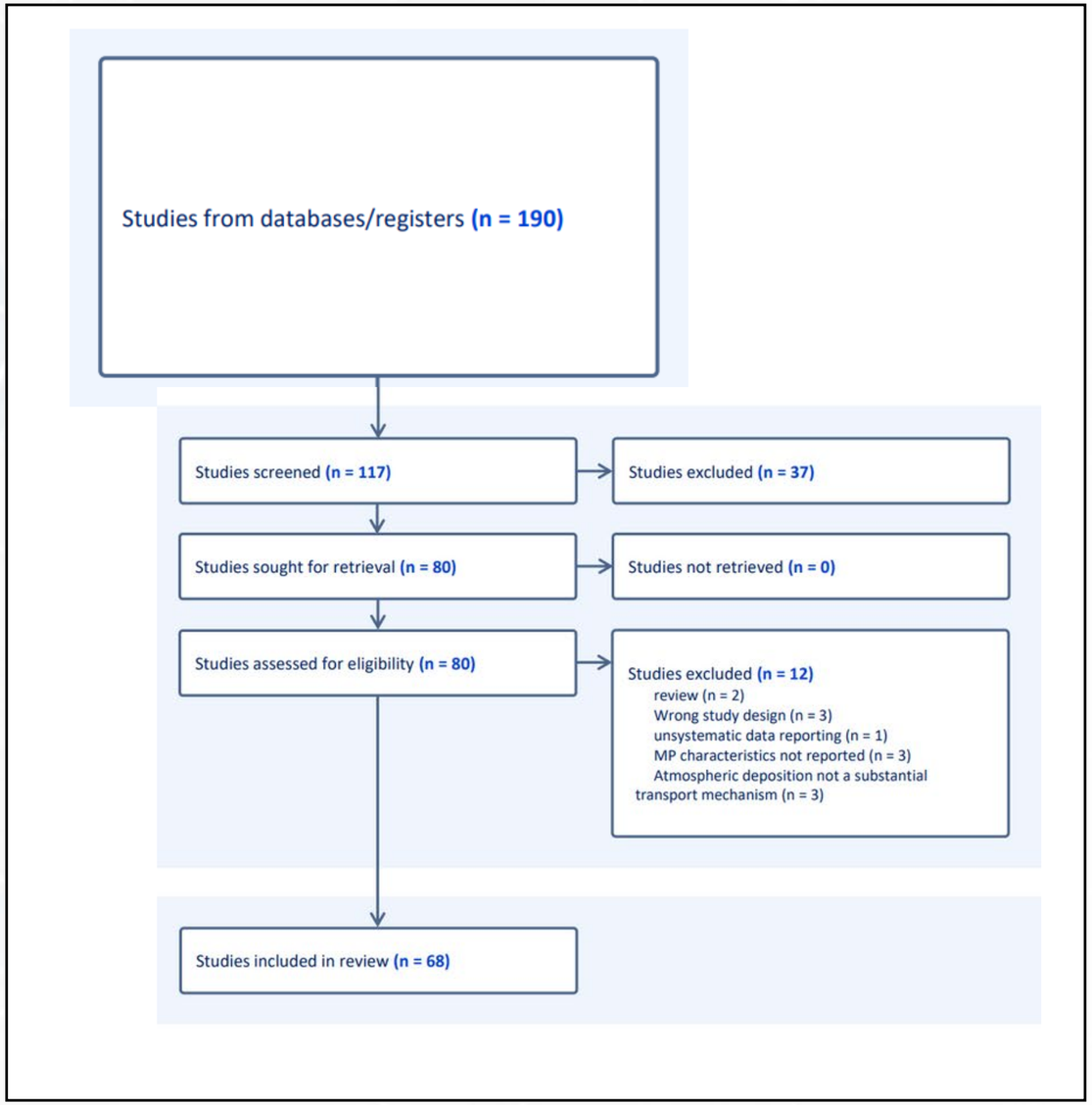
Search string:

‘microplastics AND (“atmospheric transport” OR “atmospheric deposition”) AND (“size” OR “shape” OR “color” OR “polymer composition”) AND NOT review’

190 articles returned

Abstract and Full-Text Screening

68 articles included for data extraction



PRISMA Flow Diagram created using Covidence Systematic Literature Review tool.

Article Information, **Study Location Characteristics**	• Title • Author • Location of study • GPS coordinates • Altitude • Period of sampling (dates) • Population Density
Sample Characteristics	• Number of samples taken • Sample State (depositional, surface water, soil, SAMPS, etc.) • Sample size (volume/mass)
Methods Information	• Sampling method • Sample pretreatment • Microscopes used • Polymer Identification Method • Statistical Tests • Quality Assessment/Quality Control
Microplastic Characteristics	• Number of microplastics found • Size range • Shapes • Colors • Polymer Compositions
HYSPLIT	• HYSPLIT usage (Yes/No)
Additional Information	• Competing Interests • Additional comments

Data categories extracted from the literature used in this meta-analysis.
Some features (size range, number of microplastics found, HYSPLIT usage) were not accounted for in the meta-analysis due to inconsistencies in reporting styles of the literature pool.

Meta - Analysis

Chi Square Frequency

- Observed versus expected frequencies of MP characteristics in remote and urban samples
  - Shape
  - Polymer Composition
  - Color

Interquartile Range Test

- Determining outliers in absolute difference between remote and urban sample percent compositions by MP characteristic
  - Shape
  - Polymer Composition
  - Color

Results

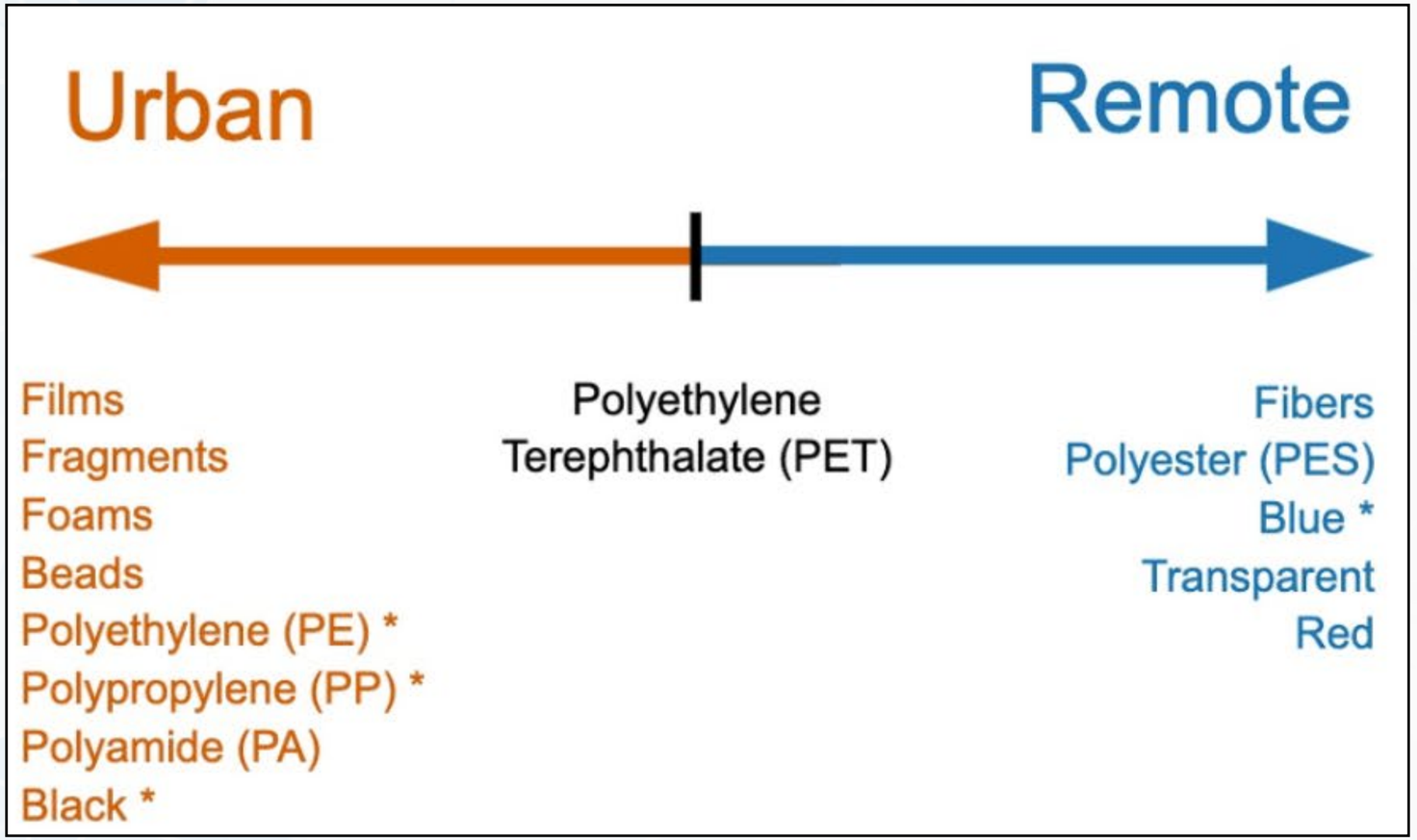
Observed vs Expected Frequencies of MP Characteristics

800 Urban Samples

1278 Remote Samples

Significant difference in frequencies between urban and remote locations of MP shapes ($p = 3.31E-47$), polymer compositions ($p = 3.69E-58$), and colors ($p = 4.13E-44$).

Interquartile Range Test -- Outliers



Distribution of Major MP Physical Characteristics by Sampling Location.
*Denotes a significant difference between urban and remote sampling location presence as determined by IQR test.

Shape

No outliers

Polymer Composition

Urban : PE, PP

Color

Urban : Black

Remote : Blue

Discussion - Implications and Key Takeaways

Significance of Patterns in Microplastic Transport

- Patterns in microplastic particles' transport extent based on physical characteristics highlight differences between urban and remote areas.

- Small p -values from statistical tests indicate significant variations in microplastic characteristics, emphasizing the need for further investigation into the mechanisms behind these differences.

Shape

$p = 3.31 * 10^{-47}$

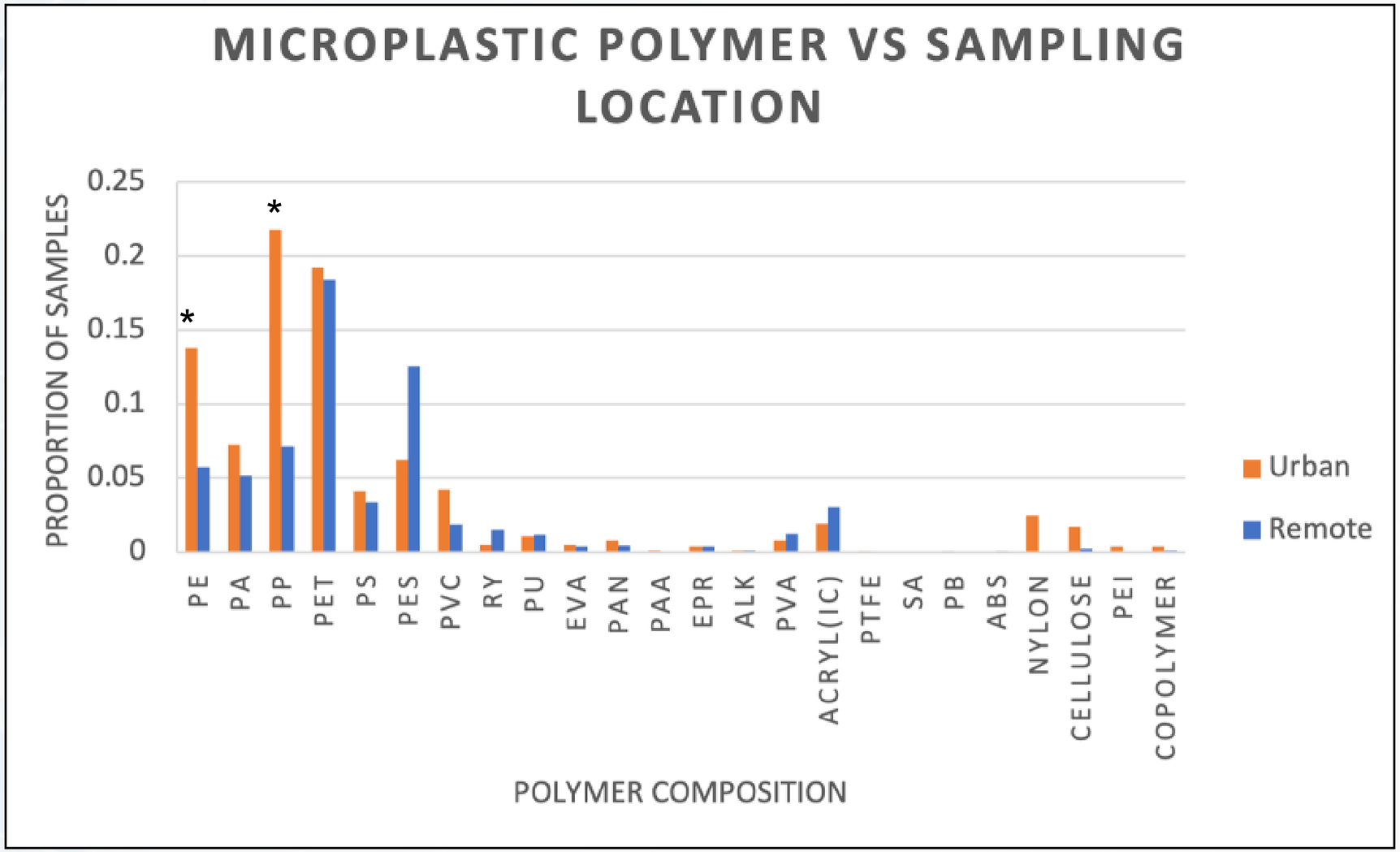
Color

$p = 4.13 * 10^{-44}$

Polymer Composition

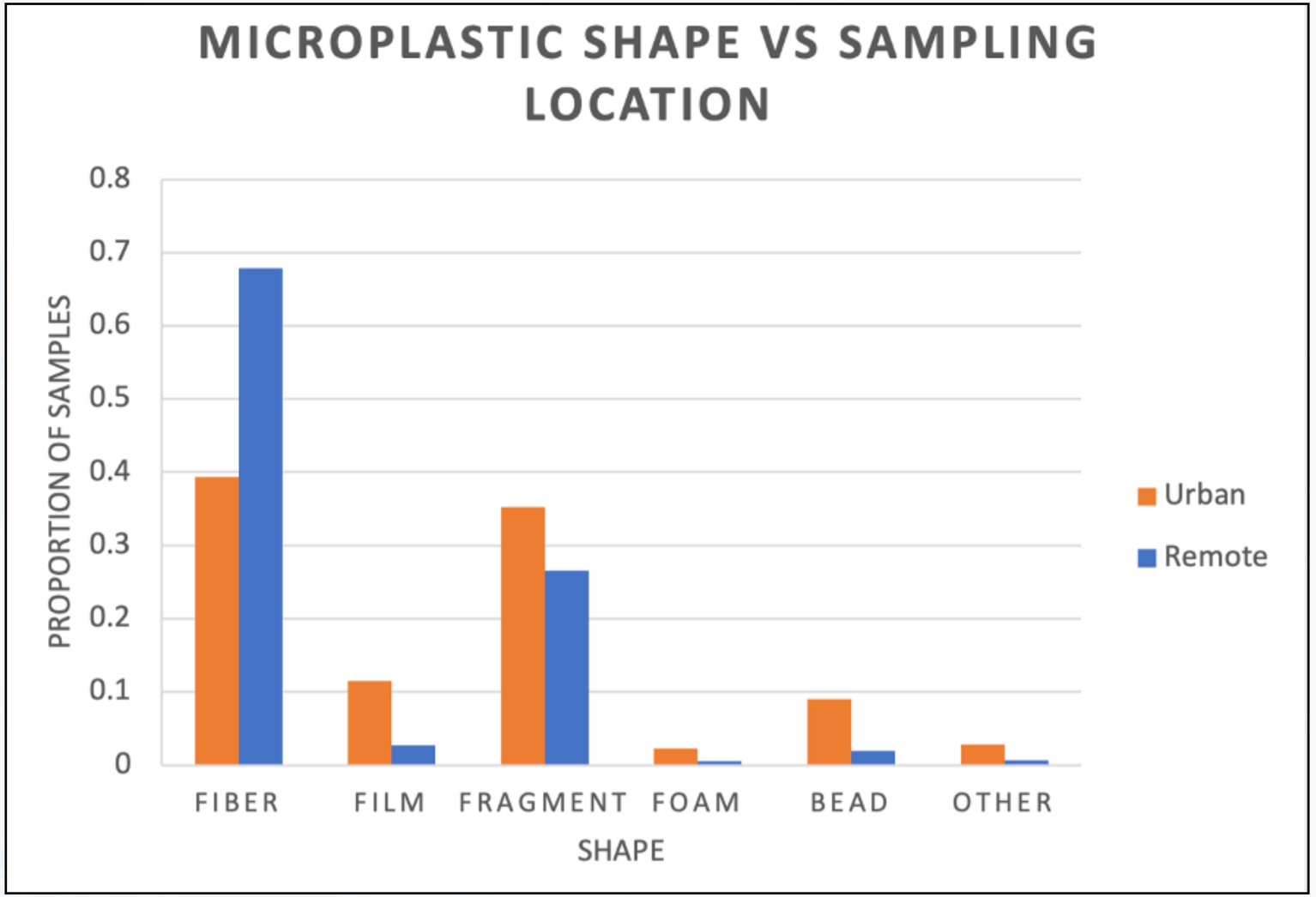
$p = 3.69 * 10^{-58}$

Polymer Composition Insights



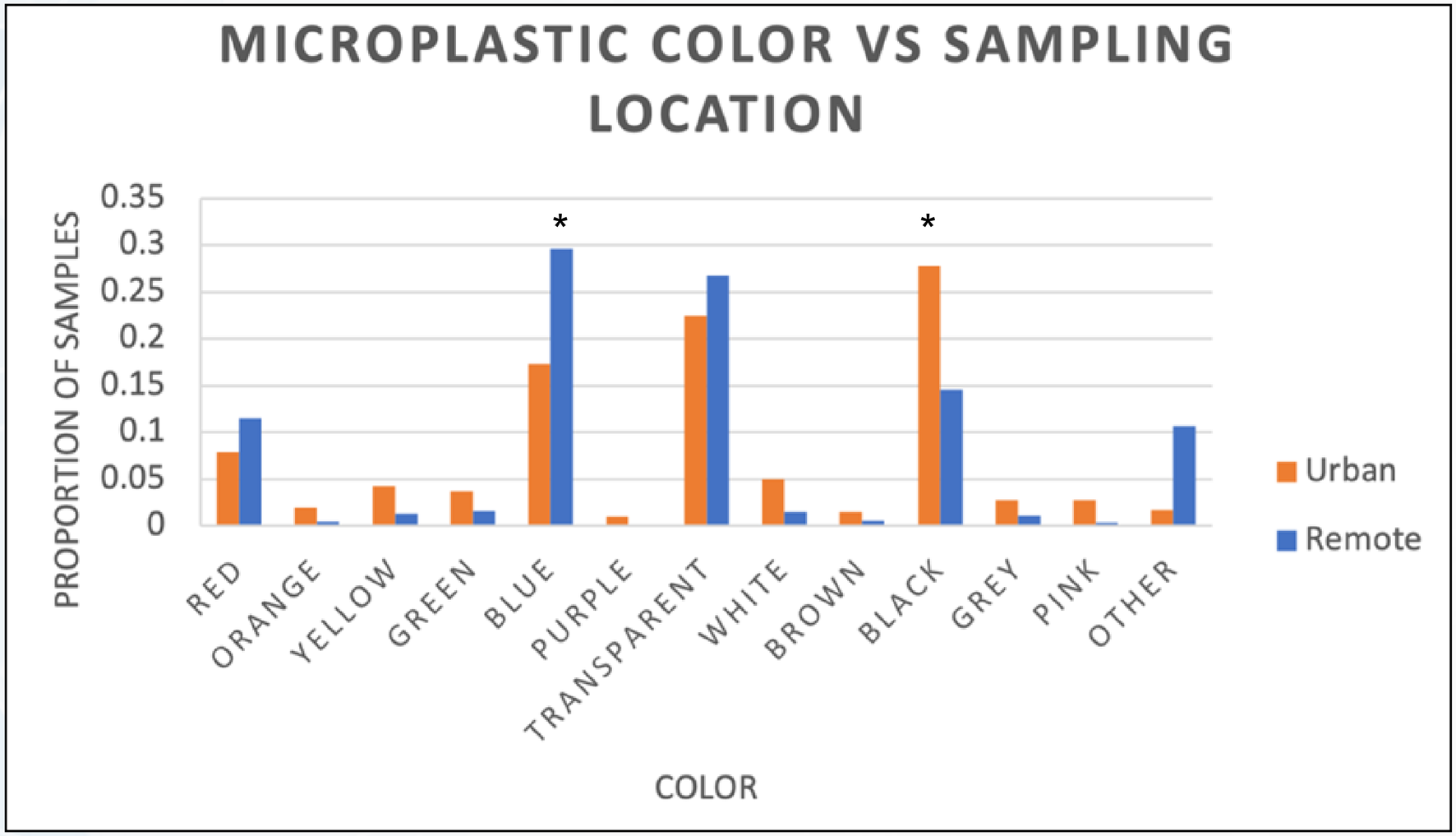
Proportional Frequency of MP Polymer Composition by Sampling Condition.
*Denotes a significant difference between urban and remote sampling location presence as determined by IQR test.

MP Shape and Transport



Proportional Frequency of MP Shape by Sampling Condition.

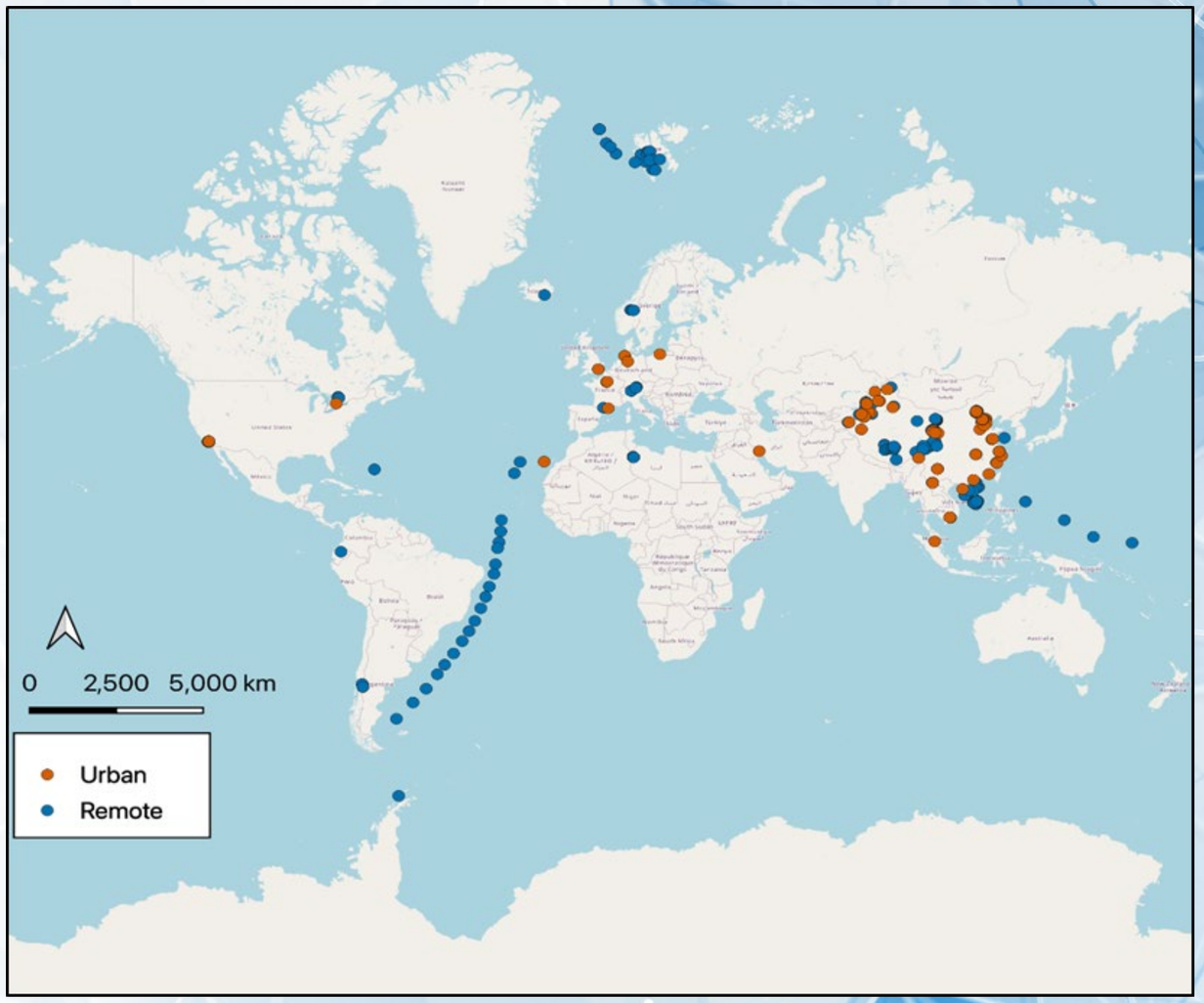
Color as a Transport Indicator



Proportional Frequency of MP Color by Sampling Condition.
*Denotes a significant difference between urban and remote sampling location presence as determined by IQR test.

Geographic and Socioeconomic Considerations

- Remote areas, including the Arctic Circle and remote oceans, are not immune to microplastic pollution, emphasizing its global impact on ecosystems and human health.
- Ethical concerns arise from the lack of data on microplastic pollution in regions with low socioeconomic status, necessitating initiatives to study pollution in these areas.



World map with locations of sample sites from the reviewed literature. MPs were found at all illustrated coordinates, as classified by the authors for each data set.
Map was created using QGIS Software. Scale bar is set to kilometers.

Conclusion

This meta -analysis of 68 studies and 2078 data sets reveals the significance of MP physical characteristics (shape, polymer composition, color) in correlation to global atmospheric transport potential.

Chi square and IQR results suggest an uncovered role that physical characteristics play in MP atmospheric transport extent.

Further work is needed to understand how specific MP characteristics interact with atmospheric cycles to extend or limit transport to remote regions.

Future Work

- Expand knowledge of the physical causes for global MP atmospheric transport extent.
- Develop effective prevention and remediation methods to combat long-range MP transport.
- Emphasize further study of underrepresented regions to comprehend full global MP pollution extent.
- Standardize reporting of MP size characteristics, and abundance.
- Identify accessible analytical techniques to enable broader testing of MP pollution.

Author Contributions

Project supervision - M.P., H.S., E.J.Á.

Conceptualization - H.S., E.J.Á., E.Z., S.F.

Methodology - H.S., E.J.Á., E.Z., S.F.

Data Collection - S.F., E.Z.

Data Analysis and Validation - S.F.

Original draft - S.F., E.Z.

Figures and tables - S.F., Á.S.G., M.P.

Review and editing of the paper - H.S., E.J.Á., M.P., P.W., E.Z., M.K.

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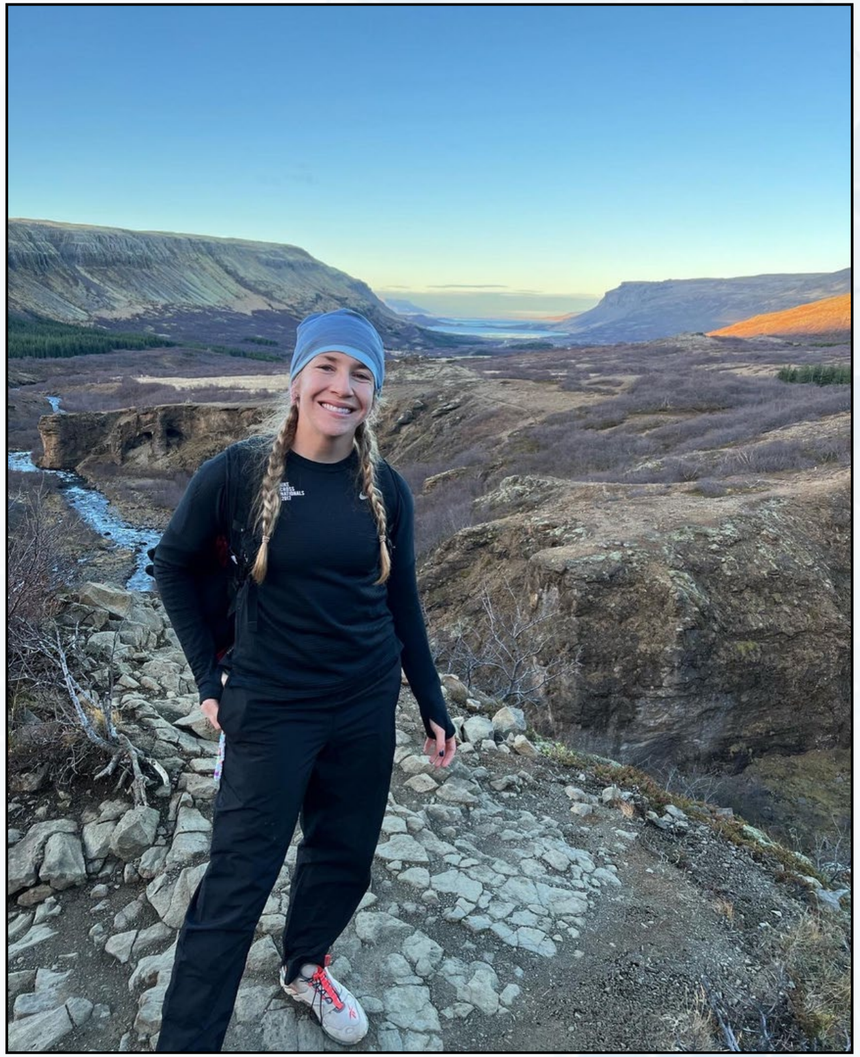

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