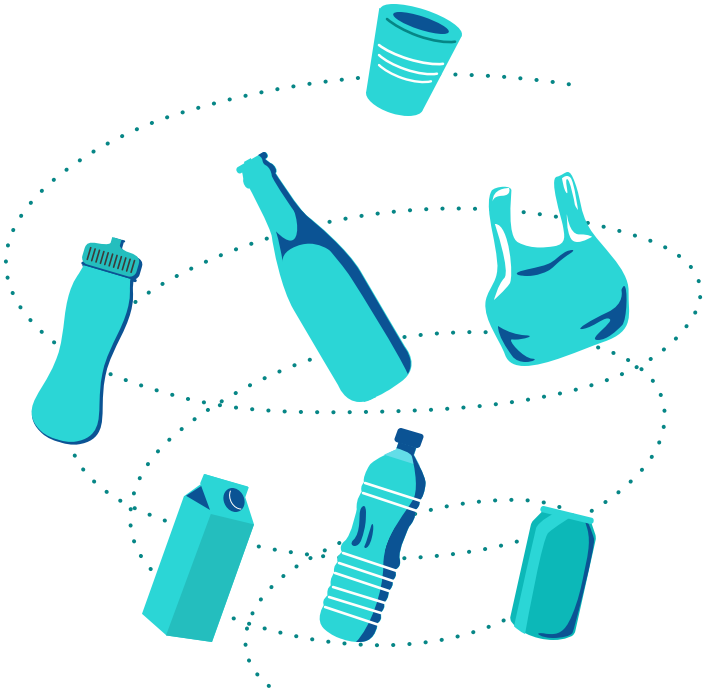
Monte Carlo Simulation:

Estimating Human Microplastic Intake through Food, Water, and Air



Team Members:
Rashi Jhawar [rjhawar3] and Tejal Bhansali [tejalrb2]

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About microplastics

What are Microplastics?

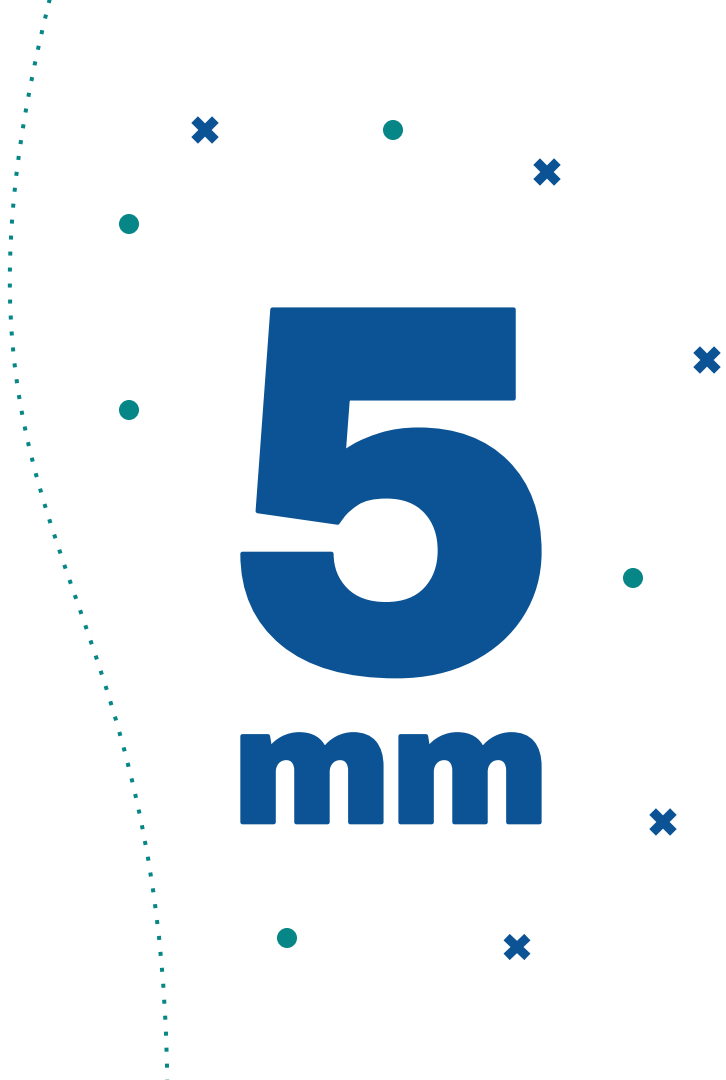
Tiny plastic particles <5 mm in size.

What is their origin?

Breakdown of larger plastic items or intentionally manufactured (e.g., microbeads) through multiple sources.

What are their types?

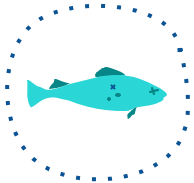
- Primary microplastics: Directly released (e.g., cosmetic microbeads, industrial pellets)
- Secondary microplastics: Result from degradation of larger plastics (e.g., bottles, bags)



How do microplastics enter our bodies?

Food

Microplastics have been detected in both plant- and animal-based food. They enter through marine pollution, farming practices, food processing and packaging, and airborne dust.



Inhalation

Indoor and outdoor air contain microplastics such as microfibers from synthetic textiles, vehicle tires, road dust, and more.

Drinking Water

Both bottled and tap water has been found to contain significant levels of nanoplastics and microplastics worldwide.

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Monte Carlo Simulation

Design Phase

Data Source – Our dataset contains microplastic intake for air, water, and food consumed across 109 countries and 18 food categories.

Random Variables	Distribution
Daily per capita intake for 18 food categories (in g)	Lognormal
Microplastic concentration in a gram of different categories of food (in mg of microplastic/g of food)	Lognormal
Microplastics consumed through water (in mg)*	Lognormal
Microplastics consumed through air (in particles)*	Lognormal
Microplastic weight (in mg)	Modified PERT

* Microplastic consumption values represent daily consumption by a single individual.

Design Phase

Assumptions:

- Daily intake of food, water, and air is modeled using a log-normal distribution, reflecting natural variability in consumption.
- The weight of individual microplastic particle follows a modified PERT distribution, capturing expert-estimated minimum (1.4e-8 mg), most likely (2.2e-7 mg), and maximum values (0.014 mg).
- The log-normal distribution uses a coefficient of variation of 25%, representing moderate dispersion in intake behavior.
- Total microplastic exposure occurs only through three main pathways: air, food, and water.

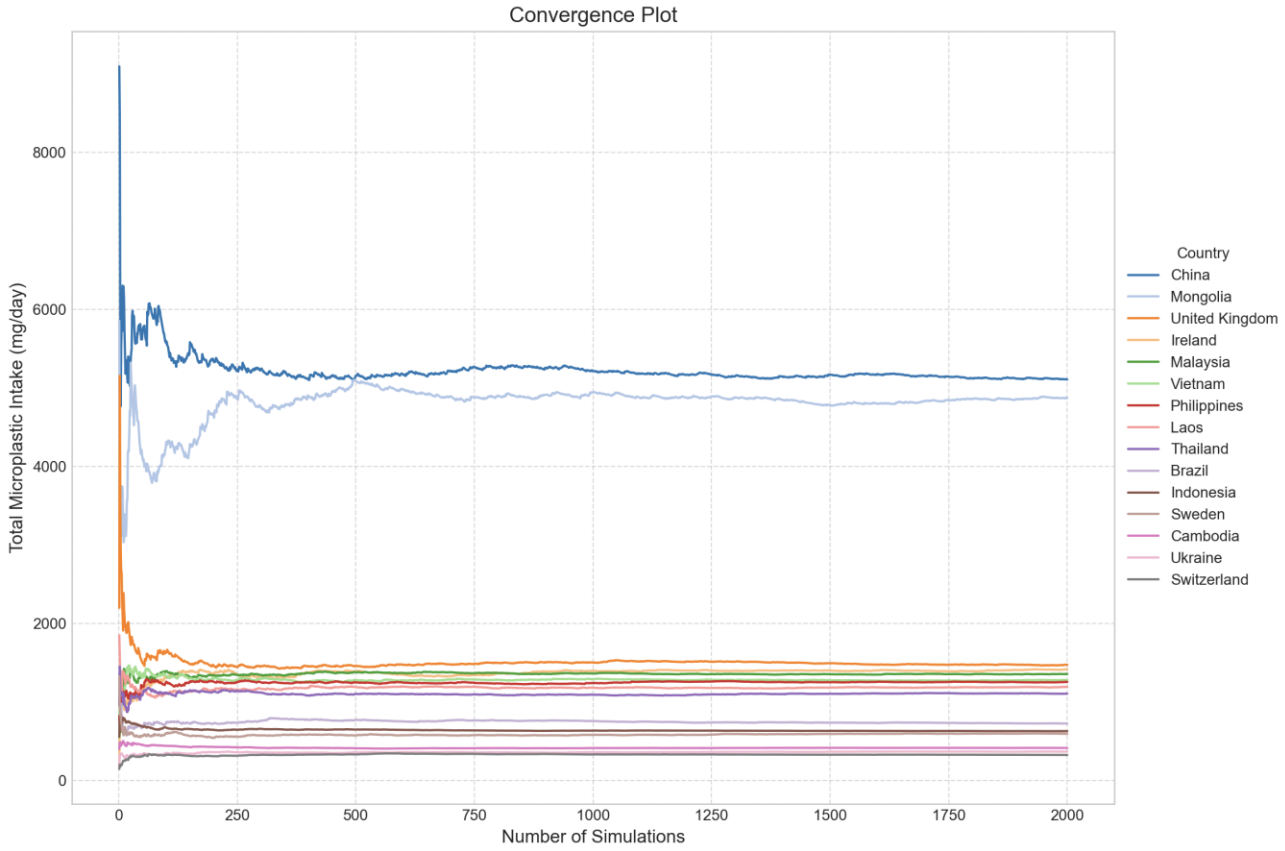
Validation Phase

- We ran the simulation for a subset of countries and found our results to be comparable with the published microplastic intake values for these countries.

Mean Microplastic Intake by Country (in mg/day):

Country	Daily_MP_Inhalation	Daily_MP_Ingestion	Daily_MP_Total	Monthly_MP_Total (in grams)
Indonesia	199.927080	429.747998	629.675078	18.890252
United States	16.804584	79.371813	96.176397	2.885292
Paraguay	26.953997	28.011157	54.965154	1.648955

Convergence Plot



Experimentation Phase

Hypothesis 1

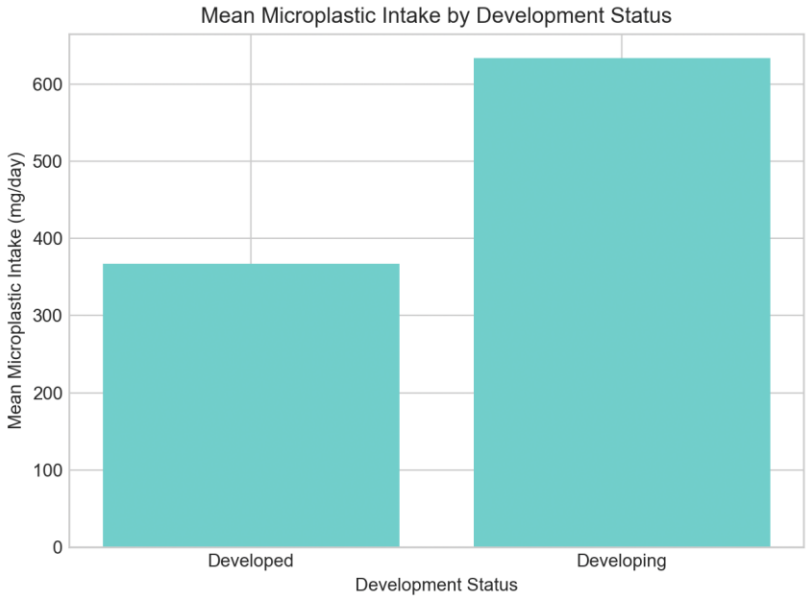
H_0: There is no significant difference in microplastic consumption between developed and developing nations.

H_A: There is a significant difference in microplastic consumption between developed and developing nations.

Hypothesis 1

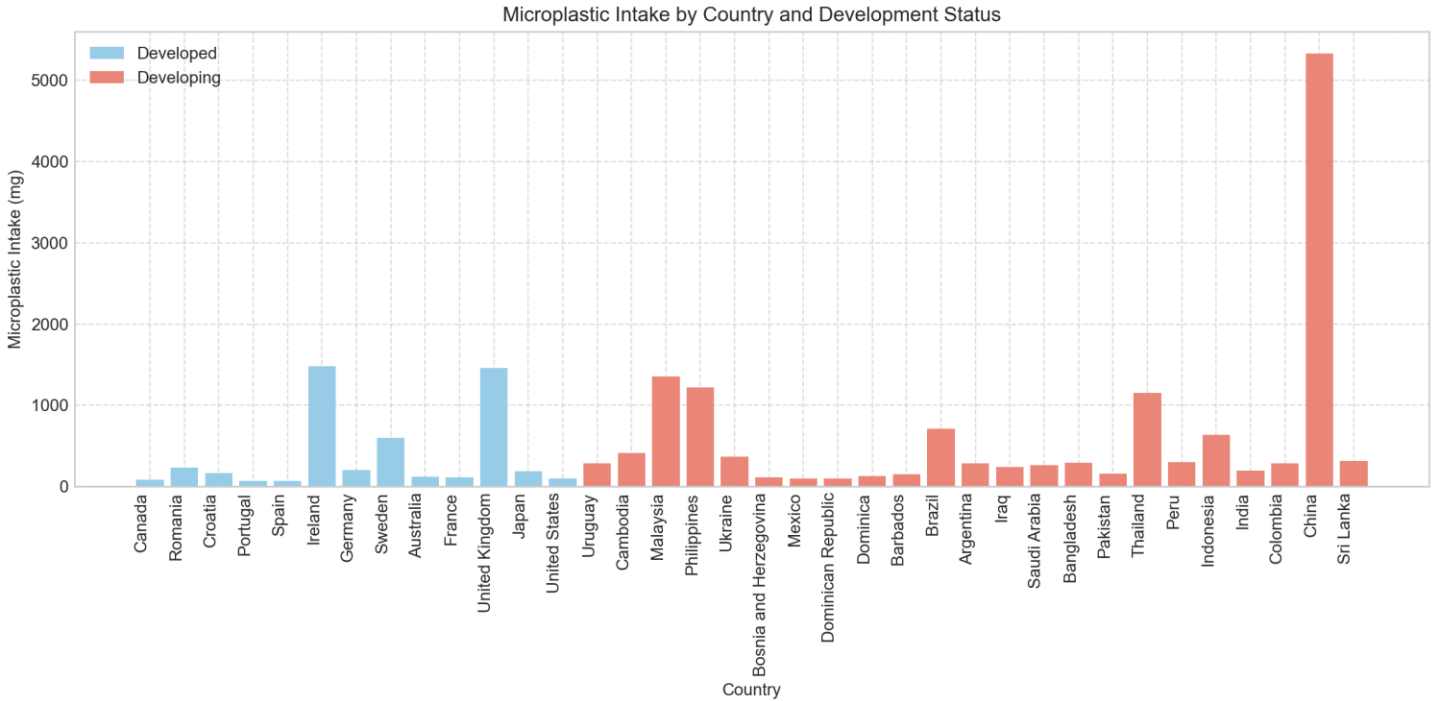
- We ran the simulation for 53 countries for 2000 simulations with the random variables defined earlier.
- Countries were classified as "Developed" or "Developing" according to a UN report.

- Initially, we observed quite some difference in the daily per capita microplastic intake for developed and developing countries.



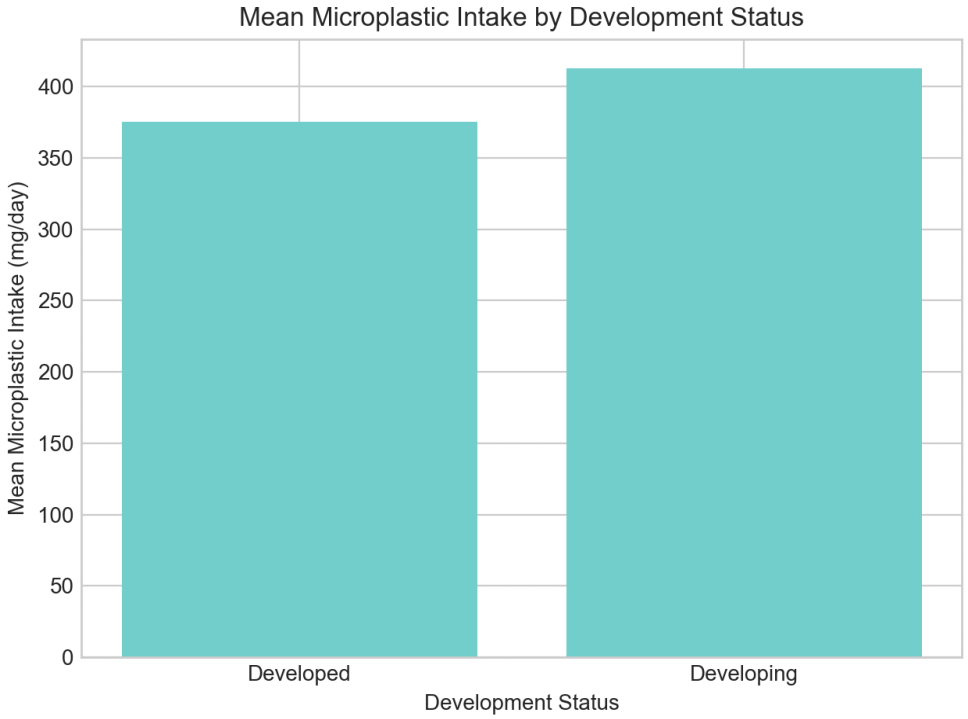
Hypothesis 1

- Further analysis showed that China is significantly higher than any of the other nations, which is possibly skewing the results.

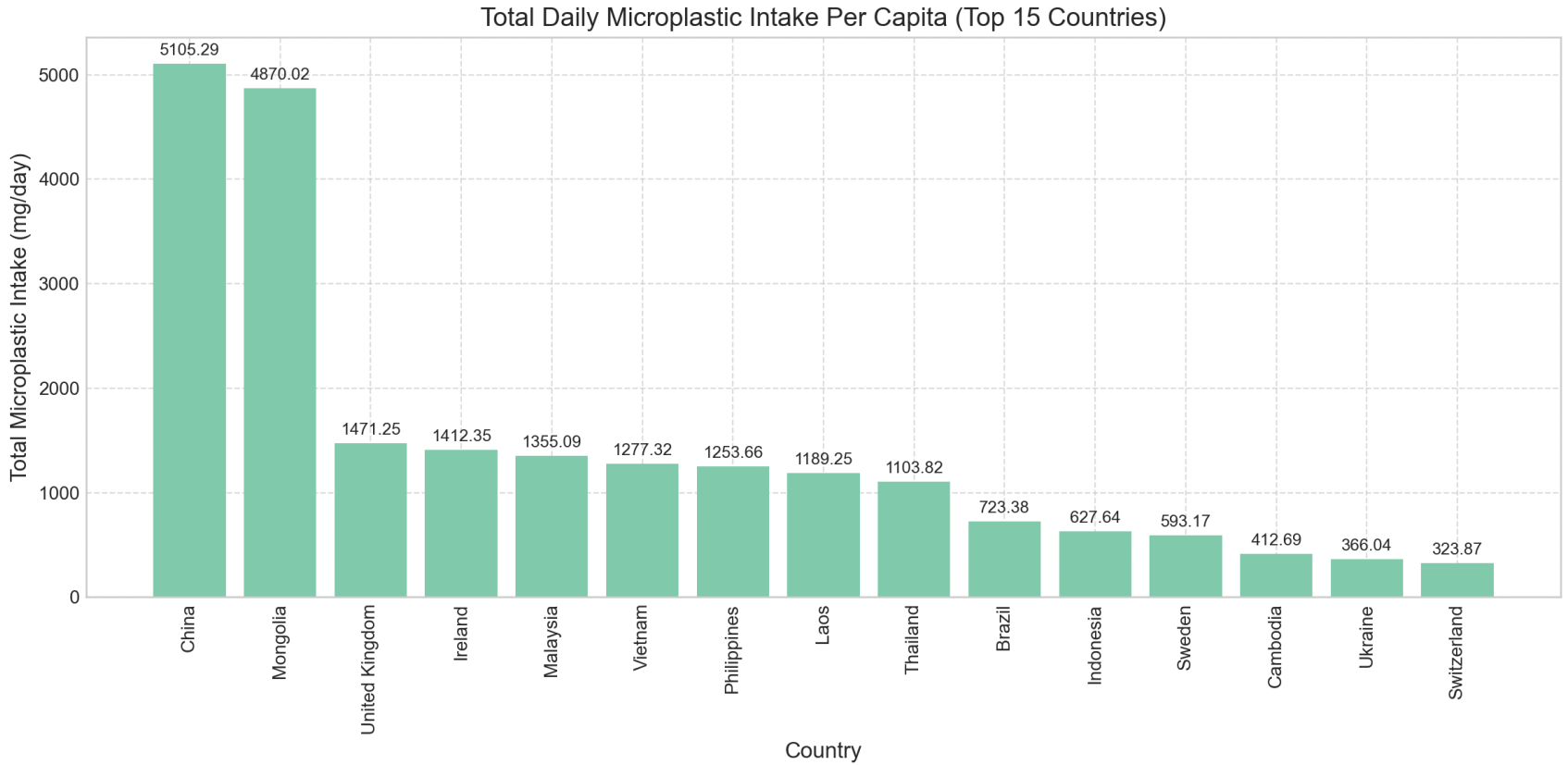


Hypothesis 1

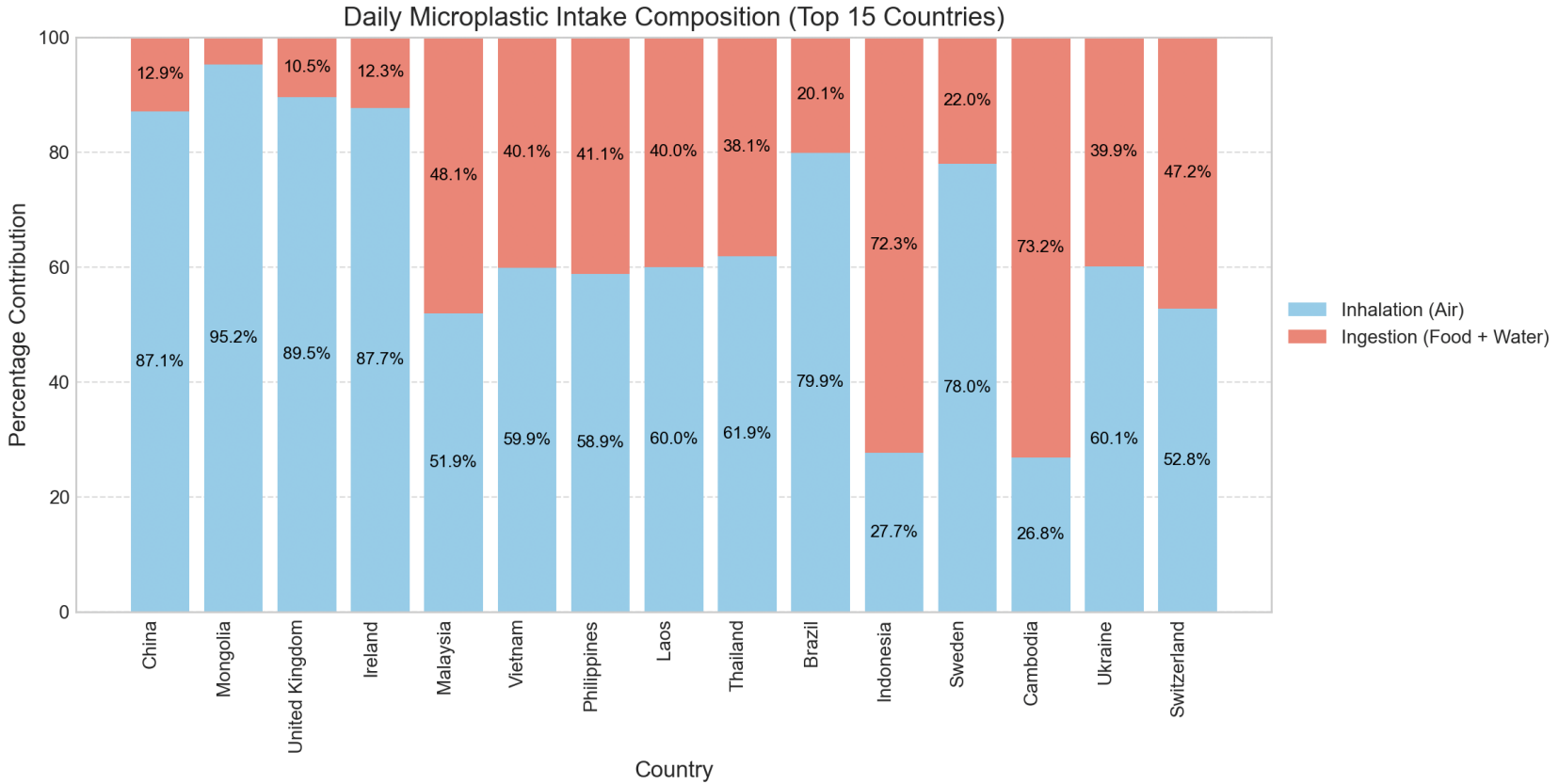
- Upon performing impact reduction on China (which is the outlier):



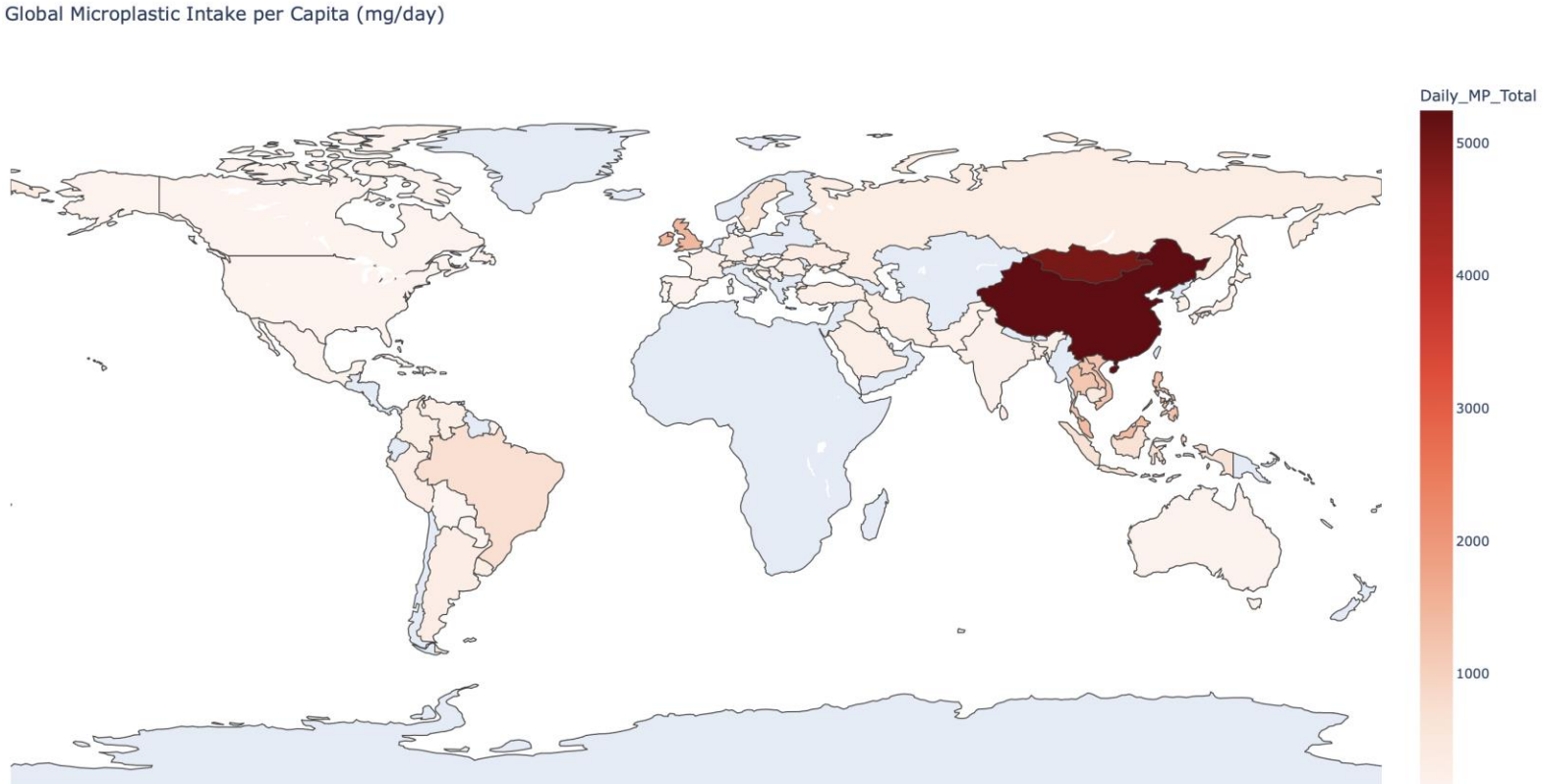
Total Daily Microplastic Intake Per Capita for Top 15 Countries



Microplastic Intake Composition for Top 15 Countries



Global Microplastic Intake per Capita through Food + Water + Air (mg/day)



Experimentation Phase

Hypothesis 2

H_0: There is no significant difference in microplastic intake across different diet groups.

H_A: There is a significant difference in microplastic intake across different diet groups.

Experimentation Phase

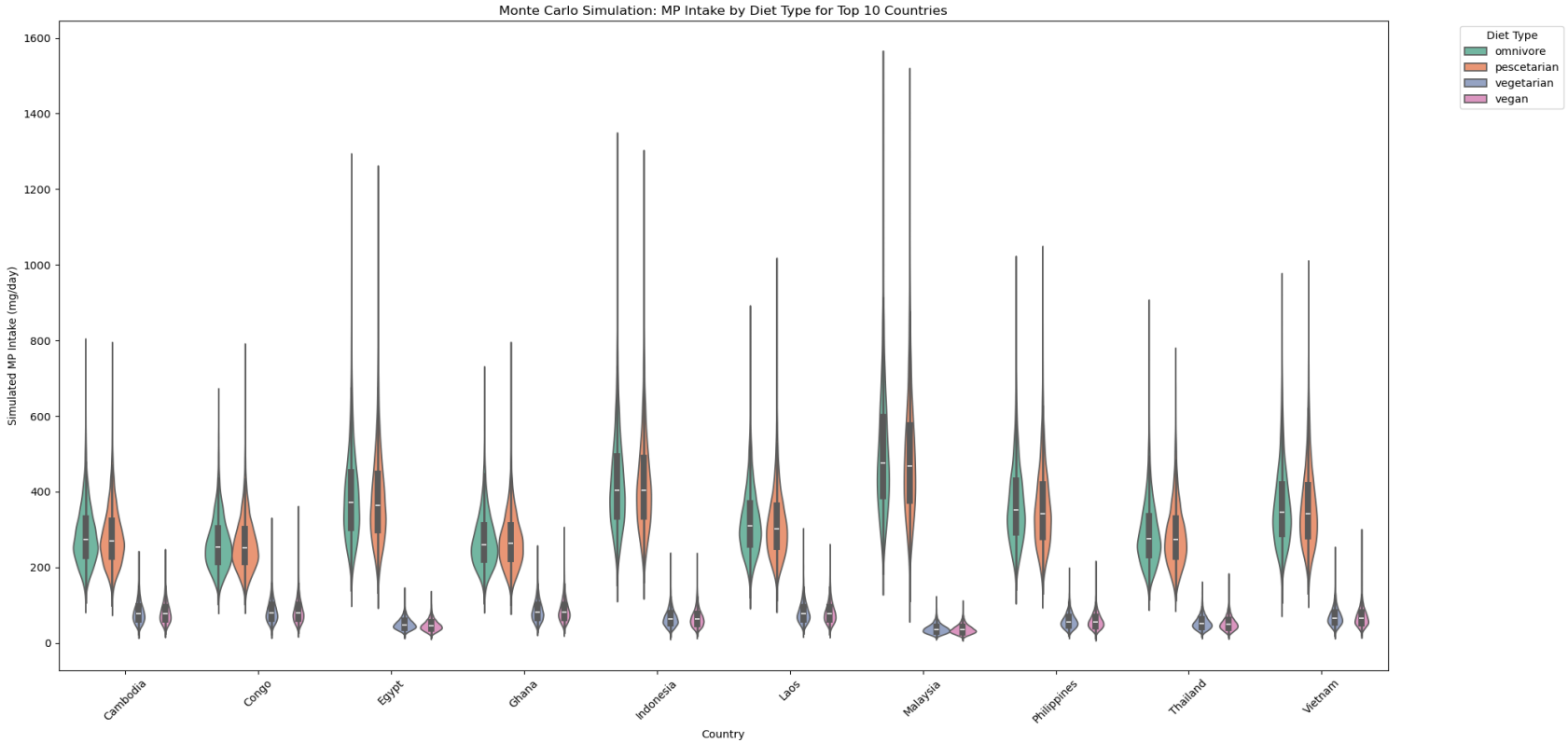
Hypothesis 2

Diet Groups – Omnivores, Pesceterians, Vegeterians and Vegans.

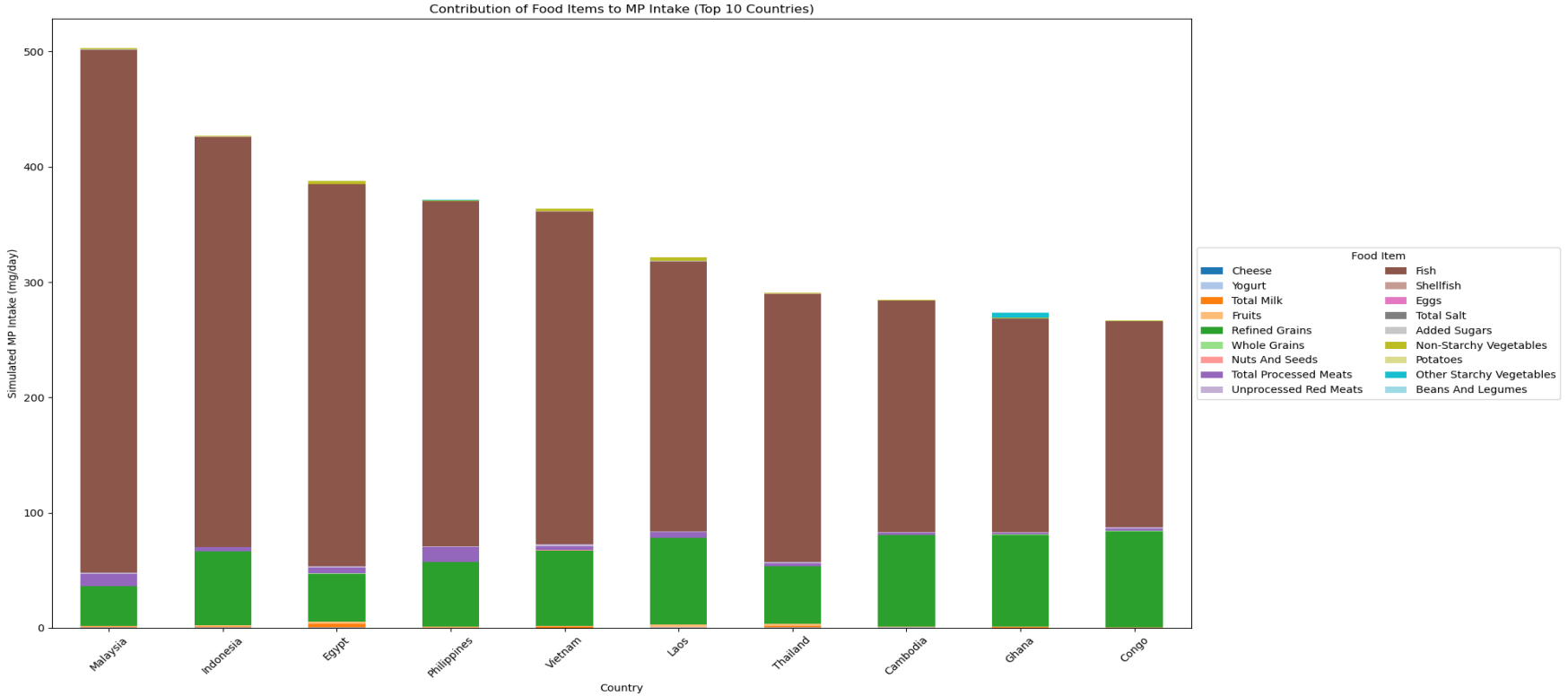
109 Countries

18 Food Items – Country, Cheese, Yogurt, Total Milk, Fruits, Refined Grains, Whole Grains, Nuts And Seeds, Total Processed Meats, Unprocessed Red Meats Fish, Shellfish, Eggs, Total Salt, Added Sugars, Non-Starchy Vegetables, Potatoes, Other Starchy Vegetables, Beans And Legumes

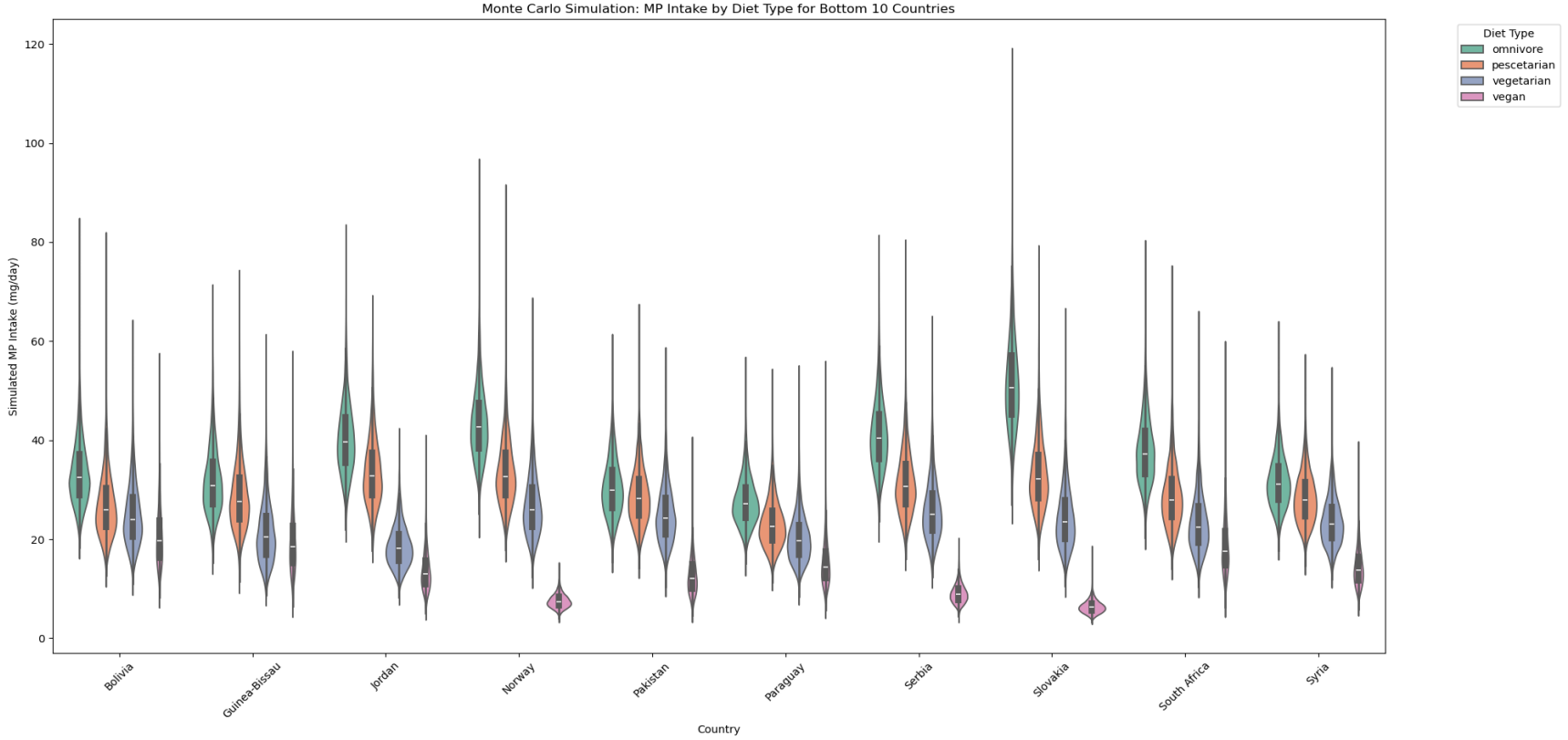
Monte Carlo simulation results for MP intake by Diet group for Top 10 Countries



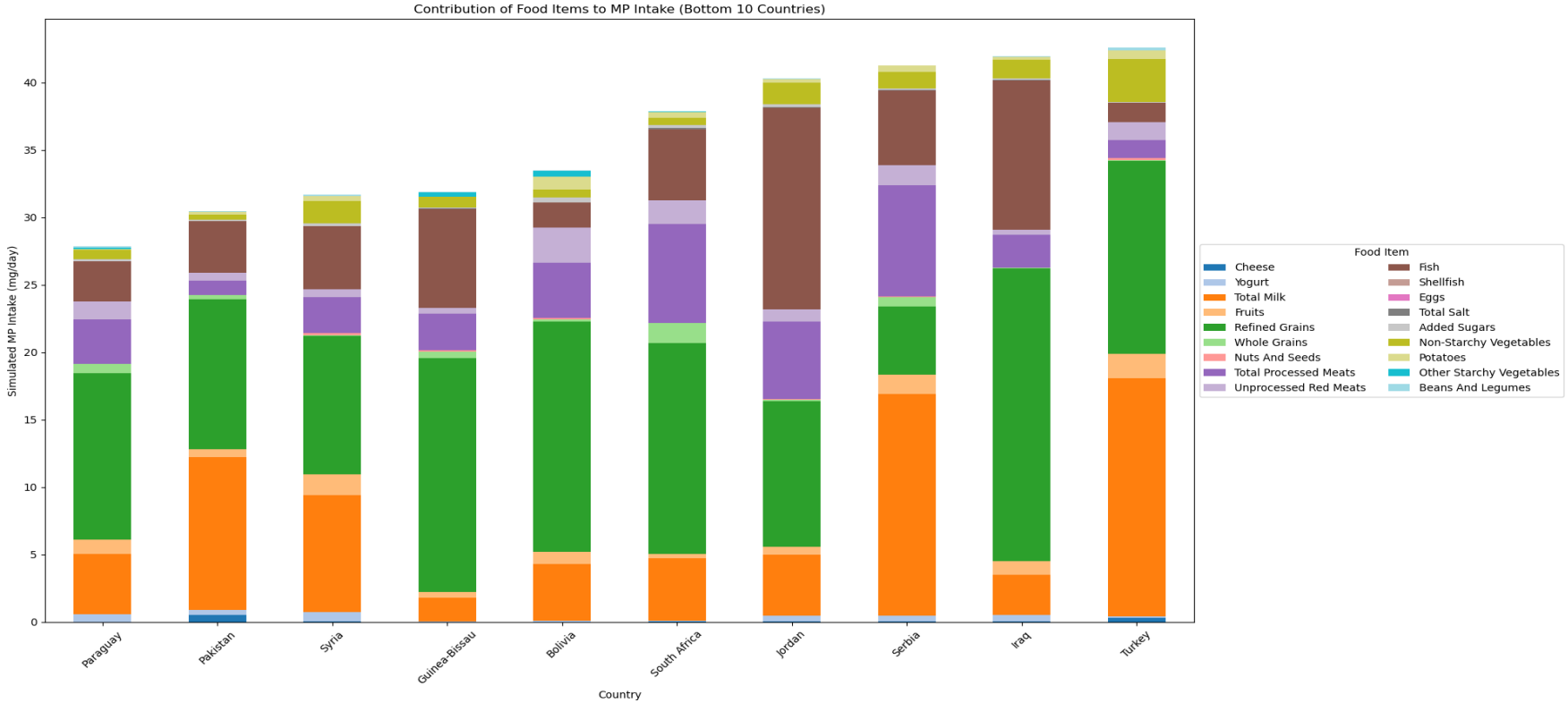
Monte Carlo simulation results for Contributions of food items to MP intake for Top 10 Countries



Monte Carlo simulation results for MP intake by Diet group for Bottom 10 Countries



Monte Carlo simulation results for Contributions of food items to MP intake for Bottom 10 Countries



Let's put our findings into perspective!

An average American consumes

0.67 grams in a week (equivalent to a paper clip)

2.88 grams in a month (equivalent to about 7 plastic straws)

35 grams in a year (equivalent to a 250ml shampoo bottle)

How can we reduce our microplastic intake?

- Recycle plastic responsibly to reduce ocean pollution and microplastics in seafood.
- Minimize plastic packaging and storage in the food supply chain.
- Improve grain processing standards to prevent contamination.
- Prevent soil pollution by managing waste, as microplastics can enter crops through soil.

Limitations and Future Scope

- First, microplastics vary greatly in size, composition, and density, making it difficult to standardize their measurement and compare across studies.
- Second, there is no single comprehensive study that evaluates all food sources uniformly, so our estimates are derived from a variety of independent reports with differing methodologies.
- Third, this project does not account for nanoplastics, which are even smaller than microplastics and may pose greater health risks — but are still largely unquantified in current literature.
- Fourth, we have not considered microplastics in indoor and outdoor air, and bottled and tap water separately.
- Lastly, our study was focused on 4 diet groups comprising of 18 food items in total, which can be broadened as a future scope.


Thank you!

References

- https://measurlabs.com/blog/microplastic-testing-standard-iso-24187/
- https://ehp.niehs.nih.gov/doi/full/10.1289/EHP8936
- https://pubs.acs.org/doi/epdf/10.1021/acs.est.4c00010?ref=article_openPDF
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