

Estimation Of Plastic Use From Personal Skincare Routines

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Abstract

Personal care and skincare products are used by millions of people daily, leading to significant consumption of products primarily packaged in plastic. As global concerns about plastic waste increase, it is important to understand consumer behavior and how the use of personal care products contributes to plastic waste generation. This study aimed to examine the usage patterns of personal care and skincare products and understand people's plastic consumption. Data were collected from 83 respondents, of whom 60.2% were female and 39.8% were male. Further, the four major age groups were 15-17 years (18.1%), 25-35 years (25.3%), 35-44 years (20.5%), and 45-54 years (21.7%). It was found that, on average, 23.65 skincare products are used per person per year. Effectiveness and product ingredients were the most important factors that influence purchasing decisions, followed by brand and price. The study also indicated that the product size ranges of 101-300 ml and 301-600 ml were the most commonly purchased size ranges. On average, each respondent consumed 1.45 kg of plastic and generated a carbon footprint of 4.34 kgCO₂e per year, through their personal care product usage. Understanding consumer patterns can support the development of more sustainable packaging solutions and provide insights into the skincare industry's contribution to increasing plastic use.

Keywords

Skincare, Plastic use, Consumer behavior, Environmental impact, Packaging

Introduction

Plastic is a widely used material worldwide due to its versatility, low production cost, and durability. Since the 1950s, the annual plastic production has increased dramatically, reaching around 460 million tons in 2019, compared to 15 million tons in the 1960s.^{1,2} In 2014, the annual plastic production reached approximately 311 million tons globally, and it could double in the next 20 years and quadruple by 2050.² This increase in production has contributed to the global waste crisis.³ About 2.01 billion tons of municipal solid waste is generated each year, of which 33% is not managed in an environmentally safe manner.⁴ Plastic waste forms a large part of this issue, with 19-23 million tons annually seeping into water bodies and polluting rivers, lakes, and oceans.⁵ Studies indicate that about 8.3 billion tons of plastic have been produced worldwide, of which 4.9 billion tons end up in natural ecosystems or landfills.⁶

Plastic production is also linked to fossil fuel consumption. About 99% of the feedstock used in plastic manufacturing is derived from fossil fuels, accounting for approximately 8-9% of fossil fuel consumption.³ Plastic use differs among various industries; the packaging sector is the largest consumer, producing huge amounts of single-use products like bottles, bags, films, and containers made of PE, PP, PET, and PVC.⁷ Plastics used in sectors such as construction or machinery can last for approximately 20-35 years.^{7,8}

Another sector known for heavy plastic consumption is the skincare and beauty sector. The skincare and beauty industry is a major economic sector and one of the large contributors to the 280 million tons of

annual global plastic production.⁹ In 2017, the global skincare market was valued at approximately \$400 billion, with facial products representing the largest segment, accounting for 75% of the market value.¹⁰ The industry's growth has led to the annual production of 120 billion units of non-recyclable packaging materials.¹¹ Due to the constantly increasing consumer interest in personal health, spending power, and availability of personal care products, the industry has witnessed significant growth.⁹

The environmental impact is quite severe in specific areas; for example, in densely populated places like Macao, more than 17% of personal care products contain microplastics, which contribute to the 3,843 tonnes of microplastics released into water bodies annually by the USA, China, and Europe.¹⁴ Large global companies such as L'Oreal, Unilever, and Estee Lauder have begun to implement sustainability tools, like L'Oreal's Sustainable Product Optimization Tool.¹⁵ And yet, the industry lacks a unified standard to work towards reducing plastic production.¹⁶

In low- and middle-income countries like India, the beauty and personal care market is valued at \$28 billion in 2024 and is growing annually by 5.6% through 2033.¹² The personal care sector produces around 187 billion pieces of packaging annually, and lower-middle-class users alone discard 2.94 billion plastic sachets every week.¹³ The industry produces more than 187 billion pieces of packaging annually. This includes sectors such as skincare, haircare, bath and body care, oral care, and cosmetics (makeup)¹³. A major driver of this trend is sachet culture, which allows consumers to access premium products at lower prices.¹³ Despite growing environmental awareness of "green beauty," much packaging is still single-use, which shows the gap between sustainable practices and consumer and manufacturer intentions. They default back to plastics for functional purposes.¹³

The cosmetics industry involves many layers of packaging, such as bottles, tubes, pumps, and outer boxes. The industry produces more than 120 billion packaging units every year, of which 70% are plastic-based.¹⁷ The most commonly used plastics in cosmetic packaging are High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), and Polyethylene Terephthalate (PET).¹⁸ HDPE is used in shampoo, conditioner, and body wash packaging for its rigidity and moisture resistance. LDPE is commonly used in squeezable tubes for its flexibility and ease of large-scale manufacturing.¹⁸ PET is usually used for toners, body oils, and serums, where aesthetics and product visibility are important due to its clarity and lightweight properties.¹⁸ Despite, there is increasing environmental awareness, zero waste packaging remains rare, as packaging is usually designed for branding and aesthetics rather than environmental friendliness.¹⁹

The huge increase in waste contributes to microplastics, which end up in ecosystems and contaminate the global food chain. In addition, the chemical additives in these containers often seep into soil and water, leading to long-term toxicity for humans and animals.²⁰ Although many people realize that plastic pollution harms the environment, they usually underestimate the extent to which their everyday habits escalate the problem. Skincare routines usually involve many plastic-packaged products, yet consumers rarely consider the environmental impact of their accumulation. This is also a concern regarding household plastic use, as it drives indirect environmental damage, with demand for personal care products contributing significantly to the carbon footprint of domestic waste.⁹

Social media trends and viral beauty products encourage frequent purchasing. Currently, there are limited tools available to help people understand the environmental impact of their skincare routines. The development of these tools is an application of the United Nations' Sustainable Development Goal 12, responsible consumption and production, which calls for a shift towards reducing waste generated by our daily choices.

Research Aim

This study aimed to measure the plastic footprint of an individual's skincare routine, uncover consumption habits related to personal care and shopping, and identify patterns in these habits. Specifically, the focus is on understanding how factors such as product usage frequency, packaging types, and purchasing behavior contribute to the overall generation of plastic waste. I will have achieved my aim if I have quantitatively measured the plastic footprint of an individual's personal care routine, identified the factors

that contribute most significantly to waste generation, and compared plastic footprints across different routines and demographic groups.

Research Objective

My research objectives are:

- To analyze and choose a method to quantify plastic footprint.
- Gather data on personal care habits by designing a suitable data collection platform that captures usage frequency, packaging types and sizes, etc.
- Identify a suitable sample size, conduct the research, and gather sufficient data.
- Analyze the data to identify trends.
- Derive conclusions about the plastic footprint of personal care routines.

Methods

Before finalizing my research method, I analyzed a few options to determine what might work best. The first method I considered was a user survey. It would allow me to reach a large number of people and collect standardized data at no additional cost. However, this method would rely on self-reported data, so responses may be inaccurate and/or subject to social desirability bias.

The next method I debated was product audits, which would involve collecting products from participants and weighing them. This would remove the reliance on self-reported data. On the other hand, this method would be very time-consuming and would make it difficult to get many people to participate.

Further, I considered interviews and focus group discussions. These would allow me to gather more in-depth, qualitative insights into the consumer behaviour and attitude towards plastic use. However, they would be time consuming, harder to scale, and would not generate quantifiable data which I would require for statistical analyses.

And finally, I considered creating a purchase log to capture people's real-time consumption rather than asking respondents to recall purchase habits, but this would also be very time-consuming and require months of logging, increasing the risk of incomplete data.

Keeping all this in mind, I decided to proceed with a user survey, as it would allow me to obtain a large sample size with reasonable accuracy and would be practical for widespread data collection.

Research design and tools used

This research uses a quantitative approach through a survey designed to assess individuals' personal care habits and their awareness of the associated environmental impact. This method enables measurement and analysis of hidden plastic waste generated by a typical personal care routine. This survey had three distinct sections to provide a holistic understanding of respondents' use of personal care products.

1. Socio-demographic characteristics such as age, gender, educational attainment, occupational status, geographical location, and relationship status were collected.
2. Multiple-choice and quantity-related questions about consumption and usage patterns were asked in the next section. These included questions about the types of products participants use (shampoo, conditioner, etc.), their frequency of use, the total number of items in their self-care routines, typical purchase sizes, and the volume of products finished within the past 12 months, including data on shared household usage.
3. Qualitative questions about consumer behavior and patterns were added in the third section. A Likert scale and multiple-choice question format was used to determine buying criteria, reasons for brand changes, and the importance of visual appearance and container materials.

Ethical Considerations

Before starting the survey, all participants were provided with an informed consent paragraph explaining the study's aim. All participants were informed that their personal information would be kept confidential. They were also briefed that their participation is completely voluntary and that they can withdraw from the survey at any time, without any consequences.

Sample Characteristics

The sample consisted of 83 respondents, of whom 18.1% were 15-17 years old, 9.6% were 18-24 years old, 25.3% were 25-34 years old, 20.5% were 35-44 years old, 21.7% were 45-54 years old, and 4.8% were 55+. 9.6% held a high school diploma, 15.7% were still in high school, 31.3% held an undergraduate degree, and 39.4% held a postgraduate degree. While the participants were dispersed globally, 50.6% lived in India, and the rest were from the US or the UK (18.07%). The participants held a variety of jobs, including students (24.1%), entrepreneurs (15.7%), software engineers/IT professionals (12.0%), and medical professionals (6.0%). About 60% of respondents reported sharing personal care products with family members. These demographics provide a balanced view of usage patterns across people with different habits.

Data Collection Procedure

Data was collected using a self-administered Google Form. Google Forms was chosen because it is an easily accessible, user-friendly platform for a large audience. Participants were contacted via social media platforms and personal/group chats, where a survey link was shared. The participants were asked to complete the form by answering all questions in as much detail as possible. Once the responses were submitted, the data were organized and processed to estimate plastic consumption and generate an overall impact score based on each participant's personal care habits.

Data Analysis Strategy

The data were collected from the survey and then processed and analyzed in several steps. Over 3 weeks, I collected empty product containers from friends and family and sorted them into size categories (small: ≤ 100 ml; medium: 101-300 ml; large: 301-600 ml; extra-large: > 600 ml). Next, I weighed each product container on a kitchen scale and calculated the average weight in grams for each product size category. I used the average weight as the representative weight for each size category. These average weights were then used to calculate each participant's total plastic use based on product repurchase frequency and product sizes reported in the survey. The total amount of plastic consumption per person was then divided by 1000 to obtain the values in kg. The kg value was multiplied by 3 to calculate each participant's carbon emissions, using emission conversion factors from the existing literature.^{21,22} Carbon emissions were estimated by multiplying plastic package consumption by an approximate mixed-plastic emission factor of 3 kg CO₂e per kg of plastic. This value was chosen because existing studies reported carbon emissions for plastic packaging (HDPE, LDPE, and PPE) in the range of 2.6 to 2.9 kg CO₂e per kg of plastic, making 3 kg CO₂e a reasonable round estimate for mixed packaging.^{21,22} Descriptive statistics, such as the mean, standard deviation, and range, were calculated for plastic use and carbon emissions. Graphical representations were developed to illustrate plastic consumption and carbon emissions across product categories. Finally, an independent t-test was conducted to examine differences between male and female respondents, and a one-way ANOVA test was run to assess whether consumption and emissions differed significantly across age groups.

I used a timeline to set how long each phase should take and the interdependence between them, along with buffer times in case of delays. I built in extra time for survey distribution and data collection, as this stage could have taken much longer than expected depending on the participants.

Project Timeline



Results

Table 1 shows the average plastic consumption per individual per year, and the average carbon emissions generated by that consumption. The mean plastic use among respondents was 1.45 kg per year (SD=1.24), with a range of 7.65 kg, showing considerable variation in plastic consumption across individuals. Similarly, the mean carbon footprint was 4.34 kgCO₂e per year (SD = 3.71), with a maximum value of 22.95 kgCO₂e, suggesting that while average emissions are relatively moderate, some respondents contribute significantly more. The high standard deviations and ranges for both variables suggest that personal care product consumption greatly differs among individuals.

Table 1: Mean and standard deviation of plastic use (in kg) and carbon emissions released by the sample group. Respondents use 1.45 kg of plastic, with a carbon footprint of 4.34 kg CO₂e.

Descriptives	Plastic use (in kg)	Carbon emission (kg CO ₂ e)
Mean	1.45	4.34
Standard Deviation	1.24	3.71
Range	7.65	22.95

In Table 2, there were no statistically significant differences in plastic consumption between female (M=1.49, SD=1.06) and male (M=1.18, SD=0.94) respondents, $t(64)=1.22$, $p>0.05$. This shows that plastic consumption levels are broadly similar across genders. Similarly, there was no significant difference in carbon emissions between female (M=4.46, SD=3.19) and male (M=3.55, SD=2.83) respondents, $t(64)=1.22$, $p>0.05$. This suggests that gender is not a significant determinant of carbon emission levels among the sampled population.

These findings show that both male and female respondents have comparable environmental footprints in terms of plastic consumption and carbon emissions. While females recorded marginally higher means on both variables, the differences were not statistically significant. This may partly reflect shared household consumption patterns, in which purchasing and waste-disposal decisions are made collectively rather than individually. Furthermore, environmental behaviors such as plastic use and carbon-generating activities may be influenced more by socioeconomic factors, lifestyle, or geographic context than by

gender alone. Studies with larger sample sizes may reveal clearer differences between men and women in their product consumption patterns.

Table 2: Independent t-test analysis of plastic consumption and carbon emissions by gender.
No statistically significant differences were found by gender.

Variable	Categories	n	Mean	SD	t	p
Plastic Consumption (kg)	Female	33	1.49	1.06	1.22	0.23
	Male	33	1.18	0.94		
Carbon Emissions (kg CO ₂ e)	Female	33	4.46	3.19		
	Male	33	3.55	2.83		

Note: $p < 0.05^*$

As shown in Table 3, single-factor ANOVAs were conducted to examine differences across age groups (15-17, 25-34, 34-44, and 45-54) for two dependent variables: plastic consumption and carbon emissions. Neither variable showed significant differences: carbon emissions, $F(3,67)=0.89$, $p>0.44$, and plastic consumption, $F(3,67)=0.79$, $p>0.49$. This indicates that age does not significantly influence either plastic consumption or carbon emissions among the sample population.

These findings suggest that environmental impact from personal care product use is broadly consistent across all age groups. While the 45-55 age bracket had the highest mean values for both carbon emissions(4.68) and plastic consumption(1.56), and the group 25-34 recorded the lowest mean values, with carbon emissions at 3.25 and plastic consumption at 1.08, these differences were not large enough to be statistically meaningful. This could reflect that personal care routines are more driven by habit and product availability than age. Studies with greater and more diverse sample sizes may reveal more meaningful differences in consumption patterns across age groups.

Table 3: Single-factor analysis of variance of plastic consumption and carbon emissions among age groups. No statistically significant differences were found by age.

Age group	Carbon emissions mean	Carbon emissions mean SS	Carbon emissions SD	F	p	Plastic mean	Plastic mean SS	Plastic SD	df	F	p
15-17	4.89	149.28	3.26	0.89	0.44	1.63	16.59	1.09	14	0.79	0.49
25-34	3.25	229.29	3.39			1.08	25.48	1.13	20		
35-44	4.17	159.43	3.16			1.39	17.71	1.05	16		
45-54	4.68	401.99	4.86			1.56	44.67	1.62	17		

Note: $p < 0.05^*$

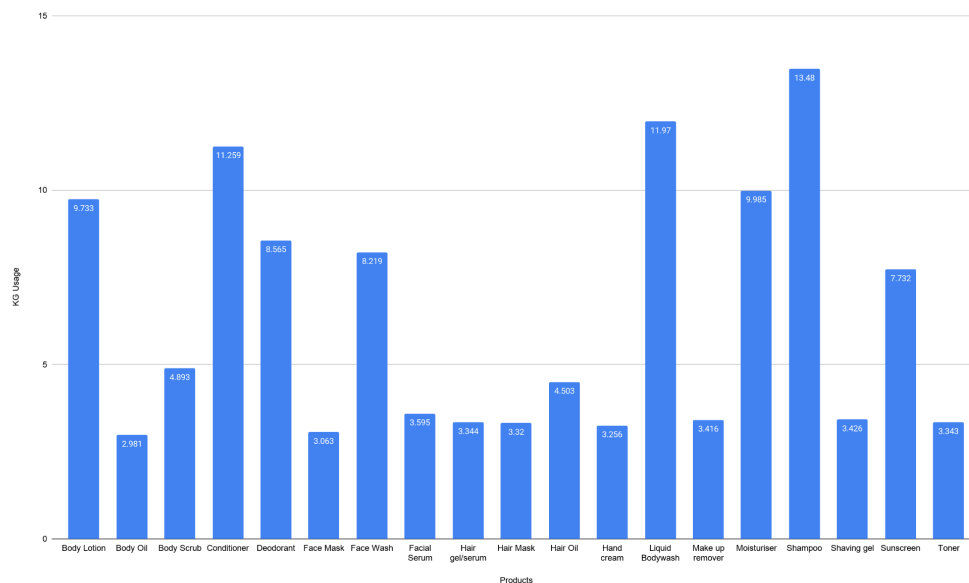


Figure 1: Graphical representation of plastic consumption by personal care products of the sample group in one year. Findings show that shampoo, body wash, and conditioner consume the most plastic, while toner, face mask, and body oil recorded the lowest.

In Figure 1 it can be seen that shampoo containers had the highest plastic consumption by weight among all personal care products (13.480 kg), followed by liquid body wash containers (11.970 kg) and conditioner containers (11.259 kg). These products, being rinse-off soap formulations, are typically packaged in larger plastic containers and are consumed more frequently, which may explain their higher kg usage. At the lower end, body oil (2.981 kg), face masks (3.063 kg), hand cream (3.256 kg) and toner (3.343 kg) had the lowest plastic consumption, likely due to their smaller packaging sizes and less frequent use.

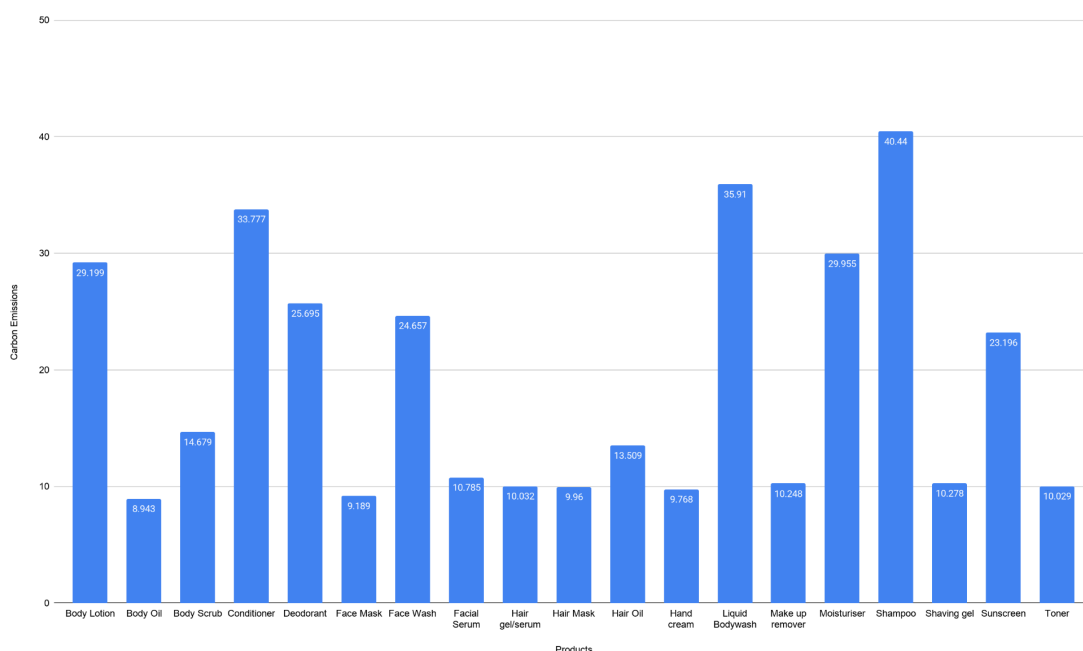


Figure 2: Graphical representation of carbon emissions generated from personal care products of the sample group in one year. Findings show that shampoo, body wash, and conditioner were the highest contributors to carbon emissions, while toner, face mask, and body oil contributed the least.

In Figure 2, shampoo is the highest contributor to carbon emissions (40.440 kg CO₂e), followed by liquid body wash (35.910 kg CO₂e) and conditioner (33.777 kg CO₂e). This pattern mirrors that observed in plastic consumption data, suggesting that products with higher material usage tend to generate greater carbon emissions across their lifecycle. In contrast, body oil (8.943 kg CO₂e), face masks (9.189 kg CO₂e), hand cream (9.768 kg CO₂e) and hair masks (9.960 kg CO₂e) contributed the least to carbon emissions, consistent with their lower plastic usage. Products such as body lotion (29.199 kg CO₂e), deodorant (25.695 kg CO₂e), and face wash (24.657 kg CO₂e) recorded moderately high carbon emissions despite relatively lower plastic weights, which may be due to manufacturing intensity driving the overall environmental impact.

Discussion

In the present study, there were no significant differences in plastic consumption and carbon emissions by gender or age group. This suggests that gender and age do not influence the amount of plastic used in personal care products or the related environmental impacts of those products. It was found that shampoos, liquid body washes, and conditioners were the highest contributors of plastic consumption and carbon emissions across all product categories. On the other hand, body oils, face masks, and toners were among the lowest contributors of plastic consumption and carbon emissions.

On average, each survey participant consumed 1.45 kg of plastic and generated a carbon footprint of 4.34 kgCO₂e per year, through personal care product use, with some variation between individuals. This establishes that everyday grooming and personal care routines carry a measurable environmental cost. This finding is broadly supported by global data: global per capita consumption of plastic has steadily risen from 1 to 60kg per capita between 1950 and 2020.¹⁹ This shows that personal care packaging contributes significantly to overall per capita plastic consumption

Shampoo, liquid body wash, and conditioner emerged as the highest contributors to both plastic consumption and carbon emissions due to their frequent use and large packaging size, whereas other products like toners, body oils, and facemasks, had the lowest impacts. This was well supported by existing literature, which confirmed that shampoo packaging is a significant contributor to environmental impact and that rinse-off personal care products are among the highest contributors to environmental footprint, driven by their frequent use and packaging.^{23,24}

Moreover, gender and age did not influence plastic consumption or carbon emissions, suggesting that the environmental burden of personal care product consumption is distributed evenly across the sample population. This finding is contrasted with existing literature, which found that there was a significant difference in personal care product consumption across age groups.²⁵ Studies also suggest that consumer knowledge and understanding of sustainable packaging is a key factor in shaping environmentally friendly behaviour.²⁶

The findings were contrasted with existing literature, which found that women use more personal care products than men in most categories, except for shaving products.^{27,28} The findings regarding age were partially consistent with the existing studies, which found significant differences in personal care product consumption across different age groups, especially those aged 25-35 and 46-55. However, these studies focused more on product purchase than on actual plastic consumption and carbon footprints.²⁵

Strength and limitations

A key strength of this study is its innovative approach to quantifying plastic consumption and carbon emissions at the individual level through personal care products. This was done by assigning weight values to product size brackets and applying an emission conversion factor. The study also offers a replicable methodology that can be scaled to apply to larger populations. This provides useful data for environmentalists and the cosmetics industry to make more informed and sustainable packaging decisions. Although this study had strengths, it also had a few limitations, including a relatively small sample size, which may limit the generalizability of the findings. Respondents reported data in general product categories rather than specific products and their exact weights, which may have led to imprecision in the calculations. The study was also limited by collecting data at a single point in time and by not having a geographically diverse sample, which meant that regional differences and long-term behaviors were not considered. Finally, self-reported data may have been affected by the social desirability effect, in which participants may have underreported their actual consumption to appear more environmentally sustainable.

Conclusion

The study aimed to measure the plastic consumption footprint and carbon emissions associated with individual use of personal care products, and to assess whether factors such as gender and age significantly influenced consumption patterns. By developing a method to quantify plastic consumption at the individual level and then linking it to carbon emissions, the study creates a practical, replicable methodology for understanding the environmental cost of everyday self-care routines. The findings show that, while certain products were larger contributors to plastic waste and carbon emissions, neither gender nor age showed significant differences. This suggests that the environmental effects of personal care products are broadly shared across the sample population.

Future studies could address this by using a larger, more diverse sample to improve generalizability. They could also explore the roles of income, brands used, and social media influence in product consumption and packaging preferences. Furthermore, future research could investigate the effectiveness of specific measures, such as refillable packaging or eco-labeling, in reducing plastic waste from personal care products. Longitudinal studies can track consumption habits over time to provide a more accurate understanding of how environmental impacts from personal care routines can change with consumer trends.

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During the preparation of this work, the author used Claude to help plan the report and improve the language.

Reflections

The method I chose to estimate plastic consumption was as follows: I collected a large number (150+) of empty plastic product containers, and sorted the containers into size brackets. I weighed each container and then used this data to calculate the average container weight for each product size category. Once I calculated the average container weight for each product size category, I used this data along with the product usage frequency and product size values reported by the survey participants, to calculate the average plastic consumption for each participant. This method was much more practical for me with the resources I had, than weighing the specific products that participants used in their routines.

I could have asked the respondents to weigh and report the exact weight of each product container for all the products they use; then the data might have been more precise. That being said, the survey would have taken much longer, and the response rates may have dropped. There was also a risk of user error if they weighed the product container while the container was not completely empty. Also, each user weighing the containers on their individual machines could be error-prone, because each machine may have its own built-in variance.

My method may have been slightly less precise, however, it was more reliable and applicable for a data set of 83 participants. This also helped make the statistical tests more meaningful and straightforward to carry out.

This project strengthened my research and data analysis skills, especially in designing a survey and using statistical tests such as ANOVA and t-tests to analyze the raw data. It gave me a clearer understanding of how everyday habits connect to larger issues, such as the global environmental issue of plastic waste.

If I repeated this research project, I would have used a larger dataset beyond my own network and tried to collect more precise packaging data directly rather than through estimates based on size brackets.

In my project, I combined self-reported data and physical measurements which I took myself, sorting empty product containers into their weight brackets and weighing each container to calculate average plastic weights. This let me convert the survey answers into quantifiable measures of plastic consumption, rather than relying on a pre-existing calculation method. I also linked these findings to statistical tests to assess whether demographic factors such as age and gender contributed to the observed variation.

Survey respondents reported their product usage in general categories such as shampoo, conditioner, body wash, etc., set by me, rather than the exact product names, brands, and product sizes, which made it harder to assign specific plastic weights to them. I overcame this challenge by grouping the products into weight-size brackets and then averaging the container weights. I then applied these averaged weights to relevant user inputs to estimate annual plastic consumption per person.

Another challenge I faced was that some participants would share products between family members. To address this, I added a survey question regarding shared household consumption so it could be included in the analysis.

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