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Reducing microplastics from facial exfoliating cleansers in wastewater through treatment versus consumer product decisions

Michelle Chang

Department of Environmental Science, Policy, and Management, University of California, Berkeley, 130 Hilgard Way, Berkeley, CA 94720, USA

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ABSTRACT

Microplastics (<5 mm) have been discovered in fresh and saltwater ecosystems, sediments, and wastewater effluent around the world. Their ability to persist and accumulate up food chains should be a concern as research is still experimenting with techniques to assess their long-term effects on the environment. I sought to characterize the microbeads found in facial exfoliating cleansers so as to better understand how to reduce this source of pollution through consumer use and wastewater treatment solutions. By sampling products from national-grossing cosmetic personal care brands, I was able to gather information on the size, color, volume, mass, and concentration of polyethylene beads in the cleansers. From that data, I modeled onto a consumer survey the estimated volume of microplastics entering a wastewater stream. Through inquiry, I learned the practices of two local wastewater treatment facilities. My findings show that consumer decisions and treatment protocols both play crucial parts in minimizing microplastic pollution.

1. Introduction

Microplastics, plastic particles smaller than 5 mm in diameter, have been detected in the Great Lakes, on beaches, in subtidal sediments, and even in wastewater effluent worldwide (Erikssson et al. 2013, Browne et al. 2010, Claessens et al. 2013, Arthur et al. 2009). These particulates arise from the fragmentation of larger pieces as they weather, or from surface water, where they are present because of the use of consumer-level plastic abrasives called microbeads in personal care products. Microplastics may not be removed by standard wastewater treatment processes and can pass through treatment facilities largely unchanged (Engler 2012).

Abrasive scrub cleansers were developed when people realized that mechanical exfoliation – the process of removing the outermost layer of skin with an abrasive material– produces smoother skin (Decker and Graber 2012, Draelos 2005). Abrasive scrubs incorporate natural and synthetic materials including polyethylene beads, aluminum oxide, ground fruit pits, and sodium tetraborate decahydrate granules to induce various degrees of exfoliation (Mills and Kligman, 1979). According to the American Academy of Dermatology, polyethylene beads are commonly used because their smoothness causes less redness and damage to the skin than some other materials, such as ground fruit pits. They have been found to be from 4 μm to 1 mm in size, which makes them a form of microplastics (Fendall and Sewell 2009, Piringer and Baner 2008). A 2009 study by the University of Auckland in New Zealand revealed that because the majority of facial cleansers now contain polyethylene microplastics, the average person is now likely to use cleansing products with microplastics on a daily basis. Microplastics from facial cleansers entering the wastewater stream from consumer usage and leaving it unfiltered may be a concern to the marine environment as they have the potential to persist, bioaccumulate in the food chain, travel long distances, serve as surface on which organisms grow, and attract organic contaminants (Arthur and Baker 2011).

In this study, I characterize the physical properties of the polyethylene beads, determine how much polyethylene from facial scrubs enters the wastewater stream by surveying consumer use, and explore implications of microplastics going unfiltered into the ocean.

2. Methods

2.1. Selecting product samples

The three top grossing skincare brands, Neutrogena, Clean & Clear, and L'Oreal Paris, were selected according to Mintel's (academic.mintel.com) brand share information. I then narrowed down which products within these brands to sample by assessing those that were available and accessible in local drugstores. I decided on 5 Neutrogena, 3 Clean & Clear and 1 L'Oreal Paris cleanser for a total of 9 product samples purchased in 2013. All sample products listed polyethylene in their ingredient list.

2.2. Collection and characterization

To characterize the (a) size, (b) color, (c) volume, (d) mass, and (e) concentration of polyethylene beads in the cleansers, I took 3 ml

E-mail address: meeseachelle@gmail.com.

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syringe extractions, washed the beads in distilled water, vacuum filtered the effluent over coffee filters, deposited the remaining beads in gridded petri dishes, studied their characteristics under a dissecting scope at 40× magnification with a calibrated ocular micrometer, and made the appropriate conversions as well as calculations under the assumption that they were mostly spherical particulates. For each brand I measured the diameters of the first 10 pieces of microplastic I encountered in each extraction, and did five measurement repetitions (Total N = 50 pieces per brand). Using R statistical analysis (R Development Core Team, 2009), I retrieved the mean, median, 95% confidence intervals (CI) and standard deviations (SD) for the bead sizes examined in each extraction.

2.3. Consumer survey

To obtain customer usage data, I surveyed 175 consumers over a span of 3 months with a nine-question online survey which I distributed through email and social media. The survey asked participants for their demographics, cleanser usage behavior, and scanned for awareness of microplastics in facial cleansers.

2.4. Wastewater modeling

To estimate the amount of microplastic entering a wastewater treatment facility from consumer cleanser usage, I made calculations using the consumer survey results and bead size data. To examine microplastic contribution on a larger scale, I modeled my results onto the UC Berkeley student housing resident population, which totaled 6259 residents (housing.berkeley.edu). Using the bootstrapping method in R and the assumption that the student hall population used the sampled products at similar rates and frequencies to my survey population, I was able to calculate a more accurate annual residential hall usage (g/yr) through refined means.

Additionally, I interviewed several local wastewater treatment facilities via email and phone to attain filter size and processing information to assess if they were equipped to handle microplastics.

3. Results

3.1. Characteristics of microplastic beads

I observed variations in microplastic bead sizes, yet the means and medians of each product were relatively similar. Microbead sizes ranged from 60 to 800 μm in diameter, with an overall mean of 264 μm and standard deviation of 102 μm (Table 1). Products D and F, had the smallest beads at 60 μm, while Product E, had the largest at 800 μm. Product F, had the largest variation in sizes (60–540) with a SD of 130 (Table 1, Fig. 1.)

Table 1
Microplastic measurements. Size of microplastic beads in nine facial exfoliating cleansers. *N* = 50 beads per product sample: (A) Clean & Clear Morning Burst Scrub Oil-free, (B) Clean & Clear Deep Action Exfoliating Scrub Oil-free, (C) Clean & Clear Daily Pore Cleanser, (D) L'Oreal 360 Go Clean, (E) Neutrogena Oil-free Acne Wash Daily Scrub, (F) Neutrogena Clear Pore Daily Scrub, (G) Neutrogena Deep Clean Gentle Scrub, (H) Neutrogena Deep Clean Invigorating Foaming Scrub, (I) Neutrogena Oil-free Acne Wash Pink Grapefruit.

Product	Mean (microns)	SD	Range	Median	95% CI
A	272	89	100–500	240	247–297
B	271	81	120–520	260	248–294
C	183	58	80–400	200	167–200
D	215	98	60–420	200	187–242
E	317	110	200–800	300	285–350
F	265	130	60–540	260	230–301
G	274	120	120–600	250	241–307
H	286	120	100–600	240	256–316
I	293	120	180–600	270	264–322

The SA/Volume ratios were consistently low (0.02–0.03) and bead mass per 1 ml of product varied little across the products (0.09–0.1 g). Product F, contained the most volume of plastic at 149 mm^3 per bottle while Product I, contained the least at 15.5 mm^3 per bottle (Table 2).

3.2. Survey results of consumer product usage

I found that 75% of the surveyed consumers use facial scrubs and factoring in their usage frequencies and rates. I discovered that on an average per consumer rate, Product F contributed the most microplastic annually at 2.68 g/yr. while Product I contributed the least at 0.54 g/yr. Summing up all consumer responses for each product, I found that Product A contributed the most microplastic annually at 10.5 g/yr. while Product H contributed the least at 1.83 g/yr.

I determined that by scaling up my survey responses to model after the Berkeley residential hall population, I calculated the total annual microplastic contribution from the student housing to be roughly 5000 g (Table 3).

3.3. Wastewater treatment

I received information from two local wastewater facility experts on treatment processes practiced in the East Bay counties and the city of San Francisco.

East Bay Municipal Utility District's (EBMUD) provides water and sewage treatment for customers in portions of Alameda County and Contra Costa County in California, on the eastern side of the San Francisco bay. A maximum of 2.2 million gallons per day (MGD) of the annual average daily plant flow of 62 MGD can be processed through the EBMUD's East Bayshore Water Recycling Plant, which includes a microfiltration system in its tertiary treatment process with a filter size of 0.1 μm. The remaining 96% of the flow receives secondary treatment only and does not undergo tertiary treatment prior to discharge into the San Francisco Bay (Vincent De Lange, EBMUD Senior Civil Engineer).

The San Francisco Public Utilities Commission (SFPUC) is a department of the City and County of San Francisco that provides water, wastewater, and municipal power services to San Francisco. The city's two main wastewater treatment plants, Southeast and Oceanside, also employ secondary treatment. At Oceanside, there are plans in the near future to install microfiltration, reverse osmosis and UV disinfection for recycled water, which accounts for a fraction of the total MGD, to be used towards irrigation of parks and similar recreational spaces. The Southeast facility discharges into the bay while Oceanside's discharge is 4.5 miles offshore into the Pacific Ocean. SFPUC's Karla Guevarra did add that other plants in the Bay Area, such as the Cities of Palo Alto and San Jose employ tertiary treatment.

4. Discussion

Polyethylene in facial scrubs as a source of microplastic marine pollution is gaining momentum in research and in the public eye. By characterizing the physical properties of microplastic beads found in a sample of products, I found little variation in sizes and colors across brands. This suggests that producers may have a uniform standard. The bead sizes in the products I sampled were all small enough to bypass filtration in certain wastewater treatment facilities. From my survey, I discovered that though the majority of the study population did use a facial scrub, they were not aware that many contained plastic particles. Laboratory studies have shown that suspension-feeding sea cucumbers along with range of organisms including mussels, barnacles, lugworms, and tiny crustaceans do ingest plastic particles, though it is unknown if plastic ingestion adversely affects their physiology or fitness (Graham and Thompson, 2009). These species serve as the foundation of an intricate food chain, which humans play a huge part in. New research also suggests that polyethylene is an excellent transporter of