RMP
REGIONAL MONITORING PROGRAM FOR WATER QUALITY IN SAN FRANCISCO BAY

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MICROPLASTIC CONTAMINATION IN SAN FRANCISCO BAY

MICROPLASTIC IS A TERM USED TO DESCRIBE FRAGMENTS OF PLASTIC 5 MM OR SMALLER

Sources of aquatic microplastic pollution include microbeads used in personal care products such as facial scrubs and toothpastes, pellets (called nurdles) used as precursors for industrial products, plastic fibers derived from washing clothes made with synthetic materials, and fragments of larger plastic items. Motivated by recent state and federal efforts to ban microbeads in personal care products, the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) characterized Bay surface waters and wastewater treatment plant (WWTP) effluents for microplastic contaminants. Nine Central and South Bay surface water samples were collected using a Manta Trawl. Two-hour sieved samples of effluent were collected from eight WWTPs discharging to the Bay. Microplastics in samples were characterized by size, type, and abundance. Preliminary results from this survey for plastic pollution in the San Francisco Bay are presented.

KEY SOURCES OF MICROPLASTIC POLLUTION

MICROBEADS made up of small pellets and fragments used in personal care products such as facial scrubs and toothpastes – see Focus on Microbeads

FOAMED PLASTIC PARTICLES from Styrofoam products, cigarette butts, and other items

FRAGMENTS from the photodegradation of larger plastic items such as plastic bottles [1]

FIBERS derived from clothes and fabrics made with synthetic materials (e.g., polyester, acrylic) or fishing lines

NURDLES larger pre-production plastic pellets used as precursors to manufacture plastic products

PATHWAYS FOR PLASTICS TO ENTER THE BAY

- Wind- and stormwater-carried trash and plastic debris from land
- Illegal dumping [3]
- Microbeads from personal care products and plastic fibers from clothing wash down the drain and enter wastewater treatment plants [4]; wastewater treatment is not specifically designed to remove microplastics, so these particles can be released in treated effluent [5]

POTENTIAL CONCERNS OF MICROPLASTICS

- Due to the hydrophobic properties of the plastic material, persistent organic chemicals including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), dioxins, and pesticides such as DDT have been shown to preferentially sorb to microplastics [6]
- Lower trophic organisms can mistake microplastics for food; ingestion can lead to physical harm, exposure to sorbed contaminants, and bioaccumulation of microplastics in higher trophic organisms [1,6,7]

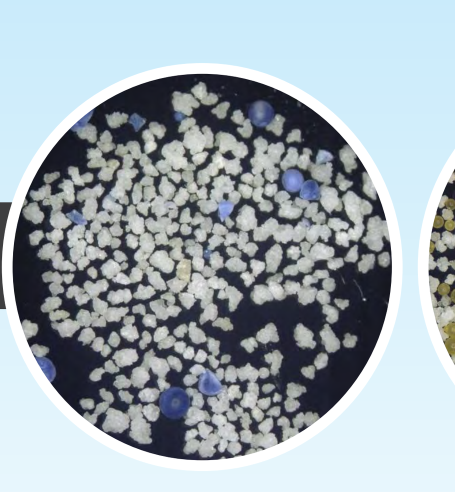
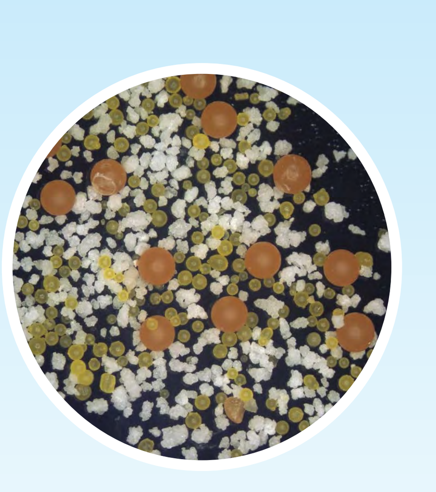
FOCUS ON MICROBEADS

MICROBEADS ARE PLASTIC PARTICLES INTENTIONALLY ADDED TO PERSONAL CARE PRODUCTS FOR THEIR ABRASIVE QUALITIES

PHOTO COURTESY 5 GYRES

Round, bead-like, brightly-colored plastic particles typically make up less than 10% of the microbead content of personal care products; the rest of the particles are rough, plain fragments [2]. Both types of plastic particle are less than 1 mm in diameter. In the present analysis, the rounded microbeads are classified as pellets, while the rough microbeads are classified as fragments. While the detection of small pellets can be considered a tell-tale sign of microbead contamination, these particles are only a small part of the plastic pollution from personal care products.

A number of recent state, federal, and international actions aim to ban or limit the use of plastic microbeads in personal care products. Many companies have already committed to switching to alternate ingredients.

Optical microscope photos of microbeads extracted from off-the-shelf personal care products showing the iconic rounded, bead-like particles (classified as "pellets" <1 mm in this analysis) along with more plentiful, rough plastic fragments. Courtesy Sherri A. Mason

METHODS

SAMPLE COLLECTION

EIGHT BAY AREA WWTPS: Treated effluent was sieved through 0.355 mm and 0.125 mm mesh, typically for two hours during peak flow.

NINE CENTRAL AND SOUTH BAY SURFACE WATER SITES: A Manta Trawl was deployed at each site for a 30-minute trawl. In some areas, trawl contents included considerable vegetation; nine small fish were collected as accidental by-catch at one site.

Although fish collection was not planned, the abundance of microplastics in these by-catch fish was determined after thorough rinsing to remove external contaminants.

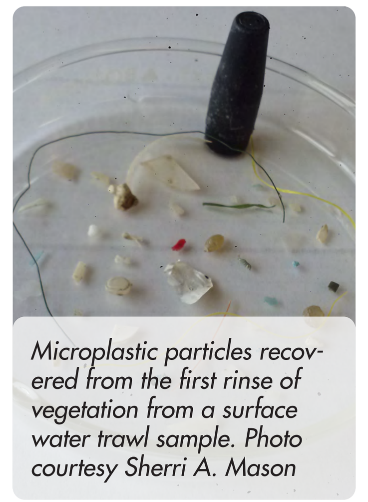
Photo of effluent sample collection courtesy Eric Dunlavey

Ian Wren of San Francisco Baykeeper deploying the Manta Trawl. Photo courtesy Meg Sedlak

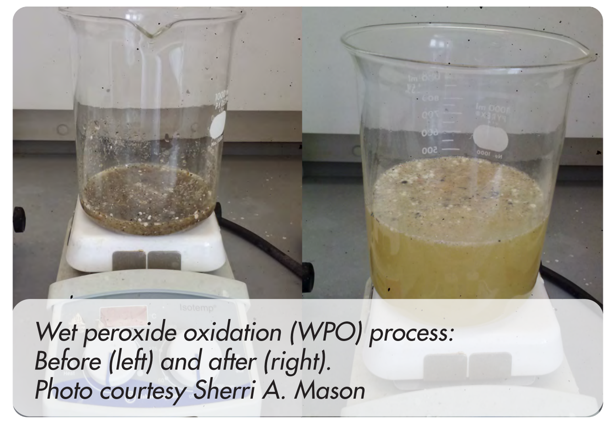
SAMPLE PREPARATION

Surface water samples required considerable preprocessing. Vegetation was rinsed in triplicate, then soaked in DI water to recover associated plastic debris. Samples were sieved into three different sized nets (0.355 mm, 1 mm and 4.75 mm), rinsed and categorized. After larger plastic debris was removed, a wet peroxide oxidation (WPO) process was used to remove natural organic material, leaving behind synthetic plastics.

The WWTP effluent samples also went through the WPO process.



Microplastic particles recovered from the first rinse of vegetation from a surface water trawl sample. Photo courtesy Sherri A. Mason



Wet peroxide oxidation (WPO) process: Before (left) and after (right). Photo courtesy Sherri A. Mason

ANALYSIS

Plastic particles were typed and counted. Extrapolations using flow rates (WWTP samples) or tow lengths (surface water samples) were used to calculate microplastics abundances.

RESULTS

FRAGMENT (INCLUDES MICROBEADS, OTHER SOURCES) PELLET (MICROBEADS, NURDLES)
FIBER (SYNTHETIC FABRIC, CLOTHING, FISHING LINES) FILM (PLASTIC BAGS, PACKAGING) FOAM (STYROFOAM, CIGARETTE BUTTS)

WWTP EFFLUENT

- The eight WWTPs discharged an average of 490,000 particles of microplastic per day (TABLE 1)
- The average count of plastic particles per gallon was lower than observed in a similar study of New York WWTPs (0.02 vs. 0.08 particles per gallon), while the average Bay Area discharge per day was comparable (490,000 vs. 420,000 particles per day) [8]
- WWTPs employing more advanced wastewater treatment technologies did not have lower concentrations of microplastics than more traditional secondary technology
- Fibers were the dominant form of microplastic pollution in effluent, and are likely derived from washing synthetic clothing and fabrics (FIGURE 1)
- Fragments, the second most abundant form of microplastic pollution, may be derived from microbeads in personal care products as well as other sources
- The absence of small pellets does not indicate a lack of microbead-based contamination, as most microbeads are classified as fragments [2]
- A breakdown of WWTP effluent microplastic abundance by size shows they were fairly evenly split between smaller and larger particles (TABLE 2)
- A 24-hour sample could provide a more comprehensive picture of microplastic pollution in treated wastewater, as peak personal care product use follows distinct diurnal patterns

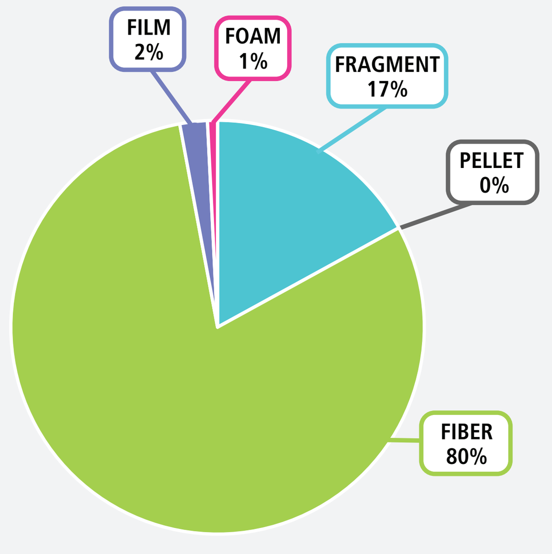


FIGURE 1. *Microplastic particles by type detected in Bay WWTP effluent samples*

WWTP	PARTICLES/ GALLON	PARTICLES/ DAY
San Jose-Santa Clara	0.01	1,000,000
East Bay MUD	0.02	870,000
Palo Alto	0.03	670,000
Central Contra Costa	0.02	560,000
Fairfield-Suisun	0.02	290,000
EBDA/San Leandro	0.01	290,000
San Mateo	0.02	140,000
SFO (sanitary plant)	0.05	32,000
Average	0.02 ± 0.01	490,000 ± 360,000

TABLE 1. *Microplastic levels in Bay WWTP effluent*

PLASTIC TYPE	0.125 – 0.354 mm	>0.355 mm
Palo Fragment	53	34
Pellet	0	0
Fiber	216	193
Film	1	10
Foam	3	1
Total Count	273	238
% of Total Microplastics	53%	47%

TABLE 2. *WWTP effluent microplastic abundance by type and size (total count)*

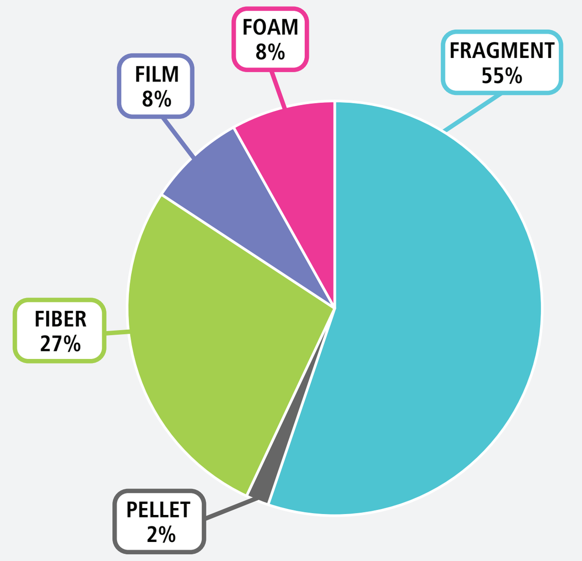


FIGURE 3. *Microplastic relative abundance by type detected in Bay surface water samples*

REGION	ABUNDANCE/KM2 (AVERAGE)
South Bay	1,000,000
Central Bay	310,000
Patapsco River Chesapeake Bay[9]	155,000
Magothy River Chesapeake Bay[9]	110,000
Lake Erie[3]	110,000
Rhode River Chesapeake Bay[9]	84,000
Corsica River Chesapeake Bay[9]	41,000
Lake Superior[3]	5,000
Lake Huron[3]	3,000

TABLE 3. *San Francisco Bay has higher average levels of microplastic contamination than the Great Lakes or Chesapeake Bay*

PLASTIC TYPE	0.355 – 0.999 mm	1.000 – 4.749 mm	>4.75 mm
Fragment	2,500,000	890,000	35,000
Pellet	96,000	16,000	0
Fiber	1,000,000	700,000	19,000
Film	160,000	270,000	47,000
Foam	190,000	310,000	14,000
Count/km2	4,000,000	2,200,000	120,000
% of Total	63%	35%	2%

TABLE 4. *Bay Microplastic Abundance by Type and Size (Count/km2)*

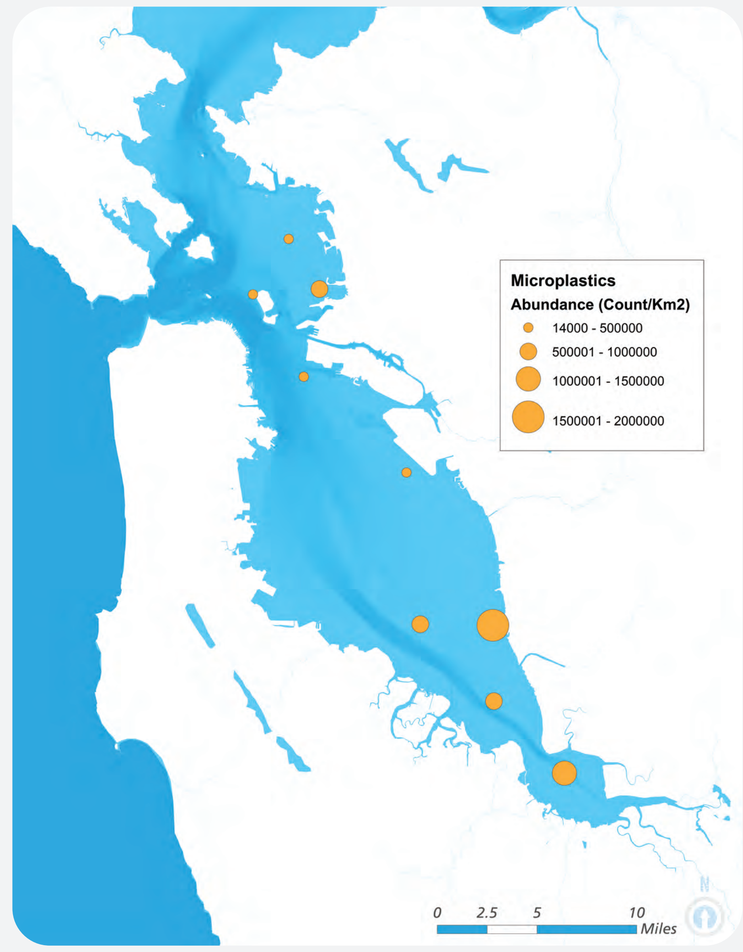


FIGURE 2. *Total microplastic abundances in Bay surface water*

BAY SURFACE WATER

- South Bay levels of microplastic contamination are typically higher than Central Bay levels (FIGURE 2)
- Average South and Central Bay microplastic levels are higher than average measurements from the Great Lakes and Chesapeake Bay (TABLE 3)
- Fragments were the dominant form of microplastic pollution in surface water, and may be derived from microbeads in personal care products as well as many other sources (FIGURE 3)
- Fibers, the second most abundant form of microplastic pollution, may be derived from fishing line as well as washing synthetic clothing and fabric
- Pellets, from microbead products and pre-production plastic nurdles, are a smaller portion of overall Bay surface water microplastic pollution
- Differences in the relative proportion of plastic types in effluent (FIGURE 1) and Bay surface water (FIGURE 3) may be due to sources of plastic from other pollution pathways (e.g., stormwater) or in situ processes such as binding with natural particles, settling to the Bay floor, or ingestion by biota
- A breakdown of Bay microplastic abundance by size shows a greater proportion of smaller (0.355 – 0.999 mm) microplastic particles (TABLE 4); smaller particles are more easily ingested by aquatic organisms [1]

FISH

- 52 pieces of microplastic were recovered from nine small prey fish collected as unintentional by-catch at one surface water site; two small pellets clearly derived from microbead products were found
- These Bay fish averaged nearly 6 pieces of microplastic per fish; in contrast, 1-3 pieces of microplastic are typically recovered from fish in the Great Lakes [10]
- These preliminary findings suggest further study of microplastic contamination of Bay fish is needed to determine whether Bay fish contain more microplastics than those in other major water bodies, and to investigate the potential for bioaccumulation of microplastics in sport fish consumed by people

CONCLUSIONS

- Microplastics are widespread in the Central and South Bays, and found at levels higher than other water bodies near highly urbanized regions of the U.S.
- Bay WWTPs discharge microplastics at levels comparable to New York WWTPs
- The data do not suggest a difference in the concentration of microplastics in effluent for WWTPs employing secondary vs. advanced secondary treatment
- Fragments and fibers were seen in the greatest abundance in both Bay surface water and effluent
- Microbeads in personal care products, a recent policy focus, consist primarily of small fragments, and to a lesser extent small pellets; our findings indicate microbeads can be found in the Bay, and are likely discharged via treated wastewater
- Monitoring microplastics in Bay sediment and biota will provide a more complete picture of Bay contamination relative to other regions

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