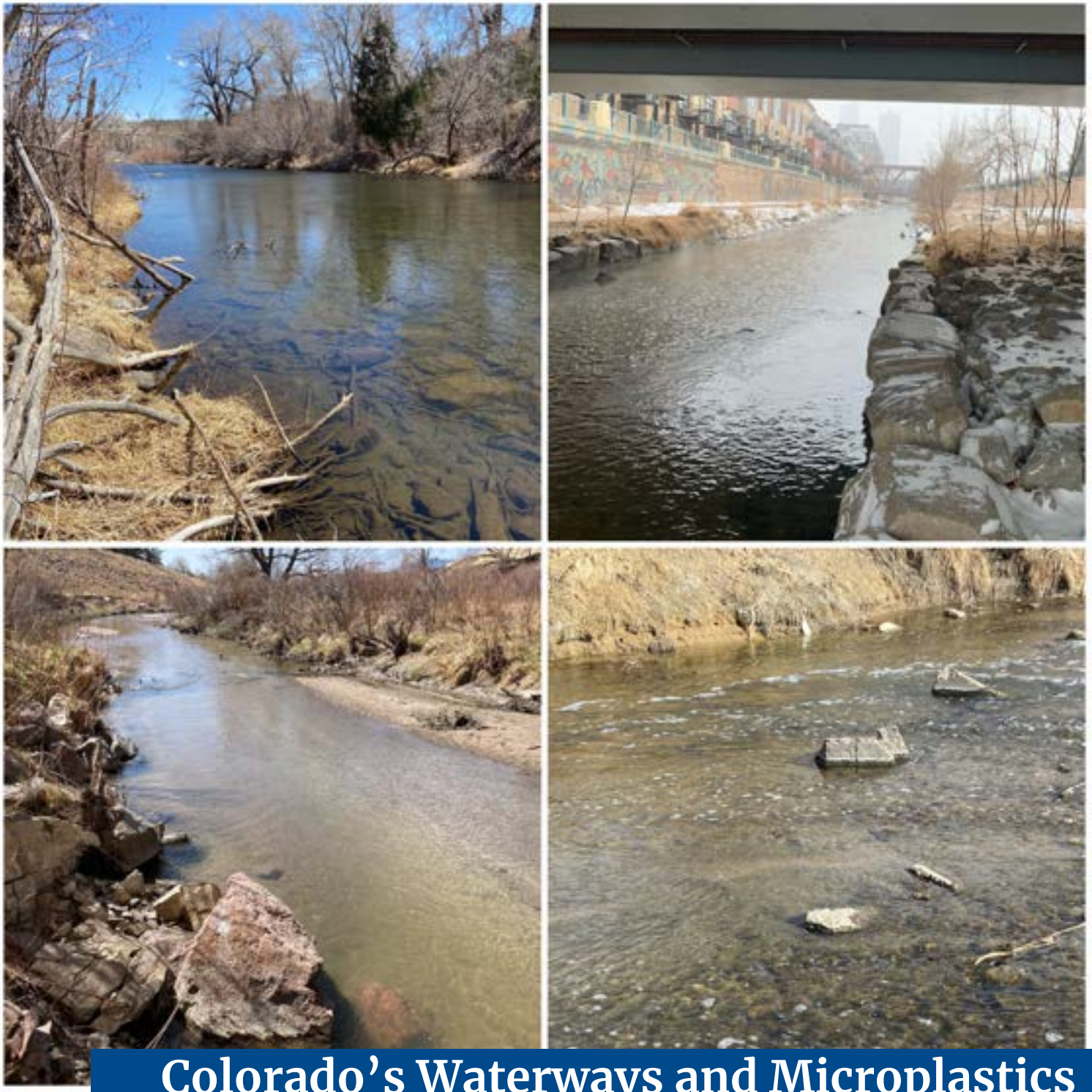

Colorado's Waterways and Microplastics

ENVIRONMENT COLORADO
RESEARCH & POLICY CENTER

CoPIRG Foundation

Colorado's Waterways and Microplastics

A Survey of Rivers and Streams along Front Range Watersheds in Colorado

Written by:

Danny Katz, CoPIRG Foundation

Lexi Kilbane, Environment Colorado Research & Policy Center

May 2023

Acknowledgements

Environment Colorado Research & Policy Center and CoPIRG Foundation thanks our individual contributors for their generous support of our work. The authors bear responsibility for any factual errors. Policy recommendations are those of Environment Colorado Research & Policy Center and CoPIRG Foundation.

Thanks to all the partners and volunteers who helped collect samples, including Gabriel Curcio and Michael Casler.

Special appreciation to Faran Savitz at PennEnvironment Research and Policy Center. This report was modeled off and pulled from *Microplastics in Waterways* and *Pennsylvania's Pristine Waterways and Microplastics*, both by PennEnvironment Research and Policy Center, and *Microplastics in Oregon*, by Environment Oregon Research and Policy Center.

The views expressed in this report are those of the authors. Participation in this project does not mean an endorsement of the views expressed therein.

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Executive Summary

Plastic is everywhere and in everything. It's used as packaging, it's in food service products, and it's in clothing. All told, Americans generate over 36 million tons of plastic waste every year, but less than 6% is recycled.[1,2] Often when talking about plastic pollution, the images that come to mind are sea turtles and birds ensnared in bags or straws, massive trash gyres in the Pacific Ocean, or whales washed ashore with hundreds of pounds of plastic waste in their stomachs. So it may not be surprising that in one study, as of 2012, 59% of 135 seabird species had ingested plastic, with that number expected to rise to 99% by the year 2050.[3]

Plastic use and pollution is pervasive, even here in scenic "Colorful Colorado." In 2020, we estimated that every day, Coloradans went through 4.6 million bags and 1.2 million polystyrene cups.[4] Plastics are often a common form of litter recovered in Colorado waterway cleanups, and the Colorado Department of Transportation spends millions of taxpayer dollars each year cleaning litter from roadsides.[5, 6]

But litter alone doesn't capture the full scope of plastic pollution. Research suggests that we could be missing 99% of the plastic that makes its way into the environment.[7] That's because plastic doesn't degrade in the environment like an apple or a piece of paper;[8] instead it breaks into smaller and smaller pieces of plastic called microplastic, which is plastic less than 5mm in length, or smaller than a sesame seed.[9]

A growing area of concern regarding our plastic waste is the environmental and public health threat posed by these microplastics. They are severe laceration and starvation hazards to wildlife and have been found in our air, food, and bodies.[10, 11] Microplastics also attract pollutants that may already exist in the environment at trace levels, accumulating toxins like DDT & PCBs and delivering them to the wildlife that eat them, often bioaccumulating through the food chain.[12]

Microplastics can enter our environment through a myriad of pathways. Litter, illegal dumping, and plastic waste are all obvious culprits. Microfibers are another prevalent type of microplastics and are introduced into the environment through clothes washing as well as usual wear and tear.[13] With wastewater treatment plants unable to fully filter these plastic fibers out, they can end up washed into waterways and ultimately in drinking water.[14] The creation of new plastic products uses small pellets called nurdles which are easily lost and frequently enter waterways.[15] Packaging and the factory processes in the creation of products like bottled water can even cause microplastic contamination.[16]

A prime location for testing microplastics is therefore in our waterways. Colorado's rivers begin in state and then flow outside making it a headwater state.[17] The river systems originating high in the Rocky Mountains drain into one-third of the landmass of the lower 48 United States.[18] According to Ceres, just one of the seven major river basins of the state, the Colorado Basin, supplies water to nearly 40 million people and sustains a $5 billion agriculture industry.[19] On the eastern side of the state, the South Platte River Basin supplies industrial and municipal water for about 5 million people, 3.5 million acres of farmland, and supports numerous recreational and wildlife areas.[20]

To better understand the scope of the microplastic problem in Colorado, Environment Colorado Research and Policy Center volunteers sampled 16 different water bodies in the Front Range. We found microplastics in 100% of our samples.

Our project took samples from waterways between February and April of 2023 and tested them for four types of microplastic pollution:

1. Fibers: primarily from clothing and textiles;
2. Film: primarily from bags and flexible plastic packaging;
3. Fragments: primarily from harder plastics or plastic feedstock;
4. Beads: primarily from facial scrubs and other cosmetic products.

The results we found were troubling:

- **100% of the sites we sampled had microfibers;**
- **88% of the sites we sampled had microfilm;**
- **75% of the sites we sampled had microfragments;**
- **0% of the sites we sampled presented microbeads.**

It's clear that the scope of plastic pollution along parts of the Front Range is extensive . **In order to address the environmental and waste crisis being caused by our overreliance on plastics, our leaders at the federal, state, and local levels should implement policies that have been previously passed and consider new action. We offer the following recommendations:**

1. Phase out single-use plastics - In 2024, Colorado laws will go into effect that phase out polystyrene cups and containers and single-use plastic bags. In 2024, preemption will also be lifted, allowing local communities to go further to target other single-use plastic items like straws and utensils.
2. Implement Colorado's Producer Responsibility law - Producer responsibility is a mechanism to shift the costs and management of postconsumer waste from local governments and consumers and onto producers themselves. Done well, these programs can disincentivize unnecessary plastic packaging production and use. In 2024, the General Assembly will need to approve a producer responsibility draft plan to keep implementation moving forward.
3. Halt policies that promote increased manufacture & use of single-use plastic - Communities and legislators across Colorado should oppose subsidies and tax breaks for new petrochemical infrastructure that doubles down on the fossil fuel-to-plastics

pipeline. For example, the City of Greeley is considering a "Waste to Energy," pyrolysis plant that would depend on a stream of plastics to function.

4. Tackle fast fashion - Clothing production and use is responsible for up to 22 million metric tons of microplastics that could end up in our oceans between 2015 and 2050.[21] Retailers must stop sending overstock, unsold and unused clothing, to landfills and incinerators and should also move away from making products containing synthetic plastic fibers, which inevitably become microplastic pollution. The state should consider legislation if companies do not take action.

5. Support reuse - Using items that are designed for reuse can reduce the quantity of plastic we produce and contaminate our waterways. Cities and the state could support reuse including grants to help restaurants invest in cleaning equipment or update public health laws to allow customers to use their own reusable containers to take food to go.

Collection site on Clear Creek.

Introduction

Every day, Americans throw away tons of plastic "stuff" -- cups, plates, bags, containers, forks, knives, spoons, condiment packets and more. Sadly, much of this plastic waste never makes it to the trash can and ends up soiling our parks and public lands, where it also washes into our rivers, harming wildlife. Once in our environment, plastic does not biodegrade.[22] Instead, it breaks into smaller and smaller pieces known as microplastic.

Often when talking about plastic pollution, the images that come to mind are sea turtles and birds ensnared in bags or straws, massive trash gyres in the Pacific Ocean, or whales washed ashore with hundreds of pounds of plastic waste in their stomachs. So it may not be surprising that 60% of all seabird species have ingested plastic, with that number expected to rise to 99% by the year 2050.[23] Studies have also estimated that by 2050 there will be more plastic in our oceans than fish.[24]

Plastic use and pollution is pervasive, even here in scenic "Colorful Colorado." In 2020, we estimated that every day, Coloradans went through 4.6 million bags and 1.2 million polystyrene cups.[25] Plastic bags are often the most common form of litter recovered in Colorado creek cleanups, and the Colorado Department of Transportation spends millions of taxpayer dollars each year cleaning this litter from roadsides alone.[26, 27]

Canadian Geese swim the perimeter of Denver's City Park lake, not far from a plastic bag caught on the bank.

A growing area of concern regarding our plastic waste is the environmental and public health threat posed by these microplastics. They are severe laceration and starvation hazards to wildlife and have been found in our air, food, and bodies. [28,29] Microplastics also attract pollutants that may already exist in the environment at trace levels, accumulating toxins like DDT & PCBs and delivering them to the wildlife that eat them, often bioaccumulating through the food chain.[30] And the evidence is mounting that humans not only ingest microplastics, but that those plastics remain in the body and cause harm.[31] Microplastic has been found in human blood and even the lungs of living patients.[32] And although not too much is known about the full scope of health

effects of microplastics in humans, plastic, and the chemicals it contains, can cause endocrine disruption, hormonal effects, and reproductive disorders.[33]

Microplastics don't arrive in our waterways from just one source. Plastic littered on roads, in streams, or in the ocean can release microplastics. Plastic waste disposed of in landfills can also release microplastics into the environment through wind, rain, and landfill leachate.[34] The burning of plastic or other waste can also create airborne microplastic particles.[35]

Cosmetic and personal care products can also release a specific microplastic called microbeads through sinks and drains.[36] While this particular type of additive has been federally banned for manufacture since 2018, some products or their long-lasting remnants may still be in circulation.[37] Nurdles, the raw plastic feedstock that are used to make new plastic items, are lost by the millions every year.[38] Synthetic materials in car tires release microplastics onto roads that are swept into stormwater infrastructure.[39]

Collection site at Waterton Canyon.

Clothing and other textiles are also a major source of microplastics. Fibers are one of the most commonly found types of microplastic and they're sourced from synthetic and hybrid materials like fleece.[40] Normal wear and tear will release microplastics into the air, and cleaning these textiles in a washing machine releases millions of microfibers into wastewater infrastructure that treatment plants are unable to fully filter out.[41] [42]

Packaging and the factory processes in the creation of products like bottled water can even cause microplastic contamination.[43]

The small size of microplastics- less than 5 millimeters- makes it easy for them to be carried by wind and rain and deposited in the environment far from their source.[44]

A prime location for testing microplastics is therefore in our waterways. Colorado is a headwater state, meaning all its rivers begin within and flow outside of the state.[45] The river systems originating high in the Rocky Mountains fully drain into one-third of the landmass of the lower 48 United States.[46] According to Ceres, just one of the seven major river basins of the

state, the Colorado Basin, supplies water to nearly 40 million people and sustains a $5 billion agriculture industry.[47] On the eastern side of the state, the South Platte River Basin supplies industrial and municipal water for about 5 million people, 3.5 million acres of farmland, and supports numerous recreational and wildlife areas.[48]

For a bird or fish, it's easy to mistake these small pieces of plastic for food -- especially when there are billions of pieces of microplastic floating in our waterways.[49] Scientists have found that ingesting even tiny particles of plastic can alter the behavior and metabolism of fish – and people can ingest these pollutants as they make their way up the food chain.[50, 51]

Over the past few years, staff with our sister organizations in Oregon and Pennsylvania have surveyed microplastics in water bodies. In March 2020, the PennEnvironment Research & Policy Center released a study of 53 Pennsylvania waterways titled "Microplastics in Pennsylvania: A Survey of Waterways." The study found one or more types of microplastic in every waterway sampled.[52]

In December 2021, Environment Oregon Research and Policy Center undertook a similar study of a variety of rural and urban water bodies, and found microplastics in all 30 locations.[53]

PennEnvironment Research and Policy Center followed with a second report in 2022 targeting 50 of the state's most pristine waterways, entitled "Pennsylvania's Pristine Waterways and Microplastics: A Survey of Exceptional Value, High Quality, and Class A Trout Rivers and Streams". Despite the strategic sampling of well-stewarded streams and rivers, their second report found similar results of ubiquitous microplastic pollution.[54]

This report pulls from and builds on the growing body of citizen science research striving to better understand the extent of our world's microplastics problem. With permission from the authors, this report recycles some of the aforementioned reports' language and builds on their methods. More specifically, our report tests the presence of microplastics in water bodies along Colorado's Front Range.

The Front Range encompasses the mountains, foothills, and plains nearest the mountains that fall east of the Continental Divide.[55] The Front Range Urban Corridor is the most densely populated area of the state, comprised of the cities of the eastern base of the southern Rocky Mountain Range.[56] The target watersheds of the Front Range are the South Platte and Arkansas watersheds, whose hydrological sub-parts are river basins of the same names.[57]

The four watersheds of Colorado.[58]

The South Platte River flows for 380 miles in the state, from the Rocky Mountains through the Denver metro area towards the High Plains, with many tributaries flowing into each other along the way.[59] The Cherry Creek confluence, near which gold was discovered in 1858, was the

focal point for the foundation of the City of Denver.[60] These waters are the ancestral home of Colorado's state fish, the Greenback Cutthroat, which Colorado Parks and Wildlife is dedicated to restocking since its brush with extinction.[61]

The Arkansas River headwaters originate in the central mountains before they meander south and east through the state and out to Kansas.[62] It is a major tributary of the Mississippi River and the sixth longest river in the United States.[63] The Arkansas River is also known for its trout fishing and diverse avian life supported by plentiful populations of Brown and Rainbow Trout.

Confluence Park in the Denver Metro provides an urban whitewater park where Cherry Creek flows into the South Platte River. Image by Kent Kanouse, 2010.[64]

A Widespread Problem

Scientists are still documenting the scope of plastic pollution and investigating its effects in freshwater ecosystems and on human health. Nonetheless, there is a growing field of data showing that microplastics are spreading across the planet and becoming more pervasive in our daily lives:

- Microplastics have been found in global and domestic samples of **tap water, sea salt, and beer**;[65]
- Microplastics have been found in a study of some of the most popular **bottled water** brands across several countries that point to contamination from packaging and manufacturing;[66]
- U.S. Geological Survey (USGS) researchers found microplastic in 90% of rainwater samples collected from sites in **Rocky Mountain National Park** and the Denver-Boulder urban corridor;[67]
- Researchers from Utah State and Cornell University found that microplastics are taken up by the air and carried around the globe through **atmospheric currents**;[68]
- Plastic pollution has now been found in isolated marine environments in **the Arctic and Antarctic**;[69]
- Research from the Chinese Academy of Sciences has shown that microplastics in the soil can be taken up by the roots of **wheat and lettuce crops** and transferred to the edible portions of those plants;[70]
- Recent studies from Utah State University and the University of Strathclyde have found high concentrations of microplastics in **fog, dust, and ocean air**;[71, 72]
- In Oregon, a recent study from Portland State University found microplastics in the stomachs of oysters and razor clams off the Oregon Coast. In fact, only two out of the nearly 300 mollusks tested were found to be plastic-free;[73]
- Microplastic pollution has been recorded at the highest elevation on Earth, **Mt Everest**, and the lowest, **the Marianas Trench** at the very bottom of the Pacific Ocean;[74, 75]
- Microplastics have been found in **human fetuses**, potentially meaning that microplastics enter the human body before birth.[76]
- Microplastics from plastic bottles, polystyrene containers, and LDPE film have been found in samples of **human blood.**[77]
- Microplastics have been found deep in the **lung tissue of living patients**, demonstrating that the plastic does not pass through our bodies but lingers.[78]

Macroplastic pollution in Cherry Creek.

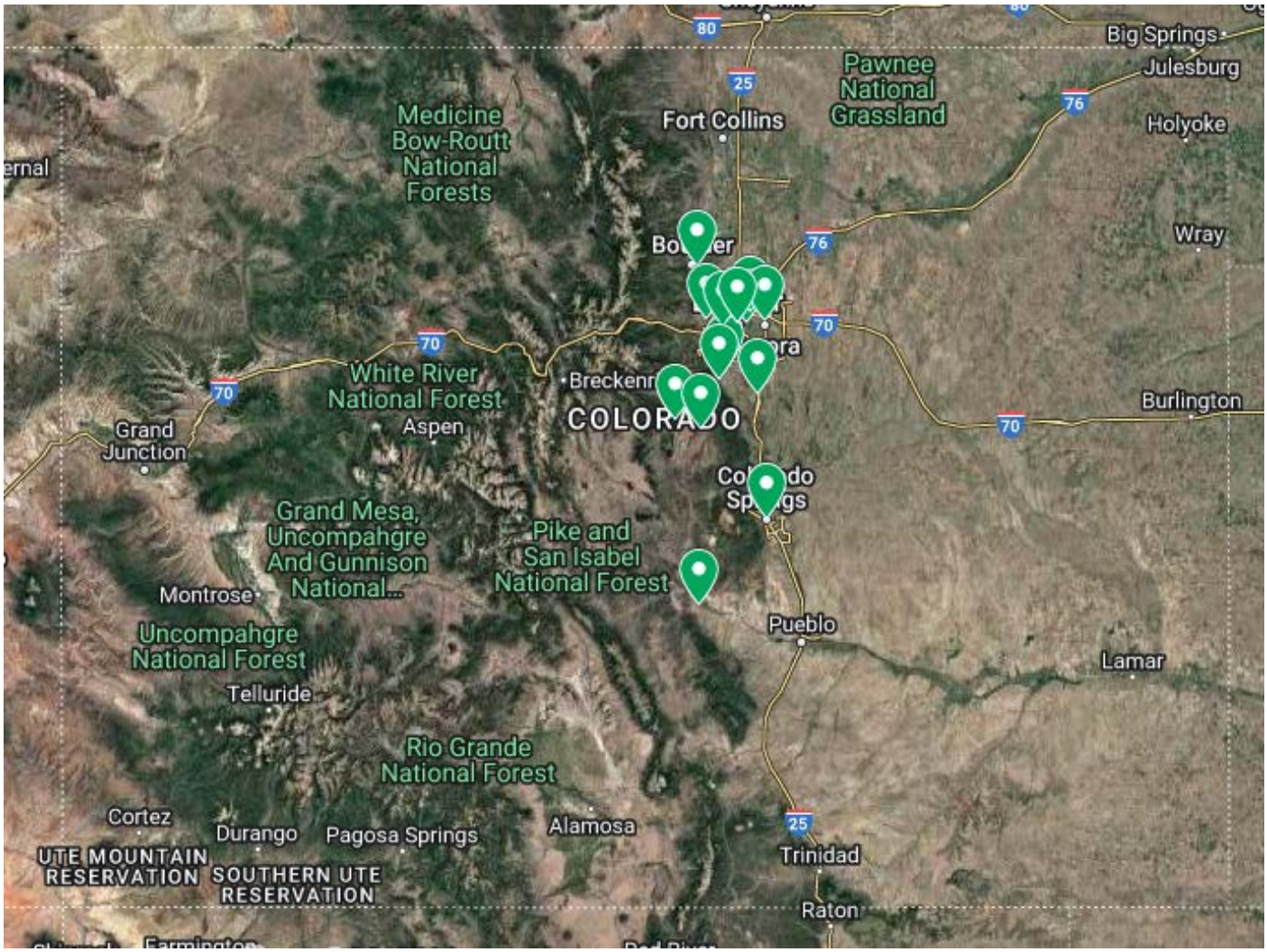
While the body of research on the effects of microplastics on human health is growing almost daily, recent studies raise a red flag for the health risks likely posed by microplastic ingestion.[79]

Research from the National Oceanic and Atmospheric Administration (NOAA) has shown that microplastic particles can attract heavy metals and chemical contaminants, which are then consumed by fish, birds, and humans (among other organisms).[80] These can include PCBs (polychlorinated biphenyls) and pesticides which can pose significant health risks when consumed by animals and humans.[81]

Methodology

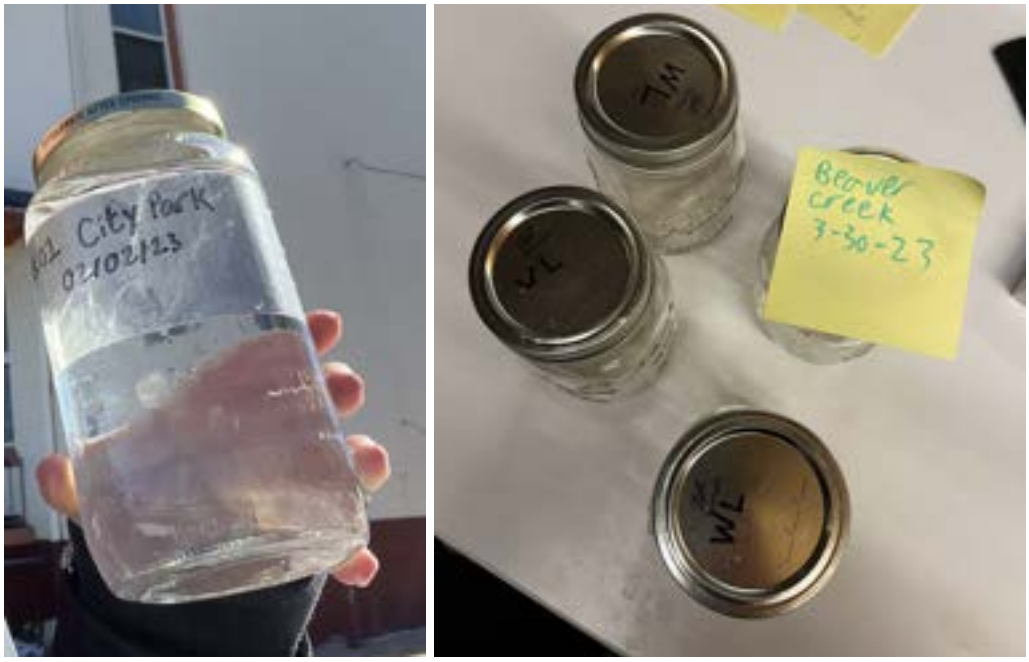
Sampling

The goal of this survey was to examine the presence and type of microplastics in waterways along Colorado's Front Range. Sixteen sampling sites were chosen nearby recreational opportunities accessible during the winter months. A map with the sampling locations and landscape photos is available here.



Green pins on the map indicate our sampling locations.

Sampling was undertaken by organizational staff and trained volunteers adhering to a consistent protocol based on best practices, video guides, and earlier reports, including the *Microplastics: Sampling and Processing Guidebook* protocol developed by NOAA, Mississippi State University Extension, Dauphin Island Sea Lab, and Sea Grant.[82] The protocol called for collecting 64 ounces of water at any given site, typically in four 16-oz glass mason jars. Derivations from the standard collection volume are noted in the Data Table.



Jars for sampling test-run and pre-analysis.

For each unit of water, collectors rinsed vessels and lids with the source water three times before collecting the sample upstream of themselves, minimizing potential for contamination. Collectors were instructed to sample from the edge of the water source so as not to disturb sediment that could later hamper the visual analysis. Once collected, samples were labeled with dates and identification numbers for tracking purposes. Collectors subsequently photographed the access point of the water source, the landscape, and visible pollution nearby. Lastly, collectors donned gloves and did a focused litter clean-up of the area, paying particular attention to macroplastics. The jars were stored at room temperature before being brought to the CoPIRG office for analysis.

Analysis

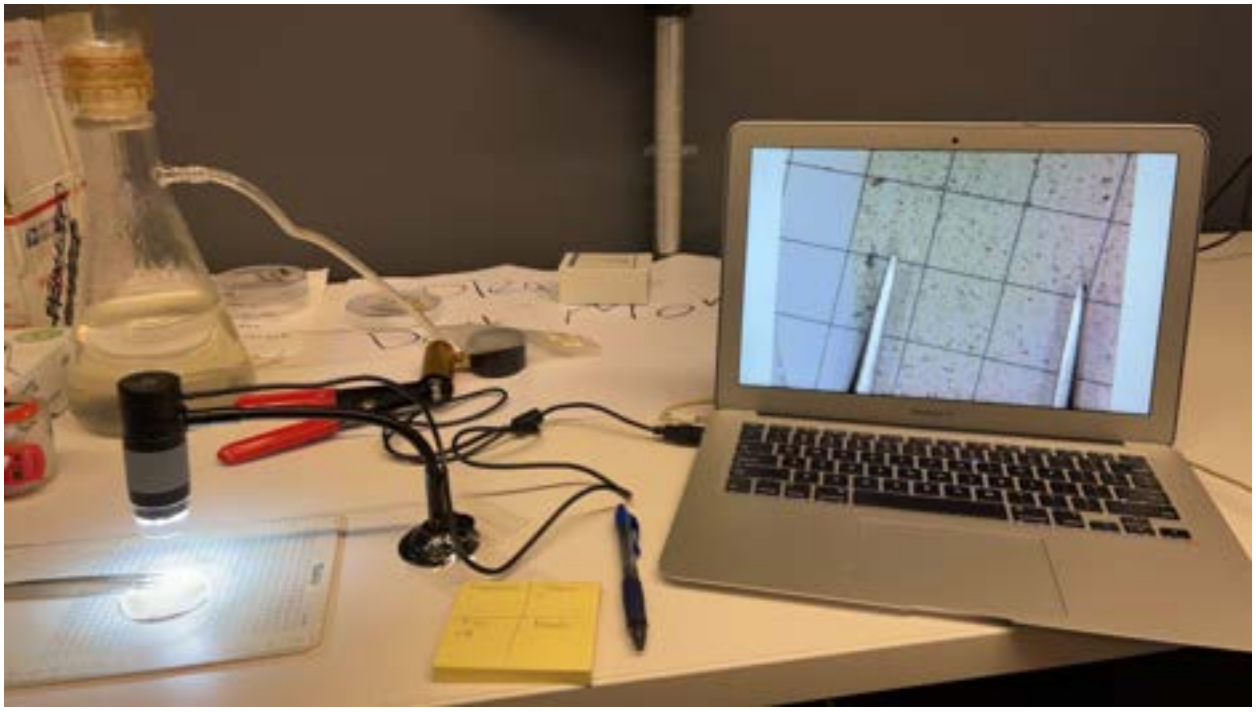
Analysis was performed on a rolling basis in an empty cubicle in the CoPIRG office. All lab materials, including the filter funnel, petri dishes, forceps, and tweezers were rinsed with filtered water between samples to minimize potential contamination from outside sources. Jars containing samples were kept sealed until they were filtered, and filters remained closed in their packaging or petri dishes until they were analyzed under the microscope.

The team initially attempted to filter test samples through a hand pump apparatus and a 47mm (diameter) .45 micron (pore size) filter, which proved difficult and potentially limiting to our sample size. Our literature review determined that a 5 micron filter would be adequate for observing microplastics while permitting a faster flow rate than the .45 micron filters, and that an automatic vacuum pump could streamline the process. Therefore, our team switched from using .45 micron filters to 47mm 5 micron Mixed Cellulose Ester (MCE) membrane filters early on in the analysis, and any derivations are noted in the Data Table. Each sample was filtered through its own membrane filter. Some samples with heavy sediment had to be broken into multiple filters per jar.

A water filter funnel with a motorized pump processes a sample.

The filter was then transferred to a graduated observation stage for visual inspection under a digital microscope at 50-200x magnification. Visual identification of microplastics was guided by earlier reports, literature, and protocols, including the *Guide to Microplastic Identification* by the Marine & Environmental Research Institute (now the Shaw Institute).[83]

To aid in visual identification, additional "squeeze tests" (the use of fine-tipped tweezers or forceps to apply pressure and test durability) were performed on any potential microplastic pieces. Any pieces that could not be positively identified through both a visual and squeeze test were not recorded.



The digital microscope provides a magnified visual of the filter.

Identified microplastics were categorized into four types:

- **Fibers** from synthetic fabrics and filaments, such as fleece, fishing line and bailing twine;
- **Fragments** from rigid plastics, including polystyrene and clear plastic containers;
- **Film** from plastic bags and food wrappers; and
- **Microbeads** from older cosmetics and personal care products.[84]

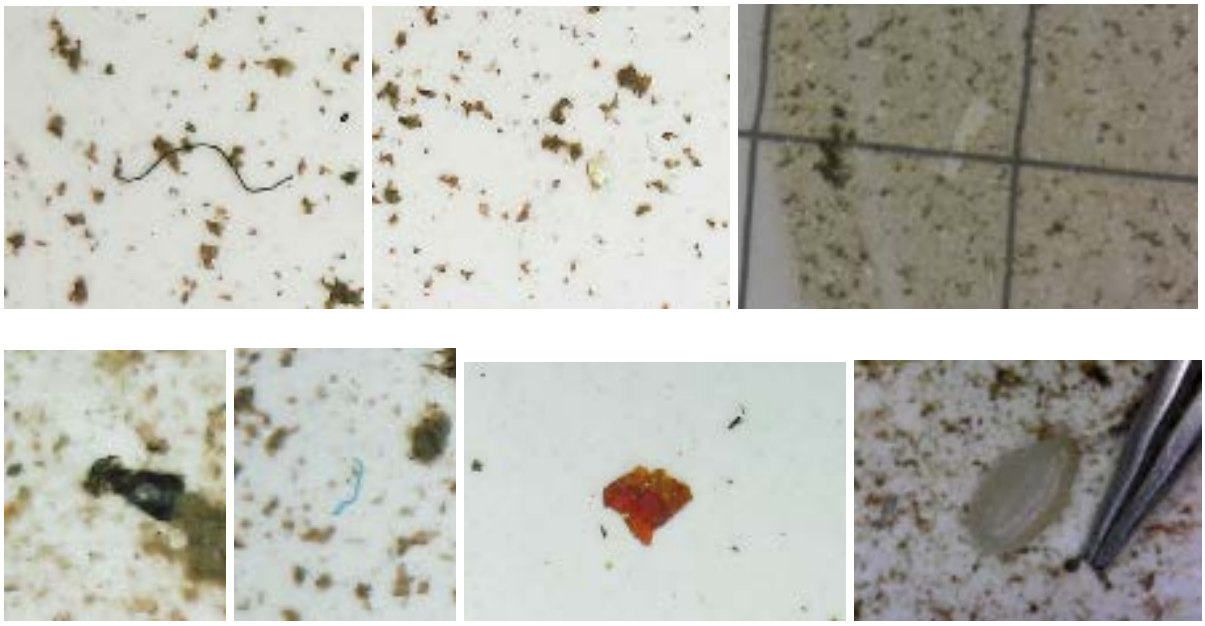
Totals for each type of microplastic in each sample from each site were recorded in the Data Table along with the date the sample was drawn and the names of the sampler and the person performing analysis. For a breakdown of this data see our Appendix.

Quality Control

Because of the prevalence of microplastics in the air and on surfaces, steps consistent with the *Microplastics: Sampling and Processing Guidebook* were taken to reduce contamination of the samples. Every jar and lid used in sampling was made of non-plastics material and was run through a dishwasher's 'sanitize' setting prior to collection. Jars and lids were then triple-rinsed with source water from the collection site, downstream from where the samples were to be collected. Once filled, samples were immediately sealed and remained so until their analysis. Those taking samples were instructed not to wear fleece or other synthetic clothing to avoid shedding fibers that could contaminate samples.

The filter flask, tweezers, forceps, and other analysis equipment was triple-rinsed with filtered water between samples to reduce contamination. Filter paper remained sealed and packaged until use and was transferred to the filtering set-up with forceps to avoid human contact. Sample jars were sealed in between the transfer of water to the filter apparatus. Once filtered, filter paper was transferred to a triple-rinsed petri dish by the forceps for keeping until analysis.

Examples of Observed Microplastics



Pictures taken under the microscope (Clockwise from top left): a microfiber; a microfragment; microfilm; microfilm to the left of an immature slug; a microfragment; a microfiber; a microfragment.

Results

Of the 16 sites tested, all 16 (100%) contained one or more types of microplastic.

More specifically, all 16 sites (100%) contained fibers; 14 sites (88%) contained film; 12 sites (75%) contained fragments; and microbeads were not found at any sites (0%). Ten sites (63%) had three types of microplastics present; 6 sites (38%) had two types of microplastics present. Ten sites (63%) had visible macroplastics in the immediate vicinity.

Table 1: Results

Location	Date of Collection	Microplastics Present?	Fibers	Fragments	Film
Arkansas River	2-19-23	yes	X	X	X
Boulder Creek	3-15-23	yes	X	X	X
Chatfield Reservoir	4-15-23	yes	X	-	X
Cherry Creek	2-22-23	yes	X	X	X
City Park	4-7-23	yes	X	X	X
Clear Creek	2-24-23	yes	X	X	X
Downstream of South Platte Confluence	3-7-23	yes	X	-	X
Holbrook Creek	2-22-23	yes	X	X	X
Monument Creek	4-20-23	yes	X	X	-
Plum Creek	4-15-23	yes	X	-	X
Sand Creek	2-26-23	yes	X	X	X
South Fork Buffalo Creek	3-30-23	yes	X	X	X
South Platte at Deckers	3-30-23	yes	X	X	-
Tollgate Creek	2-26-23	yes	X	X	X
Upstream of South Platte Confluence	3-7-23	yes	X	-	X
Waterton Canyon	3-30-23	yes	X	X	X

Policy Recommendations

Given how widespread the threat of plastic and microplastic pollution is, there is no single solution to address this pervasive problem. Multiple policy changes at the local, state, and federal level are needed to combat this issue. Below are several recommendations for Colorado and general consideration.

Phase out single-use plastics

Nothing society uses for a few minutes should be able to pollute our environment for hundreds of years. Congress, Colorado state officials, and municipalities should continue to pass laws that phase out unnecessary single-use plastics. In 2024, Colorado laws will go into effect that phase out polystyrene cups and containers and single-use plastic bags. In 2024, preemption will also be lifted, allowing local communities to go further to target other single-use plastic items like straws and utensils. Cutting off the source of some of the most prevalent forms of plastic pollution will help curtail the tide of microplastics entering the environment.

Implement Colorado's Producer Responsibility law

Producer responsibility is a mechanism to shift the costs and management of postconsumer waste from local governments and consumers and onto producers themselves. Done well, these programs can raise critical funding to expand recycling access and infrastructure across the state and disincentivize unnecessary plastic packaging production and use. In 2022, the Colorado General Assembly approved HB22-1355, Colorado's producer responsibility law and the state has contracted with a Producer Responsibility Organization (PRO) to develop the initial phase of the plan in consultation with stakeholders. In 2024, the General Assembly will need to approve the producer responsibility draft plan from the PRO to keep implementation moving forward.

Halt policies that promote increased manufacture & use of single-use plastic

Communities and legislators across Colorado should oppose subsidies and tax breaks for new petrochemical infrastructure that doubles down on the fossil fuel-to-plastics pipeline. This includes opposing proposals to subsidize or give tax breaks to bring facilities online explicitly to make new plastics, or policies that will promote plastics incineration as an alternative to recycling. For example, the City of Greeley is considering a "Waste to Energy," pyrolysis plant that would depend on a stream of plastics to function.[85] Pyrolysis uses high heat to break down materials into their chemical components, which can sometimes be recycled into new products but is most often burned for fuel.[86]

Tackle fast fashion

Clothing production and use could be responsible for up to 22 million metric tons of microplastics that ended up in our oceans between 2015 and 2050.[87] To fight synthetic textile waste, retailers must stop sending overstock, unsold and unused clothing to landfills and incinerators. State and local governments should pass laws preventing this practice so that

clothing manufacturers and retailers stop producing more clothing than society needs and uses. Retailers and clothing manufacturers should also move away from making products containing synthetic plastic fibers, which inevitably become microplastic pollution.

Support reuse

Using items that are designed for reuse can reduce the quantity of plastic we produce and contaminate our waterways. Cities could support reuse including grants to help restaurants invest in cleaning equipment so they can offer reusable utensils for on-site eating. In addition, Oregon recently passed a bill that will update public health laws to allow customers to use their own reusable containers to take food to go.[88]

Appendix

A written version of our collection and processing protocol can be viewed here.

Sampling sites can be viewed in our map, here.

The total plastics counts for each waterway can be viewed in the Data Table.

Collection site at Buffalo Creek.

Notes

1. US EPA Office of Land and Emergency Management, "Advancing Sustainable Materials Management: 2018 Fact Sheet", United States Environmental Protection Agency, December 2020.
2. The Last Beach Cleanup and Beyond Plastics, "The Real Truth About the U.S. Plastics Recycling Rate" Beyond Plastics, May 2022.
3. Chris Wilcox et al. "Threat of plastic pollution to seabirds is global, pervasive, and increasing", *Proceedings of the National Academy of Sciences*, September 22, 2015.
4. CoPIRG, "Single-Use Plastic Pollution Backgrounder", 2020. Per capita polystyrene cup usage in the U.S. is estimated at 82 cups per person per year. This number was multiplied by Colorado's population of 5.6 million (https://greendiningalliance.org/wp-content/uploads/2016/12/real-cost-of-styrofoam_written-report.pdf; http://www.metrodenver.org/do-business/demographics/population/). Per capita bag usage in the U.S. is estimated at 305.62 bags per person per year. This number was multiplied by Colorado's population of 5.6 million (http://www.earth-policy.org/images/uploads/press_room/Plastic_Bags.pdf; http://www.metrodenver.org/do-business/demographics/population/)
5. Ocean Conservancy, "The Beach and Beyond," 2019 report.
6. Colorado Department of Transportation, "Adopt-a-Highway," n.d.
7. Rebecca Hersher, "The Atlantic Is Awash With Far More Plastic Than Previously Thought, Study Finds", *National Public Radio*, August 20, 2020.
8. Yael Vondovotz, "Why isn't plastic biodegradable," Ohio State University, June 3, 2022.
9. National Ocean Service, "What are microplastics?", National Oceanic and Atmospheric Administration, January 6, 2023.
10. National Oceanic and Atmospheric Administration Marine Debris Program, "Occurrence and Health Effects of Anthropogenic Debris Ingested by Marine Organisms." National Centers for Coastal Ocean Science: Center for Coastal Environmental Health and Biomolecular Research, NOAA Marine Debris Program Office of Response and Restoration, 2014.
11. Janice Brahney et al. "Plastic rain in protected areas of the United States", *Science* Vol. 368, Issue 6496, pp. 1257-1260. June 12, 2020.
12. Julie Anderson et al. "Microplastics in aquatic environments: Implications for Canadian ecosystems", *Environmental Pollution* Vol. 218, pp. 269-280, November 2016.
13. Ellen MacArthur Foundation, "A new textiles economy: Redesigning fashion's future", 2017.
14. See note 13.
15. Neel Dhanesha, "The massive, unregulated source of plastic pollution you've probably never heard of," Vox, May 6, 2022.
16. Sherri A. Mason et al. "Synthetic Polymer Contamination in Bottled Water", *Frontiers in Chemistry*, September 11, 2018.

17. Colorado State University, Colorado Water Knowledge, "Surface Water Resources", n.d.
18. Colorado State Forest Service, "Watershed Management", n.d.
19. Feeding Ourselves Thirsty, "Colorado River", Ceres, n.d.
20. Platte River Recovery Implementation Program, "Information for Platte River Basin water users", n.d.
21. See note 13.
22. Natalie Wolchover, "Why Doesn't Plastic Biodegrade?", Live Science, March 02, 2011.
23. See note 3.
24. World Economic forum, "The New Plastics Economy: Rethinking the future of plastics", January 2016.
25. See note 4.
26. See note 5.
27. See note 6.
28. See note 10.
29. See note 11.
30. See note 12.
31. Laura Parker, "Microplastics are in our bodies. How much do they harm us?", National Geographic, May 8, 2023.
32. Rina Torchinsky, "For the first time, researchers find microplastics deep in the lungs of living people," National Public Radio, April 6, 2022.
33. Claudia Campanale et al. "A Detailed Review Study on Potential Effects of Microplastics and Additives of Concern on Human Health", *International Journal of Environmental and Public Health* Vol. 17, Issue 4. February, 2020.
34. Robert C. Hale et al. "A Global Perspective on Microplastics", *Journal of Geophysical Research: Oceans* Vol. 125. January 06, 2020.
35. See note 34.
36. See note 34.
37. U.S Food and Drug Administration, "The Microbead-Free Waters Act: FAQs", February 2, 2022..
38. See note 15.
39. Rebecca Sutton et al. "Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region", San Francisco Estuary Institute, October 2019.
40. Katie Okamoto, "Your Laundry Sheds Harmful Microfibers. Here's What You Can Do About It," New York Times, August 5, 2021
41. See note 40
42. See note 14
43. See note 16
44. Robert C. Hale et al. "A Global Perspective on Microplastics", *Journal of Geophysical Research: Oceans* Vol. 125. January 06, 2020.
45. See note 17.
46. See note 18.
47. See note 19.
48. See note 20.
49. Kyushu University. "Twenty-four trillion pieces of microplastics in the ocean and counting," ScienceDaily, 27 October 2021.

50. Karin Mattsson et al. “Altered Behavior, Physiology, and Metabolism in Fish Exposed to Polystyrene Nanoparticles” *Environmental Science & Technology* 2015, 49, 1, 553−561. December 7, 2014.
51. Madeleine Smith et al. “Microplastics in seafood and the implications for human health”, *Current Environmental Health Reports*, August 16, 2018.
52. Faran Savitz, “Microplastics in Pennsylvania”, PennEnvironment Policy and Research Center, March 3, 2021.
53. Celeste Meiffren-Swango, “Microplastics in Oregon”, Environment Oregon Policy and Research Center, December 2021.
54. Faran Savitz, “Pennsylvania’s Pristine Waterways and Microplastics”, PennEnvironment Policy and Research Center, October 26, 2022.
55. Shawn Reeser, "Understanding the Local Colorado Slang", Uncover Colorado, March 20, 2021.
56. See note 55.
57. See note 17.
58. See note 17.
59. History Colorado, "South Platte River", Colorado Encyclopedia, n.d.
60. See note 59.
61. Bill Vogrin, "Small army of CPW staff, nonprofit conservation volunteers hike steep mountainside to stock threatened greenbacks into alpine stream", Colorado Parks and Wildlife, July 19, 2017.
62. See note 20.
63. United States Geological Survey, “Largest Rivers in the United States,” n.d,
64. See note 59.
65. Kosuth M, Mason SA, Wattenberg EV (2018) “Anthropogenic contamination of tap water, beer, and sea salt”. PLoS ONE 13(4): e0194970.
66. See note 16.
67. Gregory A. Wetherbee et al. “It is raining plastic”, U.S. Geological Survey, May 14, 2019.
68. Blaine Friedlander, “Atmospheric travel: Scientists find microplastic everywhere,” Cornell Chronicle, April 12, 2021.
69. Filipa Bessa et al. “Microplastics in gentoo penguins from the Antarctic region”, *Nature*. October 2, 2019.
70. Lianzhen Li et al. “Research: Crop plants are taking up microplastics”, Provided by Chinese Academy of Sciences for Phys.Org. July 13, 2020.
71. See note 68.
72. Karen McVeigh, “Microplastics discovered blowing ashore in sea breezes”, *The Guardian*, May 12, 2020.
73. Erin Ross. “Scientists Discover Microplastics in Oregon Oysters and Razor Clams”, *Oregon Public Broadcasting*. November 13, 2019.
74. Sarah Gibbens, “Plastic proliferates at the bottom of world's deepest ocean trench” *National Geographic*, May 13, 2019.
75. Damian Carrington, “Microplastic pollution found near summit of Mount Everest”, *The Guardian*, November 20, 2020.
76. Antonio Ragusa et al. “Plasticenta: First evidence of microplastics in human placenta”, *Environment International*, Volume 146, January 2021, 106274, December 2, 2020.

77. Heather A.Leslie et al. "Discovery and quantification of plastic particle pollution in human blood", *Environment International,* Volume 163, May 2022.
78. See note 32.
79. Simon Scarr, "A plateful of plastic: Visualising the amount of microplastic we eat", *Reuters*, December 31, 2019.
80. See note 10.
81. See note 10.
82. Mandy Sartain et al. "Microplastics Sampling and Processing Guidebook", *Mississippi State University Extension,* 2018.
83. A.P.W. Barrows et al. "Guide to Microplastics Identification, A Comprehensive Methods Guide for Microplastics Identification and Quantification in the Laboratory", *Marine & Environmental Research Institute, Blue Hill, ME,* 2017.
84. The Microbead-Free Waters Act of 2015 required all personal care product manufacturers to phase out the use of microbeads in the United States by 2018.
85. Megan Smalley, "Colorado city plans development of pyrolysis plant, plastics sorting facility,"Recycling Today, March 3,2023.
86. NRDC, "Recycling Lies: "Chemical Recycling" of Plastics is Really Just Greenwashing Incineration", National Resource Defense Council issue brief, February 2022.
87. See note 13.
88. Celeste Meiffren-Swongo, "Two bills aimed at reducing plastic pollution clear final legislative hurdle, head to governor's desk,", Environment Oregon, April 26, 2023.