California Coastal Commission
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Guidance for Addressing Plastic Pollution in Coastal Development Permits and Local Coastal Programs

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Cover photo: Plastic pollution can overwhelm measures like this trash capture boom across the LA River. (Photo: Bill McDonald)

I. Executive Summary

This document provides guidance to California Coastal Commission staff, local government staff, and project applicants on strategies that can be implemented to prevent plastic pollution resulting from development projects from entering the coastal environment. Prevention of plastic pollution is crucial for protection of the coastal environment, as plastic materials and their chemical additives can adversely impact terrestrial, freshwater, estuarine, and marine ecosystems. This guidance document discusses the environmental, economic, and social impacts of plastic pollution, and supports several relevant policies in the California Coastal Act. General strategies for preventing plastic pollution in the Coastal Zone, and considerations for evaluating proposed Coastal Development Permits (CDPs), Local Coastal Programs (LCPs), and analogous long-range coastal planning documents are also discussed. These guidelines also recommend plastic pollution prevention strategies that may be incorporated into CDPs and LCPs for a variety of specific development categories, with examples of past requirements approved by the Coastal Commission.

II. Glossary of Common Terms and Acronyms

- **Best Management Practices (BMPs):** Stormwater management BMPs are measures to minimize the discharge of pollutants and avoid adverse increases in stormwater runoff resulting from development. BMPs may be structural (such as a trash capture screen in a storm drain inlet) or non-structural activities or procedures (such as street-sweeping).[1]
- **Leachate:** Leachate forms when a liquid (such as rainwater) passes through a material and dissolves or entrains potentially environmentally harmful substances that may then enter the environment.
- **Low Impact Development (LID):** LID is an approach to stormwater management that aims to maintain or replicate a site's natural hydrologic balance to minimize adverse impacts of development on water quality and quantity. LID focuses on reducing runoff volume and/or peak flow rate—which often increase due to development—thus also reducing the transport of pollutants by runoff into waterways and the ocean. LID starts with site design strategies that reduce the generation of runoff (such as minimizing impervious surfaces and preserving trees). This is supplemented as needed by small-scale structural LID BMPs (such as rain gardens or biofiltration swales), placed near runoff sources, that replicate natural hydrologic processes—infiltration, uptake by plants, evaporation, groundwater recharge, and storage—to retain or detain runoff. Many LID BMPs can remove several common types of runoff pollutants through physical, chemical, and biological processes found in nature.

[1] See the California Coastal Commission's Water Quality webpages for additional guidance on stormwater management BMPs. (https://www.coastal.ca.gov/water-quality/).

- **Marine Debris:** Any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes. Plastic pollution is the largest subset of marine debris.[2]
- **Plastics:** Conventional plastics, also called fossil-fuel or hydrocarbon-based plastics, are synthetic polymers (i.e., repeating units of molecules) derived from fossil fuels—either natural gas or petroleum—often mixed with additives, that can be molded, extruded, or pressed into solid shapes. There are also a variety of biologically-based plastics (i.e., "bio-based" plastics or "bioplastics") that are produced from renewable biomass sources (such as vegetable oil, corn starch, sugar cane, or cellulose) or through biosynthesis by microbes.
    - **Macroplastics:** The subset of plastics that are greater than 5 mm, as determined by the object's largest dimension.
    - **Microplastics:** The subset of plastics that are 5 mm or smaller, as determined by the object's largest dimension. Sources of microplastics in the environment include the breakdown of larger pieces of plastic materials and debris (i.e., macroplastics); microplastics manufactured for consumer and commercial uses; and pre-production plastic pellets (i.e., nurdles) or powder used in plastic manufacturing.
    - **Nanoplastics:** The subset of microplastics with dimensions from 1 nm to 1 µm, as determined by the object's largest dimension.
- **Toxic:** Harmful or dangerous to health or life when taken into the body; poisonous.

III. Introduction

The production and use of plastics, as well as the volume of resulting plastic waste, has risen rapidly since the invention of plastics in the mid-20th century. The annual global production of plastics grew from about 2 million metric tons (MMT) in 1950 to 381 MMT in 2015.[3] When plastics are taken out of use, they become plastic waste. An estimated 8 MMT of plastic waste enters the world's ocean each year.[4] If current practices continue, the amount of plastic discharged into the ocean could reach up to 53 MMT per year by 2030, roughly half the total weight of fish caught from the ocean annually.[5] Ocean plastic debris is a subset of marine debris. Marine debris originates from a wide variety of locations and can travel great distances before

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[2] National Oceanic and Atmospheric Administration (NOAA). (2025). "Marine Debris Program" webpage (updated Jan. 24, 2025). (https://marinedebris.noaa.gov/discover-marine-debris/what-marine-debris).

[3] Geyer, R., et al. (2017). "Production, use, and fate of all plastics ever made." Science Advances, Vol. 3(7):1700782. (https://www.science.org/doi/10.1126/sciadv.1700782).

[4] Jambeck, J.R., et al. (2015). "Plastic waste inputs from land into the ocean." Science, Vol. 347(6223):768-771. (https://www.science.org/doi/10.1126/science.1260352).

[5] Borrelle, S.B., et al. (2020). "Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution." Science, Vol. 369(6510):1515-1518. (https://www.science.org/doi/10.1126/science.aba3656).

ending up in the ocean. Based on data collected during California Coastal Cleanup Day, well over 80% of debris found on California beaches is some form of plastic.[6]

Plastic pollution is everywhere—it is found throughout every major body of water on the planet and along every shoreline and coastline in the world, no matter how remote. Every stage in the lifecycle of plastics—from manufacturing to use to disposal—can have harmful impacts on California's communities, wildlife, and environment. Plastic pollution is a global pollution problem that impacts human health and safety, endangers terrestrial and aquatic ecosystems, negatively impacts the provisioning of ecological services (i.e., the benefits people obtain from nature),[7] and costs local and national economies millions in cleanup costs and lost tourism revenue.[8]

The Coastal Commission has a long history of addressing plastic pollution through organizing volunteer beach cleanups such as California Coastal Cleanup Day and the year-round Adopt-A-Beach Program. Through these efforts, more than 2 million Californians have helped remove over 26 million pounds of trash from ocean coastlines and river shorelines since 1985. Beach cleanups are highly visible and have helped to build support for additional actions to address plastic pollution. But while they are extremely valuable for raising public awareness and promoting individual responsibility, they tend to be inefficient because of the vast areas over which waste is dispersed, especially plastic waste that has fragmented over time into very small and widely distributed microplastics.[9] Substantially reducing plastic pollution in the ocean and other coastal environments will require additional, effective interventions.[10] Reducing the release of plastic pollution into the coastal environment by being thoughtful about the use of plastics is more effective than removing plastic after it has entered the environment.

The Coastal Act contains several policies that require protection of coastal resources and coastal water quality, including protection from the effects of plastic pollution, as further described below. Consequently, the Coastal Commission has addressed plastic pollution by ensuring that CDPs the Commission issues require implementation of strategies to minimize the discharge of plastic pollution from development projects into the coastal environment, as well as to minimize the discharge of toxic chemicals that leach from plastics used outdoors. By certifying local governments' LCPs and other long-range coastal planning documents as being consistent with

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[6] California Coastal Commission. "California Coastal Cleanup Day" webpage (undated). (https://www.coastal.ca.gov/publiced/ccd/ccd.html).

[7] Beaumont, N.J., et al. (2019). "Global ecological, social and economic impacts of marine plastic." Marine Pollution Bulletin, Vol. 142:189-195. (https://doi.org/10.1016/j.marpolbul.2019.03.022).

[8] California Coastal Commission. "The Problem with Marine Debris" webpage (undated). (https://www.coastal.ca.gov/publiced/marinedebris.html).

[9] The National Academies of Sciences, Engineering, and Medicine. (2022). "Reckoning with the U.S. Role in Global Ocean Plastic Waste." Washington, DC: The National Academies Press. Pg. 145. (https://doi.org/10.17226/26132).

[10] Lau, W.W.Y., et al. (2020). "Evaluating scenarios toward zero plastic pollution." Science, Vol. 369(6510):1455-1461. (https://www.science.org/doi/10.1126/science.aba9475).

the Coastal Act, the Commission helps ensure that coastal cities, counties, and other coastal development permitting agencies (such as port districts and universities) also require development projects in their jurisdictions to minimize plastic pollution.

This document complements other Commission-adopted guidance and policies, and is intended to be read and used in conjunction with those resources.

IV. Environmental Impacts of Plastic Pollution

Overflowing trash cans can become a point source of plastic pollution if not properly maintained. (Photo: NOAA)

A. How Plastics Enter Coastal and Marine Habitats

Oceans are the Earth's ultimate downstream recipients of debris generated by human activities. Almost any plastic used on land has the potential to eventually reach the ocean. Major plastic transport pathways include waterways; coastal and inland stormwater runoff; wind-blown trash and debris; treated wastewater discharges; application of municipal sewage sludge as fertilizer on agricultural lands; microplastic tire particles emitted during vehicle use; deposition of atmospheric microplastics; direct discharges from boats and ships (including from shipping containers fallen from container ships); and debris from beach and shoreline activities.[11]

Riparian and coastal habitats, such as eelgrass meadows, estuarine lagoons, rocky intertidal areas, and coastal dunes, may retain plastics on the path to the ocean. Microplastics have been documented in estuarine plants and filter-feeding invertebrates, which form the base of the food web for many coastal ecosystems. Documentation of the distribution and impacts of plastics in various habitat types remains a growing field of study, but the presence of microplastics is largely ubiquitous across aquatic and terrestrial habitats.

B. Entanglement in and Ingestion of Plastics

While plastics impact habitats and wildlife via multiple mechanisms, there are two especially well-studied ways that plastic pollution adversely impacts marine and coastal wildlife: entanglement and ingestion. Entanglement in and ingestion of plastic debris have been documented to harm or kill a wide variety of vertebrate animals in aquatic ecosystems, including fish, sea turtles, birds, whales, seals, sea lions, and other mammals. One review found documented cases of plastic entanglement or ingestion by marine biota in 914 species from 747 studies, in which 701 species ingested plastic debris and 354 species experienced plastic entanglement.[12] On land, wildlife can also become entangled in and ingest plastic debris. Plastic entanglement and ingestion can harm or kill wildlife in several ways. Marine animals entangled in plastic debris may drown or starve, suffer physical trauma and infections, risk exhaustion from dragging heavy gear, and have impaired mobility and thus be unable to avoid vessel strikes. Plastic debris ingested by marine animals may block or cause internal injuries to the digestive system, fill up the stomach and lead to starvation, and leach toxic chemicals that are absorbed by the animal.

[11] Dris, R., et al. (2018). “Sources and fate of microplastics in urban areas: A focus on Paris megacity.” In “Freshwater Microplastics: Emerging Environmental Contaminants?” Edited by M. Wagner and S. Lambert. New York: Springer International. (https://link.springer.com/book/10.1007/978-3-319-61615-5).

[12] Kuhn, S., & van Franeker, J.A. (2020). “Quantitative overview of marine debris ingested by marine megafauna.” Marine Pollution Bulletin, Vol. 151:110858. (https://doi.org/10.1016/j.marpolbul.2019.110858).

C. Toxic Chemicals Released from Plastics

1. Leaching and Volatilization of Chemicals from Plastics

Significant adverse effects of plastic ingestion can also be attributed to the chemicals used to manufacture plastics, which can leach from ingested plastic debris into animal tissues. Plastics contain a variety of chemical additives to improve their performance, such as UV- and heat-stabilizers, chemicals to slow deterioration, plasticizers to provide flexibility or rigidity, flame retardants, and pigments. Other chemicals found in plastics result from the manufacturing process itself. Many of the chemicals in plastics are not chemically bound to the plastic matrix and can be released into the environment by leaching into fluids, volatilization into the air, or abrasion.

Left: The body of a Black-Footed Albatross chick with its stomach full of plastic marine debris, on Laysan Island in the Northwestern Hawaiian Islands. Adult birds mistake plastic floating on the ocean surface for food and feed it to their chicks. Marine debris from the California coast can collect in the North Pacific Gyre and be carried to these islands. (Photo: Vanessa Metz, California Coastal Commission)

Right: A snake entangled in an erosion control blanket's plastic netting. (Photo: Mark Backus)

Numerous laboratory and field studies have demonstrated that water leaches a variety of toxic chemicals from plastics, and that this leaching continues long-term. Toxic chemicals that are leached from plastic by stormwater runoff or by immersion of plastic debris in waterways and the ocean may be absorbed by aquatic and terrestrial organisms, leading to harm or mortality.[13]

2. Chemicals of Concern

More than 16,000 chemicals have been identified in plastic products, of which at least 25 percent are chemicals of environmental and/or human health concern because of their toxicity, bioaccumulation in organisms, environmental persistence, and/or mobility through the environment.[14] However, hazard information is lacking for over 10,000 of these chemicals.

Chemicals in plastics that are known to be hazardous to wildlife and human health include, for example, heavy metals (e.g., lead, zinc, mercury, and arsenic), polyaromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), 6-phenylenediamine (6PPD), phthalates, organophosphate esters (OPEs), and per- and poly-fluoroalkyl substances (PFAS), among many others.[15] Several chemicals in plastics have been found to be carcinogens, neurotoxins, or endocrine disruptors, among other toxic effects, and can be lethal or have sub-lethal effects that impair the survival and reproduction of organisms.[16] From animal studies, endocrine-disrupting effects from plastics-associated compounds (including reproductive disease, sperm mutations, and obesity) have been found to transmit to offspring.[17]

3. Adsorption of Chemicals onto Surface of Plastics

Plastics can also accumulate significant amounts of pollutants from the surrounding environment. In both aquatic and terrestrial environments, chemical pollutants in the surrounding water and sediment can adsorb onto (i.e., bind to the surface of) plastic, thereby highly concentrating these chemicals on the plastic's surface. Examples of toxic chemicals that adsorb onto plastics include heavy metals, and persistent organic pollutants (POPs) such as

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[13] Mayer, P., et al. (2024). "Where the Rubber Meets the Road: Emerging Environmental Impacts of Tire Wear Particles and Their Chemical Cocktails." Science of The Total Environment, Vol. 927:171153. (https://doi.org/10.1016/j.scitotenv.2024.171153).

[14] Wagner, M., et al. (2024). "State of the science on plastic chemicals - Identifying and addressing chemicals and polymers of concern." Zenodo. (https://doi.org/10.5281/zenodo.10701706).

[15] Pollard, L., & Massey, R. (2023). "Playground Surfacing: Choosing Safer Materials for Children's Health and the Environment." Lowell Center for Sustainable Production and Toxics Use Reduction Institute, University of Massachusetts Lowell. (https://www.uml.edu/docs/Playground_surfacing_report_Dec2023_tcm18-377890.pdf).

[16] Mayer, P., et al. (2024). "Where the Rubber Meets the Road: Emerging Environmental Impacts of Tire Wear Particles and Their Chemical Cocktails." (See full citation above).

[17] Manikkam, M., et al. (2013). "Plastics derived endocrine disruptors (BPA, DEHP, and DBP) induce epigenetic transgenerational inheritance of obesity, reproductive disease and sperm epimutations." PLoS ONE, Vol. 8(1): e55387. (https://doi.org/10.1371/journal.pone.0055387).

pesticides, Polychlorinated Biphenyls (PCBs), Polybrominated Diphenyl Ethers (PBDEs), PAHs, and PFAS (often referred to as "forever chemicals").[18]

When microplastic is ingested, these adsorbed chemicals can be released into the digestive system, potentially causing toxicity and leading to bioaccumulation of pollutants within food webs.[19] In addition, when airborne microplastic is inhaled, animal studies indicate that toxic pollutants associated with the plastic (both adsorbed chemicals and manufacturing additives) can be released into the lungs. From the lungs, these chemicals have the potential to transfer into the bloodstream and lymphatic system, likely causing toxicity throughout the body.[20] Microbes can also adhere to plastic debris, especially in aquatic environments, forming a biofilm that can harbor potentially pathogenic bacteria.[21]

4. Toxicity of Recycled Plastics

The use of recycled plastics also raises significant environmental concerns, as research has shown that recycling can increase plastic toxicity. As a result, recycled plastics often fail to meet safety standards set for virgin plastic. This is because they tend to contain a wider variety of potentially toxic chemicals than virgin plastics, including chemical additives used in virgin plastics manufacturing, chemicals absorbed during previous use of the plastic, and contaminants unintentionally introduced during the recycling process. One study identified 84 chemicals in the water leachate from recycled polyethylene, including unintentionally added pesticides and pharmaceuticals.[22]

Furthermore, recycled plastics have been found to contain elevated concentrations of toxic chemicals compared to virgin plastics. One study found that metal levels were 10 times higher, PFAS levels twice as high, and PAH levels three times higher in recycled plastics.[23] This study also found that recycled plastics have a larger surface area (due to changes in surface texture) compared to virgin plastics. This increases their potential to release and adsorb chemicals, as well as to generate microplastics. These risks are especially concerning for outdoor structures and products that come into contact with stormwater runoff (such as rainwater cisterns) or

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[18] Weis, J.S., & Alava, J.J. (2023). "(Micro)Plastics Are Toxic Pollutants." Toxics, Vol. 11(11):935. (https://doi.org/10.3390/toxics11110935).

[19] Jeong, E., et al. (2024). "Animal exposure to microplastics and health effects: A review." Emerging Contaminants, Vol. 10(4). (https://doi.org/10.1016/j.emcon.2024.100369).

[20] Borgatta, M., & Breider, F. (2024). "Inhalation of Microplastics—A Toxicological Complexity." Toxics, Vol. 12(5):358. (https://pmc.ncbi.nlm.nih.gov/articles/PMC11125820/).

[21] Zadjelovic, V., et al. (2023). "Microbial hitchhikers harbouring antimicrobial-resistance genes in the riverine plastisphere." Microbiome, Vol. 11:225. (https://doi.org/10.1186/s40168-023-01662-3).

[22] Kardgar, A.K., et al. (2025). "Effects of leachates from black recycled polyethylene plastics on mRNA expression of genes involved in adipogenesis and endocrine pathways in zebrafish embryos." Journal of Hazardous Materials, Vol. 495:138946. (https://doi.org/10.1016/j.jhazmat.2025.138946).

[23] Daggubati, L., et al. (2025). "Fingerprinting risk from recycled plastic products using physical and chemical properties." Journal of Hazardous Materials, Vol. 488:137507. (https://doi.org/10.1016/j.jhazmat.2025.137507).

coastal waters (such as sheet piles), where toxic chemicals may leach into the water. For rainwater harvesting intended for landscape irrigation, using cisterns or water tanks made from virgin plastic certified for potable water would likely reduce toxic chemicals leached into the water compared to using recycled plastic.

Waste tires (largely made of synthetic rubber, a type of plastic) are often recycled into outdoor products that have a high potential to continue releasing microplastic tire particles and toxic tire-associated chemicals into the environment. Outdoor products that are created from shredded or ground waste tires include artificial turf infill, playground surfacing, running tracks and trails, landscaping mulch, rubberized asphalt pavement, rubber-containing pavement seal coats, rubberized building and flooring materials, railroad ties, doormats, stormwater treatment systems (such as filter media for storm drain inlets, and rubberized permeable pavement), and civil engineering applications (such as construction fill).[24] Alternative materials should be considered for these outdoor products instead of synthetic rubber from waste tires.

D. <u>Impacts of Microplastics</u>

The adverse environmental impact of microplastics is an emerging issue of concern worldwide.[25] Due to their small size, microplastics are readily ingested, inhaled, or absorbed by organisms across all trophic levels, leading to a range of negative health effects from both the microplastic particles and the chemicals that leach from them. Microplastics also transport pollutants throughout the environment, including into waterways and the ocean, where they can cause adverse impacts to a broad spectrum of aquatic and terrestrial species.[26]

Microplastics are also found in air, clouds, and rainwater. Tire wear particles (classified as microplastics) can remain suspended in the air for up to 28 days, during which time the microplastic particles can travel long distances and pollute distant environments.[27] Microplastics found in clouds can travel thousands of miles, and they likely affect the weather. Even the most isolated areas in the U.S. accumulate tons of microplastic particles transported there by wind

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[24] Mayer, P., et al. (2024). "Where the Rubber Meets the Road: Emerging Environmental Impacts of Tire Wear Particles and Their Chemical Cocktails." (See full citation above).

[25] California Ocean Protection Council. (2022). "Statewide Microplastics Strategy: Understanding and Addressing Impacts to Protect Coastal and Ocean Health." (https://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20220223/Item_6_Exhibit_A_Statewide_Microplastics_Strategy.pdf).

[26] Jeong, E., et al. (2024). "Animal exposure to microplastics and health effects: A review." Emerging Contaminants, Vol. 10(4). (https://doi.org/10.1016/j.emcon.2024.100369).

[27] Mayer, P., et al. (2024). "Where the Rubber Meets the Road: Emerging Environmental Impacts of Tire Wear Particles and Their Chemical Cocktails." (See full citation above).

and rain; most of these microplastic particles are synthetic microfibers used for making clothing.[28]

Although the amount of microplastic pollution resulting from an individual development project may seem insignificant, it is important to reduce plastic pollution in all development projects because plastic persists long-term in the environment — from months to decades or longer — and the Coastal Act requires consideration of the cumulative impacts of development on the environment in order to protect coastal and marine resources.

1. Sources of Microplastics

Microplastics found in the environment come from many sources, including but not limited to:

- The breakdown of larger pieces of plastic litter and debris
- Tire wear particles from roadways
- Fibers shed from synthetic textiles (such as polyester microfiber clothing)
- Plastic mulch film used as crop row covers to conserve water and control weeds
- Plastic-contaminated municipal sewage sludge (biosolids) and compost manure applied as fertilizer to agricultural lands
- Plastic-based paints, sealers, coatings, and binders used to build and/or maintain structures (such as building paint, roadway markings, and sealers on dock decking)
- Fragments of artificial turf blades, and shredded waste tires or plastic-coated sand used as infill for artificial turf fields
- Shredded waste tires or synthetic rubber used for playground surfacing
- Spray-on polymer soil stabilizers, plastic geotextile fabric, and plastic netting in BMPs used for erosion control during construction
- Manufactured plastic microbeads used as abrasives (such as in personal care products, cleaning products, and industrial blasting) and to increase durability (such as in paint)
- Pre-production plastic pellets (i.e., nurdles) or plastic powder used in plastic manufacturing

2. Impacts of Microplastics on Aquatic Organisms

Due to their toxicological effects, environmental persistence, and bioaccumulation, microplastics have been documented to cause acute and chronic toxicity in numerous aquatic organisms—including fish, mammals, amphibians, marine birds, aquatic invertebrates, and

[28] Brahney, J., et al. (2020). "Plastic rain in protected areas of the United States." Science, Vol. 368(6496):1257-1260. (https://www.science.org/doi/10.1126/science.aaz5819).

zooplankton—with significant adverse effects on survival, reproduction, and growth.[29] In the ocean, microplastics are ingested by primary producers (such as algae and phytoplankton) as well as primary consumers (such as zooplankton and echinoderms), and the microplastics and the chemicals associated with them bioaccumulate as they move through the food web. Microplastics ingested by marine biota may ultimately move through the food web to humans, but there is limited knowledge of effects throughout the food web and to humans specifically.

Tire wear particles emitted from synthetic rubber tires during vehicle use are a major contributor of microplastic pollution to the environment.[30] One study found that almost 50 percent of microplastics in stormwater runoff samples from San Francisco Bay watersheds were tire wear particles. Numerous laboratory and field studies have demonstrated that a variety of toxic chemicals leach from tire wear particles (such as zinc, PAHs, phthalates, and 6PPD), many of which are highly toxic to aquatic life.

For example, recent research identified 6PPD-quinone (6PPD-q) as the likely chemical responsible for extensive pre-spawn mortality of Coho salmon in Puget Sound streams over the last 25 years: up to 90 percent of adult Coho migrating up certain streams to spawn would die after rainstorms.[31] The researchers discovered that the tire antioxidant additive 6PPD is converted by ozone into a previously unknown compound, 6PPD-q, which is highly lethal to Coho. This chemical is also acutely lethal to brook trout and rainbow trout/steelhead, and toxic to a variety of invertebrates and other fish including Chinook salmon. Stormwater runoff from roadways leaches 6PPD-q from tire wear particles, and transports both the microplastic particles and their chemical leachate into waterways. 6PPD-q has also been detected in roadway runoff and creeks across the U.S. West Coast, including the Los Angeles and San Francisco regions, and recently in the Humboldt Bay region. Pollutant source control practices (such as street sweeping) and Low Impact Development BMPs such as rain gardens, bioretention basins, and bioswales can potentially be effective at removing 6PPD-q from stormwater runoff.[32]

3. Impacts of Microplastics on Soil

Microplastics are also widely present in terrestrial ecosystems, where their annual release is estimated to be 4-23 times greater than into the oceans.[33] Microplastics tend to accumulate in

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[29] Mayer, P., et al. (2024). "Where the Rubber Meets the Road: Emerging Environmental Impacts of Tire Wear Particles and Their Chemical Cocktails." (See full citation above).

[30] Ibid.

[31] Tian, Z.Y., et al. (2020). "Ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon." Science, Vol. 371(6525):185-189. (https://www.science.org/doi/10.1126/science.abd6951).

[32] Stockwell, A. (2024). "Focus on: Municipal Stormwater and 6PPD." Washington State Department of Ecology, Publication 24-10-045. (https://apps.ecology.wa.gov/publications/documents/2410045.pdf).

[33] Horton, A., et al. (2017). "Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities." Science of The Total Environment, Vol. 586:127-141. (https://doi.org/10.1016/j.scitotenv.2017.01.190).

soil, especially in agricultural and urban areas. Agricultural soils are among the largest reservoirs of terrestrial plastic pollution and may contain more microplastics than in the oceans.[34] Major contributors include plastic mulch film used in row crops, land-applied municipal sewage sludge ("biosolids") used as fertilizer, and manure compost (see Appendix A.II.H. Agriculture for more detail).[35] In urban soils, primary sources of microplastics include tire wear particles, litter (particularly packaging materials), building and construction materials (including paints and coatings), synthetic textiles, industrial activities, and atmospheric deposition.

Microplastics in the soil can have many long-term negative effects on soil health, plants, and soil biota, and can enter the food web. They alter the soil's physical and chemical characteristics, disrupting key ecological functions and potentially reducing water infiltration and retention.[36] Microplastics also act as vectors for pollutants, facilitating the transport of toxic chemicals within the soil ecosystem. These chemicals can leach readily into the soil, be absorbed by plants, and accumulate in plant tissues.[37] Studies have shown that microplastic pollution can impair plant growth and development, including reducing seed germination.[38] These effects raise concerns not only for agricultural productivity but also for maintaining the biodiversity of native plants.

4. Impacts of Microplastics on Terrestrial Fauna—Bees as an Example

Many studies have shown that ingestion and inhalation of microplastics by terrestrial fauna across the food web can lead to a range of adverse physical and physiological health effects, including behavioral changes, tissue damage, impaired reproduction and development, and weakened immune function (making organisms more susceptible to infections and diseases).[39]

Bees—among the world's most important pollinators—are particularly vulnerable to microplastic pollution, which can compromise their health, survival, and pollination effectiveness. This is a significant concern for both honeybees and native bees that pollinate agricultural crops and other plants, including native plants. Recent research has documented multiple adverse health effects from bees' ingestion or inhalation of microplastics. Microplastics

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[34] Machado, A.A.D., et al. (2018). "Microplastics as an emerging threat to terrestrial ecosystems." Global Change Biology, Vol. 24:1405-1416. (https://onlinelibrary.wiley.com/doi/10.1111/gcb.14020).

[35] Sa'adu, I., & Farsang, A. (2023). "Plastic contamination in agricultural soils: a review." Environmental Sciences Europe, Vol. 35(13). (https://doi.org/10.1186/s12302-023-00720-9).

[36] Sajjad, M., et al. (2022). "Microplastics in the soil environment: A critical review." Environmental Technology & Innovation, Vol. 27:102408. (https://doi.org/10.1016/j.eti.2022.102408).

[37] Castan, S., et al. (2023). "Uptake, Metabolism, and Accumulation of Tire Wear Particle-Derived Compounds in Lettuce." Environmental Science & Technology, Vol. 57(1):168–178. (https://pubs.acs.org/doi/10.1021/acs.est.2c05660).

[38] Jia, L., et al. (2023). "Microplastic stress in plants: effects on plant growth and their remediations." Frontiers In Plant Science, Vol. 14. (https://doi.org/10.3389/fpls.2023.1226484).

[39] Jeong, E., et al. (2024). "Animal exposure to microplastics and health effects: A review." Emerging Contaminants, Vol. 10(4). (https://doi.org/10.1016/j.emcon.2024.100369).

have been found in the brains of honeybees, where they impair learning and memory, potentially disrupting foraging behavior and pollination.[40] Ingested microplastics, found in flower nectar, pollen, and water, can also damage bees' gut health and increase their susceptibility to bacteria and viruses. While many of these effects are sub-lethal, one study showed that ingesting two different plastics in combination reduced bees' immunity and survival.[41] Moreover, microplastic exposure may amplify the harmful effects on bee health of other chemicals in the environment, such as antibiotics used in beekeeping and insecticides applied to crops. For example, co-exposure to microplastics and the agricultural insecticide flupyradifurone has been shown to significantly reduce honeybee sucrose consumption and survival.[42]

Furthermore, microplastics have been shown to interfere with bees' pollination effectiveness. During flight, bees build up a positive electrostatic charge that attracts negatively charged pollen from flowers, thus facilitating pollination. Unfortunately, microplastics are also often negatively charged and therefore electrostatically attracted to bees. Studies have found that honeybees are often covered with microplastics, which they accumulate from the air, water, soil, and flowers.[43] Microplastics that adhere to bees can disrupt the transfer of pollen between flowers and may even impair bees' ability to fly. In addition, when microplastics transfer from bees to flowers, they can clog the flower's stigma and hinder pollination.

5. Impacts of Microplastics on Human Health

Humans accumulate microplastics primarily through consumption of food and water, and secondarily by inhalation, with a minor contribution from dermal absorption. In the context of the American diet, researchers conservatively estimate that the average person consumes and inhales between 74,000 and 121,000 microplastic particles each year.[44] Individuals who drink only bottled water may ingest an additional 90,000 microplastic particles annually, as bottled water is the largest known source of microplastics in the human body. Studies show that humans' microplastic intake is rising over time, reflecting the accumulation of microplastics in the environment. Microplastic particles (particularly nanoplastics) have been detected within many human organs across multiple systems, including the cardiovascular, respiratory,

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[40] Pasquini, E., et al. (2024). "Microplastics reach the brain and interfere with honey bee cognition." Science of The Total Environment, Vol. 912:169362. (https://doi.org/10.1016/j.scitotenv.2023.169362).

[41] Ferrante, F., et al. (2024). "Unravelling the microplastic menace: Different polymers additively increase bee vulnerability." Environmental Pollution, Vol. 352:124087. (https://doi.org/10.1016/j.envpol.2024.124087).

[42] An, T., et al. (2025). "Combined effects of microplastics and flupyradifurone on gut microbiota and oxidative status of honeybees (Apis mellifera L.)." Environmental Research, Vol. 270:121026. (https://doi.org/10.1016/j.envres.2025.121026).

[43] Edo, C., et al. (2021). "Honeybees as active samplers for microplastics." Science of The Total Environment, Vol. 767: 144481. (https://doi.org/10.1016/j.scitotenv.2020.144481).

[44] Cox, K.D., et al. (2019). "Human Consumption of Microplastics." Environmental Science & Technology, Vol. 53(12):7068-7074. (https://pubs.acs.org/doi/full/10.1021/acs.est.9b01517#).

digestive, lymphatic, urinary, reproductive, endocrine (including the placenta), and integumentary systems.[45] Most recently, microplastics have also been discovered in the human brain.

A 2025 research study reported the presence of microplastics in post-mortem human brains at what the lead researcher described as "alarmingly high" levels, 7-30 times higher than concentrations found in the liver or kidneys.[46,47] Among the 12 types of plastics detected, polyethene (widely used in packaging and containers) was the most prevalent, accounting for an average of 75% of the plastics found in brain tissue. Based on sample extrapolation, researchers determined that the average brain contains about 7 grams of microplastics—about the weight of a plastic spoon—comprising about 0.5% of the brain's weight. Notably, brain tissues from individuals diagnosed with dementia had plastic concentrations up to 10 times higher than those without dementia, although causality was not determined. The researchers also found that microplastic concentrations in the brain and liver have increased over time; brain tissues collected in 2024 contained about 50 percent more microplastics than tissues collected in 2016. This trend may reflect the rise in plastic production and the corresponding increase in human exposure to microplastic pollution.

The mechanism by which microplastics reach the brain is unknown. However, consumption of contaminated food and water is the most likely pathway, as the nanoplastic shards and flakes detected in brain tissue were small enough to cross the blood-brain barrier. Another potential route was suggested by a separate study, which detected microplastics in the olfactory bulb in the human brain, indicating that inhaled microplastic particles may travel through the nose directly to the brain.[48]

The widespread presence of microplastics within the human body has raised significant concerns about their potential health impacts; however, their full impact on human health remains largely unknown. A 2023 report to the California State Legislature, based on review of available evidence, concluded that microplastics are suspected to be a hazard to the human reproductive and digestive systems, and are also likely to adversely affect the respiratory

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[45] Roslan, N.S., et al. (2024). "Detection of microplastics in human tissues and organs: A scoping review." Journal of Global Health, Vol. 14:04179. (https://jogh.org/2024/jogh-14-04179).

[46] Nihart, A.J., et al. (2025). "Bioaccumulation of microplastics in decedent human brains." Nature Medicine, Vol. 31:1114–1119. (https://doi.org/10.1038/s41591-024-03453-1).

[47] Haederle, M. (2025). "UNM Researchers Find Alarmingly High Levels of Microplastics in Human Brains – and Concentrations are Growing Over Time." University of New Mexico Health Science News. (https://hscnews.unm.edu/news/hsc-newsroom-post-microplastics-human-brains).

[48] Amato-Lourenço, L.F., et al. (2024). "Microplastics in the Olfactory Bulb of the Human Brain." JAMA Network Open, Vol. 7(9):2440018. (https://pubmed.ncbi.nlm.nih.gov/39283733/).

system.[49] More recent research studies have also identified microplastics as a potential risk factor in cardiovascular disease,[50] and have supported the hypothesis that microplastic accumulation can trigger inflammatory responses linked to several diseases such as cancer.[51]

E. <u>Degradability of Plastics</u>

Estimates of the lifespan of conventional (i.e., fossil fuel-based) plastics in the environment—how long they take to fully degrade—have traditionally ranged from decades to centuries, or even thousands of years. However, until recently, these estimates lacked support from peer-reviewed scientific studies.[52] Conventional plastics are deemed non-biodegradable, meaning that they are highly resistant to microbial breakdown, primarily by bacteria and fungi, that convert organic matter (including plastics) into the inorganic molecules carbon dioxide and water (and methane in anaerobic conditions). Consequently, educational materials from many governmental agencies and environmental organizations have claimed that conventional plastics do not biodegrade or degrade at all. However, this widely held assumption has been challenged by recent evidence showing that some types of conventional plastics can fully degrade under certain environmental conditions.

Determining how long plastics take to fully degrade in natural environments has been difficult to determine due to the wide variety of plastic types with numerous chemical additives, and the diverse environmental conditions that affect degradation rates. However, recent research has shown that some conventional plastics fully degrade much faster than previously thought—within months to years rather than decades or centuries—and that exposure to sunlight is the trigger for this degradation.[53]

1. Plastic Degradation Pathways

Conventional plastics degrade through three main pathways. The first is mechanical degradation. For example, many microplastics found in coastal and marine ecosystems originate

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[49] California State Policy Evidence Consortium (CalSPEC). (2023). "Microplastics Occurrence, Health Effects, and Mitigation Policy: An Evidence Review for the California State Legislature." Sacramento, CA. (https://uccs.ucdavis.edu/sites/g/files/dgvnsk12071/files/media/documents/CalSPEC-Report-Microplastics-Occurrence-Health%20Effects-and-Mitigation-Policies.pdf).

[50] Marfella, R., et al. (2024). "Microplastics and Nanoplastics in Atheromas and Cardiovascular Events." New England Journal of Medicine, Vol. 390(10). (https://www.nejm.org/doi/10.1056/NEJMoa2309822).

[51] Cheng, Y., et al. (2024). "Microplastics: an often-overlooked issue in the transition from chronic inflammation to cancer." Journal of Translational Medicine. Vol. 22(959). (https://doi.org/10.1186/s12967-024-05731-5).

[52] Ward, C.P., & Reddy, C.M. (2020). "We need better data about the environmental persistence of plastic goods." Proceedings of the National Academy of Sciences, Vol. 117(26):14618-14621. (https://doi.org/10.1073/pnas.2008009117).

[53] Stevens, A.P. (2025). "Does plastic last for thousands of years in the environment?" Webpage article (March 13, 2025) in Oceanus: The Journal of Our Ocean Planet, by Woods Hole Oceanographic Institution. (https://www.whoi.edu/oceanus/feature/does-plastic-last-for-thousands-of-years-in-the-environment/).

from the fragmentation of macroplastics, which is driven by sunlight, heat, oxidation, and physical impacts such as from wind and waves. Although mechanical degradation reduces the plastic to smaller particles, it does not fully degrade the plastic into inorganic molecules (i.e., carbon dioxide, methane, and water), leaving microplastics widely dispersed in the environment.

The other two degradation pathways involve chemical processes that can fully degrade conventional plastic into inorganic molecules. In the presence of sunlight, conventional plastic can undergo "photochemical degradation," which can be either complete or partial. Complete photodegradation converts plastic to carbon dioxide and water, whereas partial photodegradation converts plastic into water-soluble molecules. These molecules can then be consumed by microbes, which release carbon dioxide when they respire. Thus, biological degradation (i.e., biodegradation) is typically preceded by prior photochemical degradation, which alters the plastic structure to allow for microbial consumption. These two degradation pathways can chemically degrade plastics into inorganic molecules and thus remove plastics from the environment. In contrast, plastics that are not exposed to sunlight, such as dense plastic debris that sinks in the ocean or plastics buried in landfills, are likely to persist much longer in the environment, for decades to centuries or even millennia.

2. Degradation by Microbes and Invertebrates

Recent research has also discovered that several microbes (such as certain bacteria, fungi, and algae) and invertebrates (such as certain snails, worms, and termites) contain enzymes capable of biodegrading polyethylene and some other conventional plastics under certain conditions.[54] Ongoing plastic biodegradation studies aim to develop sustainable bioremediation methods for plastic waste.

3. Biodegradable Plastics

In addition, "biodegradable plastics"—which can be either conventional plastics or bioplastics—are often promoted as more environmentally friendly alternatives to non-biodegradable plastics. However, substantial concerns have been raised about their actual environmental impact. While biodegradable plastics often contain additives to accelerate degradation, complete degradation of most types of biodegradable plastics in soil, freshwater, and marine

[54] Cai, Z., et al. (2023). "Biological Degradation of Plastics and Microplastics: A Recent Perspective on Associated Mechanisms and Influencing Factors." Microorganisms, Vol. 11(7):1661. (https://doi.org/10.3390/microorganisms11071661).

environments is uncommon.[55] This contributes to microplastic pollution, posing risks to organisms both through particulate exposure and by serving as a vector for pollutants.

Furthermore, biodegradable plastics typically require specific environmental conditions to biodegrade, such as the high temperatures found in industrial composting facilities. In the absence of these conditions, their persistence in the environment can be comparable to that of non-biodegradable plastics.

The four main biodegradation options for end-of-life biodegradable plastics are:

- In-soil biodegradation (only for certified "soil-biodegradable" plastics, such as agricultural mulch films).
- Commercial or industrial composting facilities (only for certified "compostable" plastics, such as food serviceware, shopping bags, and packaging materials).
- Home composting (only for certified "home compostable" plastics, such as grocery produce bags).
- Anaerobic digestion facilities (only for non-compostable but anaerobically biodegradable plastics).[56]

However, many communities lack a commercial composting facility or an anaerobic digestion facility. In addition, most biodegradable plastics cannot be recycled.

Studies have shown that both conventional and bio-based biodegradable plastics can have toxicity levels comparable to or even higher than non-biodegradable plastics, potentially causing harm or mortality in both aquatic and terrestrial organisms.[57,58] Biodegradable plastics fragment more rapidly compared to non-biodegradable plastics, accelerating the formation of microplastics and facilitating the release of potentially toxic additives, which may increase ecotoxicity. In addition, they are more prone to attracting environmental pollutants that bind to

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[55] Payanthoth, N.S., et al. (2024). "A review of biodegradation and formation of biodegradable microplastics in soil and freshwater environments." Applied Biological Chemistry, Vol. 67(110). (https://doi.org/10.1186/s13765-024-00959-7).

[56] Yu, Y., & Flury, M. (2024). "Unlocking the Potentials of Biodegradable Plastics with Proper Management and Evaluation at Environmentally Relevant Concentrations." Nature npj Materials Sustainability, Vol. 2(9). (https://doi.org/10.1038/s44296-024-00012-0).

[57] Nik Mut, N.N., et al. (2024). "A review on fate and ecotoxicity of biodegradable microplastics in aquatic system: Are biodegradable plastics truly safe for the environment?" Environmental Pollution, Vol. 344:123399. (https://doi.org/10.1016/j.envpol.2024.123399).

[58] Malafeev, K.V., et al. (2023). "Understanding the Impact of Biodegradable Microplastics on Living Organisms Entering the Food Chain: A Review." Polymers, Vol. 15(18):3680. (https://pubmed.ncbi.nlm.nih.gov/37765534/).

their surfaces, allowing these plastics to accumulate higher concentrations of toxic chemicals that can be transported into the food chain.[59]

Biodegradable microplastics in soil have been shown to have adverse effects on plant growth and seed germination.[60] However, their degradation may also contribute to improved soil quality and nutrient cycling. In contrast, in freshwater environments, their impact on nutrient cycling can cause eutrophication, resulting in harmful algal blooms that adversely affect aquatic ecosystems.[61] Research has also shown that biodegradable microplastics are more likely than non-biodegradable plastics to be ingested by fish and accumulate in their bodies, leading to physical and behavioral impairments.[62] Ongoing studies are focused on developing alternative biodegradable plastics that function effectively while minimizing environmental threats.

4. Soil-Biodegradable Plastics

Certain plastics have been certified as "soil-biodegradable" for specialized applications, such as agricultural mulch films used to cover row crops to conserve water, raise soil temperature, and suppress weeds. Soil-biodegradable plastic mulch is typically made from polyethylene (a conventional hydrocarbon-based plastic), although some may be partially made of bioplastic. Designed for annual use, soil-biodegradable plastic mulch is intended to be tilled into the soil at the end of each crop cycle. However, biodegradation can take several years. In California, plastic mulch film is considered soil-biodegradable if it meets the international standard EN 17033, which requires that 90 percent of the plastic breaks down into carbon dioxide and water (with the remaining 10 percent converted into microbial biomass) within two years in an aerobic incubator at 68-82° F. However, field studies have shown that in-soil biodegradation may occur more slowly.

One study, which modeled field data from a Mediterranean climate similar to coastal California, estimated that soil-biodegradable plastic mulch could take 21-58 months to reach 90 percent biodegradation in the soil.[63] When these mulches are applied annually and tilled into the soil, researchers estimate that the plastic remaining in the soil will reach a steady-state concentration. Assuming a five-year biodegradation period, the residual plastic concentration in the soil is estimated to reach and remain at three times the initial concentration (i.e., a steady-

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[59] Campanale, C., et al. (2024). "A critical review of biodegradable plastic mulch films in agriculture: Definitions, scientific background and potential impacts." TrAC Trends in Analytical Chemistry, Vol. 170:117391. (https://doi.org/10.1016/j.trac.2023.117391).

[60] Ibid.

[61] Payanthoth, N.S., et al. (2024). "A review of biodegradation and formation of biodegradable microplastics in soil and freshwater environments." (See full citation above).

[62] Malafeev, K.V., et al. (2023). "Understanding the Impact of Biodegradable Microplastics on Living Organisms Entering the Food Chain: A Review." Polymers, Vol. 15(18):3680. (https://pubmed.ncbi.nlm.nih.gov/37765534/).

[63] Griffin-LaHue, D., et al. (2022). "In-field degradation of soil-biodegradable plastic mulch films in a Mediterranean climate." Science of The Total Environment, Vol. 806(1):150238. (https://doi.org/10.1016/j.scitotenv.2021.150238).

state plastic concentration of 56.3 g/m^2).[64] Microplastics generated in the soil during the biodegradation of plastic mulch continue to cause adverse ecosystem impacts until fully biodegraded.[65] Additionally, fragments of soil-biodegradable plastic mulch may be transported off-site by wind or runoff, entering environments (such as rivers or oceans) where conditions may not support further biodegradation.

5. Compostable Plastics

Some biodegradable bioplastics are certified as "compostable"—meaning they are biodegradable in municipal or industrial composting facilities. However, only plastics certified as "home compostable" are biodegradable in a home composting system.[66] Starting in 2025, California law (PRC 42281.2) requires stores to provide pre-checkout bags (such as produce bags) that are made of either paper or certified compostable plastic. The law allows bags labeled as either "compostable" (meaning only in an industrial composting facility), or also as "home compostable," but consumers may not be aware of the difference.

Moreover, studies have shown that home compostable plastics often fail to fully biodegrade in home composting systems, as the necessary conditions (such as temperature, moisture, and aeration) are not consistently met. In one U.K. study involving 902 participants conducting home composting experiments, 60 percent of certified home compostable plastics still had visible plastic fragments after 21 months in a home composter.[67] The study also revealed that participants were confused by the labeling of biodegradable plastics, as 60 percent of the plastics they attempted to compost were not actually certified as home compostable. The researchers concluded that "home composting is not at present a viable, effective or environmentally beneficial waste processing method for compostable or biodegradable plastics in the U.K." As compostable plastics are incompatible with most recycling and anaerobic digestion systems, they are typically disposed of by landfilling or incineration.

6. Photodegradable and Oxo-Degradable Plastics

Plastics labeled as "photodegradable" or "oxo-degradable" are conventional plastics that contain an additive that causes fragmentation of the plastic when exposed to light and oxygen. While often promoted as "degradable" or "biodegradable," these claims are misleading. Rather

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[64] Yu, Y., & Flury, M. (2024). "Unlocking the Potentials of Biodegradable Plastics with Proper Management and Evaluation at Environmentally Relevant Concentrations." (See full citation above).

[65] Campanale, C., et al. (2024). "A critical review of biodegradable plastic mulch films in agriculture." (See full citation above).

[66] UrthPact. (2020). "Certified Compostable Products: What to Look For and What It Means." Webpage article June 2, 2020. (https://www.urthpact.com/certified-compostable-products-what-to-look-for-and-what-it-means/).

[67] Purkiss, D., et al. (2024). "The Big Compost Experiment: Using citizen science to assess the impact and effectiveness of biodegradable and compostable plastics in UK home composting." Frontiers in Sustainability, Sec. Waste Management, Vol. 3. (https://doi.org/10.3389/frsus.2022.942724).

than fully breaking down, these plastics simply fragment into microplastics that persist in the environment and contribute to long-term pollution.[68]

7. Bioplastics

Bioplastics (i.e., biologically-based plastics), which are made from renewable biomass sources (such as corn or cellulose) or through biosynthesis by microbes, are also promoted as environmentally friendly alternatives to conventional plastics. However, in both aquatic and terrestrial environments, most bioplastics exhibit persistence and ecotoxicity similar to conventional plastics.[69] A common misperception is that all bioplastics are biodegradable. In reality, most bioplastics do not readily biodegrade in soil or water under natural conditions. For example, research has shown that many bioplastics (including bioplastic textiles) degrade slowly in the ocean.[70] While many bioplastics are labeled as compostable, most require the high temperatures of industrial composting facilities to biodegrade.

Several studies indicate that the toxicity of bioplastics is comparable to that of conventional plastics. For example, recent research suggests that biodegradable starch-based bioplastic, commonly used in food packaging, is potentially as toxic as petroleum-based plastic.[71] Bioplastics typically contain toxic chemical additives similar to those found in conventional plastics. Furthermore, some common bioplastics, such as polylactic acid (PLA), are brittle and less durable, which can necessitate a broader range of chemical additives to achieve desired properties such as strength, flexibility, and UV protection. Therefore, some bioplastics may contain more toxic chemicals that can leach into the environment compared to conventional plastics.

The production of plant-based bioplastics also raises environmental concerns associated with cultivating biomass crops, including water and energy consumption, fertilizer and pesticide pollution, and the diversion of land from food production.[72] To address these issues, researchers

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[68] Napper, I.E., & Thompson, R.C. (2019). "Environmental Deterioration of Biodegradable, Oxo-biodegradable, Compostable, and Conventional Plastic Carrier Bags in the Sea, Soil, and Open-Air Over a 3-Year Period." Environmental Science & Technology, Vol. 53(9):4775-4783. (https://doi.org/10.1021/acs.est.8b06984).

[69] Gibbens, S. (2018). "What you need to know about plant-based plastics." Webpage article (Nov. 15, 2018). National Geographic Society. (https://www.nationalgeographic.com/environment/article/are-bioplastics-made-from-plants-better-for-environment-ocean-plastic).

[70] Royer, S.-J., et al. (2023). "Not so biodegradable: Polylactic acid and cellulose/plastic blend textiles lack fast biodegradation in marine waters." PLoS ONE, Vol. 18(5):e0284681. (https://doi.org/10.1371/journal.pone.0284681).

[71] Liu, J., et al. (2025). "Long-Term Exposure to Environmentally Realistic Doses of Starch-Based Microplastics Suggests Widespread Health Effects." Journal of Agricultural & Food Chemistry, Vol. 73(16):9867-9878. (https://doi.org/10.1021/acs.jafc.4c10855).

[72] Yadav, K., & Nikalje, G.C. (2024). "Comprehensive analysis of bioplastics: life cycle assessment, waste management, biodiversity impact, and sustainable mitigation strategies." PeerJ, Vol. 12:e18013. (https://doi.org/10.7717/peerj.18013).

are exploring sustainable alternative biomass feedstocks for biodegradable bioplastics, such as cultivated marine algae, shrimp shells from seafood industry waste, and seashells. [73,74]

V. Economic and Social Impacts of Plastic Pollution

A. Economic Impacts

A 2013 study on behalf of the Natural Resources Defense Council estimated that California communities spend a minimum of $428 million per year to manage trash that has escaped into the environment.[75] This figure does not account for other costs associated with trash in the environment, however, such as non-market ecosystem service valuations or the depreciation of environmental services and resources. For example, a 2014 study from the National Oceanic and Atmospheric Administration (NOAA) found that removing 50-100% of the litter on Orange County beaches could benefit California residents by $67-$148 million annually during the 3 summer months by reducing the loss of tourism revenue if tourists chose to visit cleaner beaches.[76]

B. Social Impacts

From the exploration and extraction of natural gas and oil to the disposal of plastic waste, the entire life cycle of plastics has harmful impacts on humans. After extraction, natural gas and oil are sent to refineries to be chemically processed in petrochemical facilities. These facilities can negatively impact the quality of life, and potentially the health, of residents in communities surrounding the facilities.[77]

Similarly to plastic production, plastic waste also has impacts. Prior to 2018, the U.S. exported most of its plastic waste to China. However, China banned most plastic waste imports after 2018, so the U.S. diverted its plastic waste exports to other Southeast Asian countries, such as Malaysia, Indonesia, and Thailand. Although the total amount of plastic waste exported has decreased significantly, the increase of plastic waste imports to this new region of Southeast Asian countries that are not as well equipped as China has resulted in increased burning of

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[73] Ferreira-Filipe, D.A., et al. (2021). "Are Biobased Plastics Green Alternatives? — A Critical Review." International Journal of Environmental Research & Public Health, Vol. 18(15):7729. (https://doi.org/10.3390/ijerph18157729).

[74] Ho, N., et al. (2025). "Calcium carbonate-based biodegradable composites as an alternative material to industrial plastics." MRS Communications, Vol. 15:219-226. (https://doi.org/10.1557/s43579-025-00695-z).

[75] Kier Associates. (2013). "Waste in Our Water: The Annual Cost to California Communities of Reducing Litter that Pollutes Our Waterways." Prepared for the National Resources Defense Council (NRDC). (https://www.nrdc.org/sites/default/files/oce_13082701a.pdf).

[76] Leggett, C., et al. (2014). "Assessing the Economic Benefits of Reductions in Marine Debris: A Pilot Study of Beach Recreation in Orange County, California." Cambridge, MA: Industrial Economics, Inc. (https://stacks.stanford.edu/file/druid:ks485yz2876/MarineDebrisEconomicStudy.pdf).

[77] Ibid.

trash, illegal disposal, and unregulated recycling operations.[78] This has had extensive health and social impacts, including polluted water supplies, crop losses, and increased respiratory ailments from incineration of plastic waste in the regions most impacted by the increased plastic waste imports.[79]

Plastics also contribute substantially to disease and associated social costs in the United States. A recent study estimated that in the United States in 2018, a cost of $249 billion (equal to 1.22% of the gross domestic product) can be attributed to the disease burden due to chemicals used in plastic materials.[80] Prioritizing plastic pollution prevention measures in communities most impacted by plastic pollution and supporting the public participation processes can enable impacted residents to play a meaningful role in helping to shape plastic pollution reduction strategies.

Given the impacts that plastics can have across their entire life cycle, reducing or eliminating single-use plastics at the source is a key strategy in reducing harm associated with plastic pollution. To achieve that end, effective and open communication with those communities most impacted by the plastic life cycle is important to achieve more meaningful engagement, equitable processes, and stronger coastal protection benefits for all Californians.

VI. Plastic Pollution and the California Coastal Act

Development in the coastal zone generally requires a CDP from either the Coastal Commission or the local government if they have a certified LCP. LCPs become effective after the Coastal Commission certifies their conformity with the policies of Chapter 3 of the Coastal Act. The policies of the Coastal Act, as well as any implementing LCP policies, provide standards for planning, permitting, and regulatory decisions made by the Coastal Commission and by coastal cities and counties. Several policies in the Coastal Act address issues relevant to the environmental impacts of plastic pollution resulting from development, including:

- Section 30230: Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all

[78] INTERPOL. (2020). "Strategic Analysis Report: Emerging Criminal Trends in the Global Plastic Waste Market Since January 2018." Lyon, France. (https://www.interpol.int/en/News-and-Events/News/2020/INTERPOL-report-alerts-to-sharp-rise-in-plastic-waste-crime).

[79] Global Alliance for Incinerator Alternatives (GAIA). (2019). "Discarded: Communities on the Frontline of the Global Plastic Crisis." Berkeley, CA. (https://www.no-burn.org/resources/discarded-communities-on-the-frontlines-of-the-global-plastic-crisis/).

[80] Trasande, L., et al. (2024). "Chemicals Used in Plastic Materials: An Estimate of the Attributable Disease Burden and Costs in the United States." Journal of the Endocrine Society. Vol. 8(2). (https://doi.org/10.1210/jendso/bvad163).

species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.

This policy provides a broad basis for protection and enhancement of marine resources. This policy requires that uses of the marine environment sustain the biological productivity of coastal waters and maintain healthy populations of all marine species. Plastic pollution in the ocean may impair the health and biological productivity of marine life populations.

- Section 30231: The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface water flow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.

This policy establishes the Commission's authority to protect the water quality of all coastal waters, including waterways, lakes, wetlands, estuaries, and marine waters. It requires that coastal water quality be maintained, and where feasible restored, to protect marine organisms and human health. The Commission (and local governments with certified LCPs) may protect water quality in a variety of ways, including by controlling wastewater discharges and stormwater runoff. Plastic pollution resulting from development degrades coastal water quality to the detriment of both aquatic life and human health.

- Section 30240: (a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on such resources shall be allowed within such areas.

  (b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreational areas.

This policy mandates that Environmentally Sensitive Habitat Areas be protected from significant disruption of habitat values. Plastic pollution resulting from development can have adverse impacts on aquatic and terrestrial biota, which could potentially disrupt habitat values.

- Section 30251: The scenic and visual qualities of coastal areas shall be considered and protected as a resource of public importance. Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and, where feasible, to restore and enhance visual quality in visually degraded areas.

> New development in highly scenic areas such as those designated in the California Coastline Preservation and Recreation Plan prepared by the Department of Parks and Recreation and by local government shall be subordinate to the character of its setting.

This policy protects the scenic qualities of coastal areas, which can be visually degraded by plastic pollution, particularly in waterways, along shorelines, and on the coastline.

VII. General Strategies for Addressing Plastic Pollution in the Coastal Zone

Preventing plastic pollution is important during both the construction phase of a development project and long-term over the life of the development. The following general strategies can help reduce plastic pollution and should be considered during planning and permitting efforts to ensure consistency with the policies of the Coastal Act. These strategies are consistent with past Commission actions; see examples for specific development categories in Appendix A, below.

1. Use Non-Plastic Materials

Use alternative (non-plastic) materials for outdoor structures, products, and activities, whenever feasible. For example, avoid the use of plastic take-out food serviceware; plastic sheeting for crop covers; plastic netting in erosion and sediment control products; spray-on plastic polymer soil stabilizers; plastic polymer binders and sealers for paving products; plastic and wood-plastic composite dock decking; synthetic rubber playground surfacing; and artificial turf.

2. Select Low-Toxicity Plastics Resistant to Releasing Plastic Particles

If the outdoor use of a substantial amount of plastic is deemed necessary for a development project, select plastics with documented low toxicity (particularly aquatic toxicity), if feasible. Also select plastics for outdoor uses that are resistant to releasing plastic particles, if feasible, and avoid the long-term outdoor use of granular, shredded, or thin pieces of plastic that are prone to shedding plastic particles.

3. Minimize Discharge of Plastics During Installation and Maintenance

If the outdoor use of plastics is deemed necessary for a development project, implement procedures to minimize the discharge of plastics into the environment during installation and maintenance of the plastic components, particularly in overwater and in-water structures. Examples include containing and removing plastic sawdust and fragments generated during installation or maintenance of plastic structural components (such as dock decking); and preventing spills or drips of plastic-based coatings, sealers, and grout from entering coastal waters during overwater or in-water application.

4. Monitor Plastics in Structural Components

Regularly inspect plastics used in permanent or temporary structural components (such as plastic sheeting, dock floats, pile wraps, silt fences, and synthetic weed-mat) and promptly repair or replace any component that shows signs of damage or degradation, to minimize the release of plastic fragments. Remove erosion and sediment control products made of plastic (such as silt fences) and plastic mesh construction site fencing promptly when no longer required.

5. Contain Plastic Litter and Debris

Prevent plastic litter and debris from entering the environment by implementing effective containment measures. For example, provide conveniently located recycling bins, trash cans, and cigarette butt receptacles; use covered bins to minimize wind- and wildlife-driven dispersal of plastic litter and debris; establish a maintenance schedule based on peak usage to prevent bin overflow; and implement controls to limit plastic releases from plastic production and transportation industries.

6. Remove Plastic Debris from Runoff, Wastewater Discharges, and Waterways

Address stormwater and wastewater pathways that transport plastics into coastal waters through targeted interventions. For example, install structural Low Impact Development (LID) BMPs, such as bioretention basins, to retain stormwater runoff on-site and thereby capture runoff pollutants, including plastic debris and chemicals leached from plastics. Use trash capture devices to filter larger plastic debris (> 5 mm) from stormwater runoff; and filter plastic particles and synthetic fibers from wastewater discharges. Where applicable, install floating trash interceptors in heavily polluted waterways to catch floating debris before it reaches the ocean.

VIII. Addressing Plastic Pollution in Coastal Development Permits

A. <u>Overview of Coastal Development Permits</u>

In areas where the Coastal Commission retains permitting jurisdiction and areas without a certified LCP, the Commission is generally responsible for reviewing CDP applications to ensure the proposed project is consistent with the Chapter 3 policies of the Coastal Act (Public Resources Code Sections 30200-30270). In areas with a certified LCP, the local government is responsible for reviewing the compliance of proposed CDP projects with the requirements of the certified LCP and, where applicable, the public access and recreation policies of the Coastal Act.

The Commission and/or local governments may require changes to the proposed project, conditions, or other mitigation measures, to ensure compliance with Coastal Act policies or LCP requirements. Thus, through the CDP process, the permitting authority can minimize plastic pollution associated with a proposed development.

B. Considerations for Evaluating Plastic Pollution in Proposed CDP Projects

The following sections outline key issues to consider when evaluating potential impacts of plastic pollution in CDP applications.

1. Evaluate Plastic Pollution Both During Construction and Post-Construction

For CDP projects, project reviewers and designers should evaluate strategies to prevent plastic pollution both during construction and through long-term, post-construction measures over the life of the project. To avoid adverse impacts on coastal resources, the general strategies for addressing plastic pollution in the Coastal Zone—outlined in section VII above—should be considered.

2. Evaluate Plastic Pollution Throughout the Coastal Zone

Plastic pollution from coastal development projects is of concern not only for development over or in water, or directly adjacent to waterways and the ocean, but also for terrestrial ecosystems. Plastic debris generated by development and activities throughout the coastal zone can be transported to the ocean and other coastal habitats through stormwater runoff, wind, atmospheric deposition, waterways, and treated wastewater discharges.

3. Identify Proposed Outdoor Uses of Plastics

Project reviewers should evaluate project descriptions and plans to determine whether significant amounts of plastic materials are proposed for use in outdoor structures, products, and activities. However, this may be challenging because proposed materials are often not clearly or comprehensively identified. For example, a project may propose the use of straw wattles (also known as fiber rolls) for sediment control during construction but not mention that the straw wattles will be bound by plastic netting. Or a project may propose a recreational trail made of "stabilized" decomposed granite but not explain that this means that the natural granite particles will be held together by a polyurethane plastic binder.

The terminology used to describe outdoor materials or products may not clearly indicate that plastics, rather than natural materials, are being proposed. For example, the materials used in Poured-in-Place (PIP) "rubber" playground surfacing are typically labeled as rubber, recycled rubber, or virgin rubber (i.e., not derived from recycled materials). However, these surfacing materials consist of granules of synthetic rubber (which are plastics) and shredded waste tires (which also contain synthetic rubber), held together by a polyurethane binder (which is also a plastic). Labeling the materials used in PIP playgrounds simply as "rubber" may lead to the misconception that the playground is made from natural rubber derived from rubber trees, and therefore non-toxic.

As another example, “geotextiles” are permeable fabrics that are commonly used in structural BMPs to separate layers such as gravel and soil. Geotextiles are also often used on the surface of the ground for weed suppression and soil erosion control, both during project construction and over the long term. However, project descriptions often do not state that geotextile fabrics are typically made of plastics such as polypropylene or polyester.

Key terms that may indicate that a proposed construction material or product is a type of plastic include, but are not limited to, polymer, resin, rubber, binder, sealer, encapsulated, coated, pile wrap or jacket, composite, netting, sheeting, geotextile, synthetic, artificial, or stabilized. Polyethylene, polypropylene, nylon, and polyester are types of plastic that may be used for sheeting, wrapping, geotextiles, and beach access mats; and polyurethane is a type of plastic used in sealers, coatings, and binders commonly used in various outdoor structures. Also, many project descriptions just list the abbreviations for types of plastics, such as EPDM (ethylene propylene diene monomer), TPV (thermoplastic vulcanizate), TPE (thermoplastic elastomer), SBR (styrene-butadiene rubber), HDPE (high-density polyethylene), and PVC (polyvinyl chloride). Determining the specific type of plastic proposed for each outdoor project component may require careful investigation.

4. Evaluate Potential for Discharges of Plastic Pollution

Project reviewers should evaluate a project’s potential to discharge plastic pollution that could adversely impact coastal resources. If substantial amounts of plastics are proposed for structural components used outdoors (such as for playground surfacing or artificial turf), reviewers should evaluate whether these materials are likely to release plastic fragments into the environment. Microplastic granules and shreds — including those held together by a plastic-based binder — and thin plastic materials (such as artificial turf blades, netting, and sheeting) are generally more prone to shedding than thicker, solid plastic components. In addition, plastic-based products applied as liquids (such as sealers, coatings, binders, and stabilizers) can release microplastics over time due to wear and weathering.

Project reviewers should also consider how certain categories of development, land uses, locations, and environmental conditions of proposed development or land uses may increase the potential for plastic pollution. For example, dock piles wrapped in plastic to protect against saltwater corrosion may be more prone to shedding plastic fragments if located in high-impact vessel docking areas.

Recreational activities and special events can also generate litter containing plastic debris, especially when adequate trash and recycling containers are not readily available. In addition, cigarette butt litter may be more prevalent near building entrances where indoor smoking is prohibited, especially if dedicated receptacles are not provided. In marinas and harbors, plastic litter is often prevalent, perhaps due to items accidentally falling or being blown from vessels or docks into the water.

5. Evaluate Toxicity of Plastics

If substantial amounts of plastic are proposed for outdoor structural components or products, project reviewers should seek information on the toxicity of chemicals that may leach from the specific types of plastic, particularly if plastic particles or leachate could be discharged into environmentally sensitive areas. This analysis is particularly relevant for projects such as artificial turf, playground surfacing, and dock decking. This analysis should evaluate the potential toxicity (aquatic and/or terrestrial) of the plastics used in structural components, products, and activities during both the project's construction and post-construction phases.

Project reviewers can request that applicants provide a material Safety Data Sheet (SDS) from the manufacturer of plastic products to evaluate the material's potential toxicity. An SDS is required by the Occupational Health and Safety Administration (OSHA) for worker safety, but it also contains relevant information about potential environmental impacts of the material. Additional toxicity information may be obtained from product manufacturers, government sources such as the California Department of Toxic Substances Control, and scientific research publications.

6. Evaluate Effectiveness of BMPs to Minimize the Discharge of Plastics

Project reviewers should evaluate the anticipated effectiveness of any proposed BMPs intended to minimize the discharge of plastic debris and chemicals leached from plastics, both during construction and over the life of the development. This evaluation should include a review of the maintenance plan for all structural BMPs. For example, trash capture devices for stormwater runoff should be maintained frequently enough to prevent previously captured plastic debris from being resuspended and released during subsequent storms. Types of BMPs to consider include:

- **Source Control BMPs –** Source Control BMPs, which can include structural devices or operational activities, reduce the generation of pollutants (including plastic debris), and prevent them from entering stormwater runoff, waterways, and the ocean. Examples include covering outdoor trash receptacles; protecting materials stored in outdoor work areas from rainfall, runoff, and wind; and using municipal street sweeping machines. Source Control BMPs should be a high priority for all projects, as applicable.

- **Structural LID Stormwater Management BMPs –** If a proposed project is likely to result in the long-term discharge of significant amounts of macroplastic debris and/or microplastics (such as a roadway or large parking lot), structural stormwater management LID BMPs (also known as Green Infrastructure) may be appropriate.[81,82] LID BMPs that retain runoff on site through infiltration and evapotranspiration (such as rain gardens and bioretention basins) also retain the pollutants carried in runoff. These BMPs have been shown to be the most effective at removing microplastics, and the chemicals that leach from plastics, from stormwater runoff.[83] Where retaining runoff on site is not technically feasible, flow-through biofiltration LID BMPs (such as bioswales or biofiltration planter boxes) that filter runoff through a constructed system of vegetation, enhanced soils, and gravel are also generally effective at removing both macroplastic and microplastic pollution, as well as many chemicals that leach from plastics.

- **Manufactured Stormwater Treatment Devices –** If LID BMPs are technically infeasible for a proposed project, a variety of manufactured stormwater treatment devices (such as hydrodynamic separators) may be used. When properly maintained, these devices can effectively remove macroplastic debris from stormwater. However, they are typically ineffective at removing microplastics and soluble chemicals leached from plastics. Additionally, a common issue with many manufactured treatment devices is the potential for captured sediment and debris to become resuspended and released during subsequent storms. Thus, these devices need frequent maintenance to function properly. Manufactured treatment devices are commonly used as pre-treatment BMPs to reduce the clogging of more effective LID stormwater management BMPs by sediment and debris.

- **Trash Capture Devices –** Trash capture devices are manufactured stormwater treatment BMPs designed to screen out and capture larger pieces of trash and debris (greater than 5 mm) from stormwater runoff before it is discharged to waterways or the ocean. A trash screen installed in a storm drain inlet is a common example. However, these devices are typically not designed to capture microplastics. Trash capture devices may be appropriate for projects expected to generate significant amounts of macroplastic debris (such as urban roadways), when the use of LID stormwater management BMPs (such as a bioretention basin or rain garden) is not feasible. In addition, the State Water Board requires installation of a certified Full Capture System for trash in certain types of development projects.[84]

The State and Regional Water Boards, under their Municipal Separate Storm Sewer System (MS4) stormwater permits, also require that MS4 permittees (such as cities, counties, Caltrans, and universities) require implementation of LID site design strategies and structural LID BMPs

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[81] Kwarciak-Kozłowska, A., & Madeła, M. (2025). "The Occurrence and Removal of Microplastics from Stormwater Using Green Infrastructure." Water, Vol. 17(14):2089. (https://doi.org/10.3390/w17142089).

[82] See the California Coastal Commission's Water Quality webpage on Low Impact Development for more information. (https://www.coastal.ca.gov/water-quality/low-impact-dev/).

[83] Han, Z., et al. (2025). "Microplastics removal from stormwater runoff by bioretention cells: A review." Journal of Environmental Sciences, Vol. 154:73-90. (https://doi.org/10.1016/j.jes.2024.07.007).

[84] California State Water Resources Control Board. "Trash Implementation" webpage (undated). (https://www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html).

for certain types and sizes of development.[85] Public Resources Code Section 30412 describes the respective roles of the Coastal Commission and the State Water Resources Control Board and Regional Water Quality Control Boards. It states that the Commission may not "modify, adopt conditions, or take any action in conflict with any determination by the State Water Resources Control Board or any California regional water quality control board in matters relating to water quality...." There may be situations where a Coastal Act decisionmaker can impose requirements related to water quality that are more protective of coastal resources than those imposed by the Water Boards, if they are not in conflict with the Water Boards' determinations. However, Coastal Commission and Water Board staff should be consulted if there is a question regarding whether there might be a conflict between these agencies' recommendations or requirements.

See Appendix A for recommended plastic pollution prevention strategies tailored to several specific categories of development, including:

- Overarching Issues: Trash and waste management, and the construction phase of projects
- Commercial and Industrial: Food services, hotels, aquacultural operations, and plastic manufacturing and transportation
- Public Works and Facilities: Municipal wastewater treatment plants, dredging, and roadways
- Overwater and In-Water Structures: Docks, piers, piles, and sheet piles
- Long-term Erosion Protection: Turf reinforcement mats, geocells, rock bags, and oyster reefs
- Recreation and Special Events: Marinas, playground surfacing, artificial turf, and fireworks
- Permeable Pavements: Reinforced turf, permeable interlocking concrete pavers, stabilized loose rock paving, and resin-bound paving
- Landscaping: Synthetic landscaping materials, and irrigation pipes and lines
- Agriculture: Plastic film mulch for row crops, and application of sewage sludge as fertilizer

[85] California State Water Resources Control Board. "Municipal Stormwater Program" webpage (undated). (https://www.waterboards.ca.gov/water_issues/programs/stormwater/municipal.html).

IX. Addressing Plastic Pollution in Coastal Planning Documents

A. Overview of Local Coastal Programs and Analogous Plans

The Coastal Act requires that the 61 cities and 15 counties in coastal California prepare Local Coastal Programs (LCPs) to govern land use and development and protect coastal resources in the coastal zone. Each LCP includes a Land Use Plan (LUP) and an Implementation Plan (IP). The LUP specifies the kinds, locations, and intensity of uses allowed in the local jurisdiction. The IP includes measures to implement the LUP, such as development standards and zoning ordinances. LCPs become effective only after the Commission certifies their conformity with the policies of Chapter 3 of the Coastal Act. Once an LCP is certified by the Commission, the local government becomes responsible for reviewing most CDP applications within their jurisdiction. The Commission also reviews and certifies LCP amendments and updates.

Similarly to LCPs, Long-Range Development Plans (LRDPs), Port Master Plans (PMPs), and Public Works Plans (PWPs) are other types of long-range local coastal planning documents that allow a public agency to regulate coastal development in its jurisdiction. After certification by the Commission, the agency—such as a university for an LRDP, a port district for a PMP, or a public agency for a PWP—relies on the certified plan to implement the Coastal Act at the local level in the agency's jurisdiction.

The Commission's website has a multitude of resources to aid local jurisdictions and other agencies in preparing, updating, and/or amending LCPs or analogous long-range coastal plans.[86] These documents need to be updated periodically to address emerging issues such as plastic pollution, in addition to other regular updates. Local governments and other agencies should review these materials when developing policies for plastic pollution reduction in LCPs or analogous long-range coastal plans. Local governments should also consult with Commission staff early in their LCP amendment or update process to help identify opportunities for reducing plastic pollution.

B. Model LCP Water Quality Guidance Document

The Commission's [Model LCP Water Quality Guidance](https://www.coastal.ca.gov/water-quality/local-gov/) provides examples of water quality protection policies and development standards to aid local governments and agencies in developing or updating the water quality chapters of their long-range coastal planning document.[87] This guidance document is also intended to assist Commission staff in reviewing the water quality components of these proposed planning documents, and in reviewing

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[86] See the California Coastal Commission's LCP webpage for additional information. (https://www.coastal.ca.gov/lcps.html).

[87] See the California Coastal Commission's Water Quality webpage for local governments for additional information. (https://www.coastal.ca.gov/water-quality/local-gov/).

proposed CDP projects as well. The Model LCP Water Quality Guidance recommends an LID approach to stormwater management (also known as Green Infrastructure) that prioritizes on-site retention of stormwater runoff to the extent feasible. LID BMPs that retain runoff on site—through infiltration, evapotranspiration, or rainwater harvesting —also retain pollutants carried in runoff (including microplastics and chemicals leached from plastics). If on-site runoff retention is technically infeasible, flow-through LID biofiltration BMPs (such as a rain garden) that filter runoff through a constructed system of vegetation and enhanced soils are also generally effective at removing both macroplastic and microplastic pollution, as well as many chemicals that leach from plastics.

C. Considerations for Addressing Plastic Pollution in Coastal Planning Documents

LCPs and analogous coastal planning documents can help reduce plastic pollution by incorporating relevant policies and development standards. These may include the general strategies for addressing plastic pollution in the coastal zone (see Section VII above), key considerations for evaluating plastic pollution in proposed CDP projects (see Section VIII above), and applicable recommendations from the Coastal Commission's Model LCP Water Quality Guidance.

For example, LCP policies can require that outdoor structures, products, and activities prioritize the use of alternative, non-plastic materials wherever feasible. For development projects that propose substantial outdoor use of plastics, the LCP could require an alternatives analysis to identify feasible non-plastic alternative products. If the use of plastics is deemed necessary, the LCP could require the avoidance of plastic types prone to fragmentation and environmental discharge (such as granulated, shredded, or thin plastic materials) and require the selection of plastics that have documented low aquatic toxicity. Reducing or eliminating unnecessary single-use plastics at the source is also a key strategy in preventing plastic pollution.

LCPs could also include a policy that regulates the application of municipal sewage sludge (i.e., biosolids) used as a fertilizer on agricultural lands, to reduce this major source of microplastic pollution. Although the State and Regional Water Boards in California, along with the U.S. EPA, regulate the use of biosolids as a soil amendment, this does not preempt or supersede the authority of local agencies to prohibit, restrict, or control the application of biosolids to lands within the local government's jurisdiction.[88]

To ensure that LCP policies result in plastic pollution prevention, consider including the following LCP policies:

[88] California State Water Resources Control Board. (2024). "Biosolids" webpage (updated Dec. 30, 2024). (https://www.waterboards.ca.gov/water_issues/programs/biosolids/).

- Set timelines for adoption of plastic phase-outs, if established by local or state legislation;
- Identify current baselines and target reductions in plastic pollution in the Coastal Zone and the means to achieve those targets; and
- Establish monitoring and reporting mechanisms so that both local jurisdictions and the public can track progress and compliance.

X. Conclusion

Addressing plastic pollution in California is a significant and growing challenge, driven by the State's expanding population and the increasing use of plastic. Despite the scale of the plastic pollution problem, knowledge and research about its sources and impacts remains relatively nascent. This guidance reflects current knowledge, best practices, and the most broadly applicable strategies and lessons learned.

While no single solution can eliminate plastic pollution, a suite of actions across all stages of the plastics lifecycle could achieve meaningful societal and environmental benefits. This complex issue involves plastic producers, numerous state regulatory agencies, local governments, and citizens. Effectively confronting this escalating environmental threat will require action from every entity with a relevant role or responsibility in managing plastic use and waste.

The Coastal Commission has a longstanding history of addressing plastic pollution within its regulatory framework. This document is intended to identify the types of interventions that can be implemented and to support the Commission, its local government partners, permit applicants, and the public in advancing further plastic pollution reductions through planning and permitting actions. Local governments and project applicants are encouraged to consult with Commission staff early in the planning or permitting process to help identify opportunities for reducing plastic pollution in accordance with this guidance. See the Commission's Contacts website to find the appropriate district office to contact.

Appendix A

Plastic Pollution Prevention Strategies for Specific Development Categories

Table of Contents

Overview

Given the adverse impacts of plastic pollution on the marine environment and human health, it is important for the Coastal Commission and other stakeholders to apply effective permitting approaches and policy frameworks to support plastic pollution reduction and prevention, particularly through CDPs and coastal planning documents. The examples below highlight past Commission actions, organized by the most ubiquitous types of development that frequently raise plastic pollution concerns.

While not an exhaustive list, the common development categories addressed below include commercial and industrial developments (e.g., restaurants, hotels, aquacultural operations, and plastic manufacturing and transportation), public works and facilities (e.g., roadways, municipal wastewater treatment plants, and dredging), overwater and in-water structures (e.g., docks, piers, piles, and sheet piles), recreation and special events (e.g., marinas, playgrounds, artificial turf, and fireworks), permeable pavements, landscaping, and agriculture. Overarching issues that apply to several development categories (e.g., trash and waste management, and the construction phase of projects) are also discussed.

I. OVERARCHING ISSUES

While each category of development presents unique challenges, opportunities, and considerations for preventing or reducing plastic pollution, there are also overarching issues that apply broadly across multiple types of development. These issues include:

A. Trash and Waste Management

All facilities, especially visitor-serving facilities, should have a waste management plan to adequately capture trash produced by and around the facility. This could include the strategic placement and regular maintenance of adequate waste receptacles, especially during peak use periods. Waste receptacles should be selected and configured to comply with local disposal ordinances – for example, if a municipality requires separate collection of trash, recycling, and composting, adequate receptacles for each should be provided. Facilities staff may also require training in proper waste sorting and disposal, especially where multi-bin systems are used. Project reviewers could include training requirements as permit conditions.

Waste receptacles can become a point source of plastic pollution when they overflow, are not properly maintained, or are accessed by wildlife. A permit condition could require all waste receptacles remain covered to prevent wildlife intrusion and reduce the dispersal of waste by wind and rain. Maintenance schedules should be designed to handle peak usage periods, and they could also be required as a permit condition.

Tobacco product waste, especially cigarette filters, is a problematic source of plastic pollution. Each discarded cigarette filter can fragment into as many as 15,000 microfibers, and 99% of filters are made of cellulose acetate, a type of plastic. Improperly extinguished cigarettes can also pose a fire threat when disposed of in trash receptacles. However, harmful tobacco product waste is not limited to cigarette filters, but also includes electronic smoking devices (such as e-cigarettes), heated tobacco products, and cigarillo tips. Waste from vaping devices contains hazardous components such as nicotine and batteries, which can leak toxic chemicals and heavy metals into waterways and soil. Single-use or disposable vapes, which are not intended to be reused once the nicotine inside the device has been depleted, contain lithium-ion batteries that are not intended to be recharged, are highly flammable, and are difficult to extinguish if ignited.

Project reviewers could consider requiring designated cigarette filter receptacles, as well as receptacles for single-use vaping devices, in areas where smokers congregate. These receptacles could include signage to encourage proper disposal and educate smokers that cigarette filters and vaping devices contain plastic, release toxic chemicals, and can pose serious risks to wildlife and the coastal environment. A plan for adequate maintenance of these receptacles may also be included in permit conditions to ensure that these receptacles do not overflow.

Examples of Past Commission Actions – Below are some examples of past Commission actions with requirements for trash and waste management to prevent plastic pollution:

- Special Condition 2.A in CDP No. 1-19-0462 (Mad River Floodplain Enhancement and Public Access Improvement Project, McKinleyville Community Services District). Install a nature study trail, benches, viewing area, and improvements to a small boat launch. Required installation of one or more waste receptacles, and an operation and maintenance plan detailing the schedule for waste management and public access facility upkeep.
- Special Condition 27.C in CDP No.5-19-0971 (Large Scale Remodel of Dana Point Harbor, Dana Point Harbor Partners, LLC). This condition required a marine debris reduction plan that includes a service plan for recycling, trash bins, and compost. The plan shall specify the amount of trash and recycling bins in the project area of the proposed development and weekend maximum usage statistics to ensure that adequate bins are being deployed and that the trash and recycling management program is robust and avoids over-filled bins that might result in adverse impacts to nearby natural resources.

B. Plastic Pollution Prevention During Construction

1. General Requirements During Construction

Several manufactured products commonly used during the construction phase of a project may be made wholly or partially of plastic. If these plastic products deteriorate or are not properly contained or disposed of, plastic fragments may be released into the environment. To address this concern, the Commission has previously imposed the following general construction-phase requirements:

- Frequent inspection of all construction-phase structural BMPs with plastic components, and prompt repair or replacement if the plastic becomes damaged or degraded.
- Removal of construction-phase structural BMPs that contain plastic when they are no longer required.
- Use of non-plastic alternatives for construction-phase structural BMPs, if they meet the project’s technical requirements.
- Implementation of operational source control BMPs (such as waste management and stockpile management BMPs) to minimize the discharge of debris and pollutants resulting from construction and demolition activities.

- Procedures to fully contain and properly dispose of plastic particles and plastic debris generated during construction and demolition activities (such as plastic sawdust and paint chips).
- Procedures for spill prevention during application of liquid products containing plastics (such as spray-on soil stabilizers and paint).

2. Common Plastic-Based Products Used During Construction

Below are examples of manufactured plastic-based products commonly used during construction, along with non-plastic alternatives to consider where technically feasible.

- **<u>Temporary Rolled Erosion Control Products</u>**

Temporary rolled erosion control products (RECPs), including fiber rolls (also known as wattles), mulch control netting, and erosion control blankets, are construction-phase structural BMPs that commonly contain plastic netting, which has been found to entangle and kill wildlife.[89] These BMPs are called temporary because they are designed to degrade into plastic fragments within a period ranging from months to years. However, they are commonly left in place permanently, particularly if vegetation has grown up through the netting. The plastic netting in temporary RECPs (commonly made of polypropylene, nylon, polyethylene, or polyester) may be marketed as UV-degradable, photodegradable, or oxo-degradable. However, this is not the same as biodegradable, as the netting degrades into plastic fragments that persist in the environment. There are several temporary RECPs that contain loose-weave natural-fiber netting (such as jute, sisal, and coir) or are netting-free, which the Commission has required in many past actions to prevent plastic pollution and wildlife entanglement.

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[89] Metz, V. (2012, updated 2016). "Wildlife-Friendly Plastic-Free Netting in Erosion and Sediment Control Products: Water Quality Factsheet for Permit Applicants." On the California Coastal Commission's Water Quality webpage for permit applicants. (https://www.coastal.ca.gov/water-quality/permits/).

Fiber rolls and erosion control blankets also contain a filling or matrix, which can either be made from natural-fiber materials such as straw, coir (coconut fiber), or excelsior (fine curled wood fibers), or from synthetic plastic fibers. These erosion control products can therefore consist of all natural-fiber materials, all synthetic plastic materials, or a combination of both. For example, a natural-fiber matrix bound with plastic netting is very widely used for both fiber rolls and erosion control blankets. Products with a natural-fiber matrix are often misleadingly labeled as "biodegradable" even when the netting and stitching are made from non-biodegradable plastics. Temporary RECPs composed entirely of natural-fiber materials are the preferable choice to avoid plastic pollution.

A fiber roll (straw wattle) with plastic netting, used for sediment control during construction in Trinidad, California. (Photo: Vanessa Metz, California Coastal Commission)

In addition, some fiber rolls made from natural fibers may be treated with a spray-on acrylic plastic polymer called polyacrylamide (PAM) to enhance their ability to trap sediment. Particles of PAM plastic may be released to the environment when the fiber roll degrades. This can be avoided by using fiber rolls that are not treated with PAM.

- **<u>Synthetic Geotextiles</u>**

Geotextiles (also known as filter fabrics) are permeable fabrics that are manufactured from plastic fibers (such as polypropylene or polyester); the fabric may be woven or non-woven (i.e., bonded fibers). Geotextiles have several temporary uses during construction, including erosion protection on disturbed soils; covering material and soil stockpiles; and used as liners in sediment traps and basins. However, geotextiles are vulnerable to deterioration including from

UV exposure, high soil pH, and high temperatures, and many geotextiles degrade rapidly when exposed to sunlight, leading to the discharge of plastic fibers into the environment.[90]

Several non-plastic erosion control BMPs, such as natural-fiber erosion control blankets, may be suitable alternatives to synthetic geotextiles for certain uses; however, natural-fiber products may not necessarily provide adequate durability and longevity for some applications. Although natural-fiber erosion control blankets are sometimes marketed as “biodegradable geotextiles,” they are technically not geotextiles. However, biodegradable geotextile fabrics made from bio-based plastics have recently been developed, such as a polyester called “bio-based poly (butylene succinate)” or Bio-PBS.[91] If bio-based plastic geotextiles are available and meet the project’s technical requirements, they may be a suitable alternative to non-biodegradable hydrocarbon-based plastic geotextiles for short-term uses.

Geotextiles are also commonly installed underground for long-term use in some structural BMPs, such as in bioretention basins to separate the stone aggregate layer from the underlying soil and prevent sediment from clogging the aggregate. Geotextiles are also often used in infrastructure projects such as roads and highways, stone-lined stormwater channels, and beneath riprap to prevent soil erosion. For long-term underground applications like these, synthetic geotextiles may be the best option, as their service life when protected from UV exposure may be considerably longer than that of biodegradable alternatives.

- **Silt Fences**

A silt fence is a temporary sediment control product designed to prevent sediment from leaving the site through stormwater runoff. It is constructed of a woven plastic geotextile fabric stretched between supporting poles. Silt fences are commonly left in place throughout project construction, sometimes for several years. However, over time, the geotextile fabric may degrade and fray due to UV exposure and wear, creating a wildlife entanglement hazard and releasing plastic fibers into the environment. Heavy-duty silt fences feature plastic or metal mesh for added reinforcement in the event of a heavy sediment load; however, the reinforcement mesh can entangle wildlife and release plastic debris as it degrades. Plastic-free sediment control products (such as fiber rolls made from natural materials) are preferable alternatives if they meet the project’s technical requirements.

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[90] U.S. Environmental Protection Agency. (2021). “NPDES: Stormwater Best Management Practice—Geotextiles, Matting and Netting.” EPA-832-F-21-028T factsheet. (https://www.epa.gov/system/files/documents/2021-11/bmp-geotextiles-matting-and-netting.pdf).

[91] Aliotta, L., et al. (2022). “A Brief Review of Poly (Butylene Succinate) (PBS) and Its Main Copolymers: Synthesis, Blends, Composites, Biodegradability, and Applications.” Polymers, Vol. 14(4):844. (https://pmc.ncbi.nlm.nih.gov/articles/PMC8963078/).

A degraded geotextile silt fence in Eureka, California.
(Photo: Vanessa Metz, California Coastal Commission)

- **Plastic Sheeting**

Plastic sheeting (typically made of polyethylene) is a thin, waterproof material used for several short-term construction purposes, such as lining temporary concrete wash-out basins; providing emergency erosion protection for slopes and disturbed areas; or covering soil and material stockpiles during rain events. Plastic sheeting is suitable only for temporary emergency protection of slopes and stockpiles, as exposure to sun, wind, and general wear can cause the material to degrade and release plastic fragments into the environment. Additionally, runoff from plastic sheeting can contribute to erosion at the base of slopes and stockpiles. To minimize these impacts, plastic sheeting should be removed as soon as it is no longer needed, and non-plastic alternatives should be considered, whenever technically feasible.

- **Spray-on Soil Stabilizers and Tackifiers**

Soil stabilizers and tackifiers, known as hydraulic erosion control products, are spray-on chemicals used to promote adhesion among soil particles or mulch materials. These products can be derived from either natural materials or plastic. These plastic-based products are commonly made with acrylic polyacrylamide (PAM) and other synthetic polymeric emulsion blends. Natural soil stabilizers and tackifiers are often made from plant materials (such as guar gum, psyllium, natural resins, or corn starch) or from the mineral gypsum. Mulches used with tackifiers may also be natural (e.g., straw, coir, or bark) or synthetic, incorporating plastic fibers.[92]

Soil stabilizers and tackifiers are temporary erosion control measures used during construction or early plant growth for permanent vegetative soil stabilization. Soil stabilizers (also called soil binders) form a film upon drying that increases soil adhesion, reducing soil erosion by water and wind. Tackifiers are adhesive compounds that bind mulch materials together and anchor them to the soil surface. Tackifiers may be applied directly to the soil or used in hydraulic mulches (also known as hydro-mulches) along with cellulose and/or wood fiber mulch. In hydroseeding, tackifiers help keep the seeds in place, particularly on slopes.

In most cases, soil stabilizers must be routinely monitored and reapplied to maintain effective erosion control. If plastic-based soil stabilizers and tackifiers are used, over time the products will degrade and release plastic-coated soil and/or mulch to the environment. For this reason, natural soil stabilizers and tackifiers should be prioritized when selecting hydraulic erosion control products. Where technically feasible, plastic-free erosion control BMPs, such as vegetated stabilization, gravel mulch, biodegradable mulches by themselves, compost blankets, and temporary rolled erosion control products, are generally preferrable alternatives.

- **Sandbags and Gravel Bags**

Sandbags have several temporary uses during construction, such as creating berms and dikes for flood control or erosion protection; forming linear barriers to pond sheet-flow runoff and allow sedimentation; and securing plastic liners around the perimeter of concrete washout basins. Gravel bags, which are more permeable to water than sandbags, are usually placed on a level contour to intercept sheet-flow runoff and allow sedimentation.

[92] Minnesota Pollution Control Agency. (2023). "Erosion prevention practices – tackifiers and soil stabilizers" webpage. In Minnesota Stormwater Manual. (https://stormwater.pca.state.mn.us/index.php?title=Erosion_prevention_practices_-_tackifiers_and_soil_stabilizers).

Sandbags and gravel bags consist of fabric sacks filled with sand or gravel. The bags are typically made from either natural burlap or from plastic fabrics (e.g., woven polypropylene, polyethylene, or polyamide). However, burlap bags are not typically used during construction due to their limited durability. “Sandless sandbags,” made from a non-woven plastic fabric filled with an absorbent plastic polymer (usually sodium polyacrylate), expand when wet to block water flow, but can release plastic polymers if damaged and are generally not a preferred alternative.

Plastic fabric bags degrade with UV exposure and need to be replaced every two to three months. However, sandbags and gravel bags are often left in place longer, leading to deterioration and the release of plastic fibers into coastal waters by wind or runoff. Where technically feasible, non-plastic erosion and sediment control BMPs (such as natural-fiber fiber rolls) may be preferable. If non-plastic alternatives are not available or feasible, plastic pollution concerns can be addressed through frequent inspection and prompt replacement or removal of degraded or no-longer-needed bags.

3. Containment of Plastic During Construction, Demolition, and Maintenance Activities

- **<u>Containment of Plastic Debris</u>**

Construction and demolition activities involving plastic-containing building materials can generate significant amounts of plastic debris and microplastic pollution into the coastal environment. For example, building a deck with wood-plastic composite boards may produce several pounds of plastic-laden sawdust per 100 square feet of deck. Measures to contain and collect plastic and wood-plastic composite sawdust and debris, particularly during overwater construction, should be considered. The Commission also frequently requires operational Source Control BMPs, such as waste management and stockpile management BMPs, to prevent pollutants and debris (including plastics) from entering stormwater runoff and coastal waters during construction and demolition activities.

Also consider avoiding unnecessary use of plastics during maintenance activities for outdoor structures. For example, avoid using abrasive plastic microbeads as a blasting medium for removing paint from metal bridges. Containing and collecting plastic microbeads during sandblasting is difficult, particularly over water, making them a source of microplastic pollution. If technically feasible, opt for non-plastic sandblasting media to reduce environmental impact.

- **<u>Maintenance of Exterior Paints and Coatings</u>**

The removal of exterior paints and coatings during maintenance of coastal structures and vessels is another potential source of microplastic pollution. Most exterior paints are made from synthetic plastic polymers with various additives. Once dried, these paints can break into particles that represent a significant fraction of microplastics found in the ocean. Globally, paint particles are estimated to account for 10-17% of microplastic inputs to surface waters.[93] Major sources of paint microplastic pollution include deteriorating or disturbed coatings on boats and ships (including during boat hull paint maintenance), road markings, and the exterior surfaces of buildings. Maintenance of large coastal structures such as bridges may also contribute significantly to paint microplastic pollution locally.

Because effective non-plastic alternatives for paints, coatings, and road markings are often limited, it is important to prioritize the containment and proper disposal of paint chips and particles released during construction, maintenance, and demolition activities. Spill prevention procedures for liquid paint and coating products should also be implemented where feasible.

Examples of Past Commission Actions – Below are some examples of past Coastal Commission actions with requirements for plastic pollution prevention during the construction phase of projects:

- Special Condition 2 in CDP No. 6-20-0279 (Ocean Ranch Estates, Solana Beach). Required BMPs to prevent discharge of demolition debris, including plastic from greenhouses. Prohibited plastic netting in temporary erosion and sediment control products, including in heavy-duty silt fences.
- Special Condition 3(b) in CDP No. 1-20-0711 (Wastewater Treatment Facility Improvements, City of Arcata). Required containment of abrasive blast materials and loose coating materials from existing metal pipe crossings over slough during surface preparation for recoating.
- Special Condition 6 in CDP No. 6-22-0152 (Carlsbad Slope Stabilization, City of Carlsbad). Required that all stockpiles, demolition and construction materials, debris, and waste be covered during rain events and protected from stormwater runoff.

II. COMMON DEVELOPMENT CATEGORIES WITH PLASTIC POLLUTION CONCERNS

The sections below include discussion of the ways in which plastic may be used in several common development categories, why it contributes to the plastic pollution problem, and how the Commission has approached the matter in past actions.

[93] Turner, A. (2021). "Paint particles in the marine environment: An overlooked component of microplastics." Water Research X, Vol. 12:100110. (https://doi.org/10.1016/j.wroa.2021.100110).

A. Commercial and Industrial

1. Food Services

Restaurants often generate increased demand for food packaging, tableware, and other plastic-derived materials. These materials, especially single-use plastics and expanded polystyrene (commonly known as Styrofoam) can have adverse effects on marine wildlife if they enter the ocean, where fish, seabirds, sea turtles, and marine mammals can ingest or become entangled in plastic debris, causing suffocation, starvation, or drowning.

In addition to requiring specific measures to reduce single-use plastics through permit conditions, the Commission has also frequently encouraged restaurants to participate in the Surfrider Foundation's Ocean Friendly Restaurants (OFR) program, which provides widely adopted, proven criteria for eliminating expanded polystyrene, reducing single-use plastics, and requiring reusables. This voluntary certification program promotes implementing proper recycling practices, using reusable tableware for on-site dining, offering disposable utensils for takeout only upon request, prohibiting plastic bags, and providing straws made from naturally occurring materials (e.g., paper straws) or reusable straws upon request. Local jurisdictions can consider referencing OFR certification standards in LCP policies and Coastal Development Permit conditions.

Additionally, the Commission has required that trash enclosures and recycling receptacles be adequately provided, kept covered, and properly maintained.

Examples of Past Commission Actions – Below are some examples of past Coastal Commission requirements for restaurant projects:

- Special Condition 2 in CDP No. 5-20-0598 (McKinley Family Trust, San Clemente). Required the restaurant to participate in a marine debris reduction program to reduce waste and single-use plastic serviceware and packaging on-site and for takeout orders.
- Special Condition 8 in CDP No. A-5-VEN-15-0038 (Dunes Development LLC, Venice). Required BMPs to reduce pollutants in runoff from the restaurant by self-contained washdown areas, equipment, and accessories; equipping restaurant with a grease interceptor; and requiring connection to a sanitary sewer.

2. Hotels

Hotel developments often raise similar plastics pollution issues as restaurant projects, but they may introduce additional concerns related to laundry and housekeeping services. These activities can contribute plastic microfibers to sewer systems and the marine environment if not adequately filtered. Hotels with high occupancy and/or those that offer recreational amenities to non-guests can also be a significant source of harmful marine litter, including items such as cigarette butts.

To prevent plastic waste from entering the environment, the Commission has required hotels to implement smoke-free environments (including providing adequate signage) to reduce cigarette litter; install microplastic filters on laundry systems; provide recycling receptacles to capture as much litter as feasible; replace single-use plastic containers with reusable alternatives where feasible (such as for shampoos and soaps); and participate in regional programs that support and monitor the implementation of such measures.

Plastic reduction strategies for visitor-serving accommodations can include the Surfrider Foundation's Ocean Friendly Hotels (OFH) program, which certifies hotels and lodging facilities that eliminate single-use toiletry bottles, replace disposable cups and utensils with reusable options, and implement refillable systems for guest amenities. Water bottle refill stations can also be installed in public areas, to reduce the use of disposable plastic water bottles.

Examples of Past Commission Actions – Below are some examples of past Coastal Commission requirements for hotel projects:

- Special Condition 21 in CDP A-5-VEN-21-0011 (Wynkoop Properties LLC). Required the hotel restaurant to participate in a marine debris reduction program; required service plan (including signage) for recycling, trash bins, and compost; required installation of microfiber filtration system for all hotel laundry and catch basins or nets for larger debris at terminus of drainage outlets.
- Special Condition 15 in CDP A-6-ENC-22-0049 (Alila Marea, Encinitas). Required maintenance of a smoke-free environment to reduce cigarette litter, installation of recycling receptacles and a microfiber laundry filtration system, substitution of one-time use containers for reusable containers where feasible, and joining regional programs that implement and monitor such measures.
- Suggested Modification 7 in LCP-5-DPT-21-0079-2 (Dana Point Harbor Hotels). Required the hotel to minimize plastic consumption, waste, and litter through coordination of a marine debris reduction program, accomplished via membership in, or certification from, an established program.

3. Aquaculture

Aquaculture facilities have a history of contributing plastic pollution to the marine environment. Plastic is commonly used in the lines, nets, and bags used to grow oysters and other shellfish, and plastic zip-ties are often used to secure these bags in place along the lines. Storms, wave action, and other disturbances may cause this equipment to break apart, further contributing to plastic pollution in the marine environment.

The Commission has found that some level of plastic loss is inevitable from these developments and has therefore required regular cleanups from aquaculture producers as mitigation. Additional opportunities to reduce plastic pollution in aquaculture projects may include exploring alternative products for things like zip-ties that frequently are lost.

Examples of Past Commission Actions – Below are some examples of past Coastal Commission requirements for aquaculture projects:

- Special Conditions 5 & 10 in [CDP No. 9-18-0163](CDP No. 9-18-0163) (Carlsbad Aquafarms, Inc., San Diego Co.). Required benthic monitoring for marine debris, and Marine Debris Management Plan with annual inspections and cleanups.
- Special Condition 6 in [CDP No. 9-19-1242](CDP No. 9-19-1242) (Tomales Bay Oyster Company, Marin Co.). Required marine debris reduction and management practices (gear marking, training, clean up events, ongoing operations).

4. Plastic Manufacturing and Transportation

The manufacture of all forms of plastic requires the transportation and use of either plastic pellets or plastic powders, which are then melted and shaped into all the various forms of plastic products. Both the transportation and use of these pellets and powders present the potential for loss to the environment. In 2007, the California legislature passed AB 258, which requires that plastic pre-production pellets be included in the water quality standards that the State Water Resources Control Board and Regional Water Quality Control Boards monitor and enforce via National Pollutant Discharge Elimination System (NPDES) discharge permits. This law, enacted in 2009, targets, at a minimum, plastic manufacturing, handling, and transportation facilities, and requires the implementation of specified minimum BMPs for the control of discharges of pre-production plastic. As such, primary regulatory authority over discharge from these facilities falls to the Water Boards.[94]

There are standard BMPs for the plastics industry, detailed in an industry-led program known as Operation Clean Sweep, that plastic manufacturers should follow to ensure that plastic pellet loss is avoided.[95] The Water Boards are responsible for ensuring that these practices are put in place. However, Coastal Commission and local government staff should consult with staff at the appropriate Regional Water Board when addressing an application for a new or expanded plastic manufacturing, handling, or transportation facility to ensure that NPDES discharge permit requirements are being met and to determine if any additional conditions are needed to achieve Coastal Act or LCP consistency.

[94] See Coastal Act § 30412. (https://www.coastal.ca.gov/coastact.pdf).
[95] Plastics Industry Association. (2025). “Operation Clean Sweep” webpage. (https://opcleansweep.org/).

B. Public Works and Facilities

1. Municipal Wastewater Treatment Plants

There are two potentially significant issues with plastics associated with Municipal Wastewater Treatment Plants (MWTPs): 1) the presence of microplastics (predominately microfibers) in the liquid effluent released by the plants, and 2) microplastics in the sewage sludge (i.e., biosolids) removed by the plants, which can be applied as fertilizer to agricultural lands. The State Water Resources Control Board and the Regional Water Quality Control Boards (collectively "Water Boards") are responsible for direct permitting and inspection of MWTPs and for setting discharge requirements. Currently, effluent and sewage sludge are not tested for the presence of microplastics. Additionally, there is not yet a standard method for testing either effluent or sludge for microplastics. It is likely that most plastic materials larger than 5 mm are removed during the earliest stages of filtration, before reaching the sludge and well before the discharge of effluent water into receiving waterbodies; however, it's impossible to know how complete the process is without testing. The sewage sludge likely carries relatively heavy loads of microplastics given that the filtration process is designed to allow solid material to settle into the sludge before the effluent is released; again, though, it is impossible to know the amount without a testing protocol.

When addressing a CDP application for a MWTP, the appropriate Regional Water Board staff should be consulted to address any potential concerns about microplastic pollution resulting from the plant's operations. Applicants could seek to implement testing protocols for input wastewater, effluent, and sludge to establish the extent to which microplastics are removed during the filtration process. The permitting authority can also work with the applicant and Regional Water Board to develop a plan for appropriate placement of the treated sewage sludge, as sludge spread on agricultural land further from the coast and major rivers will likely discharge less microplastic to the ocean. However, it is important to remember that Coastal Act review of MWTPs and other treatment work projects is somewhat limited in scope, and that coordination with the Water Boards and consideration of any Water Board requirements is needed when reviewing CDP applications for treatment works.[96]

A policy could be included in new or updated LCPs regulating the application of biosolids to agricultural lands, to avoid this major source of microplastic pollution. Although the State and Regional Water Boards in California, along with the U.S. EPA, regulate the use of biosolids as a soil amendment, this does not preempt or supersede the authority of local agencies to prohibit,

[96] See Coastal Act § 30412(b), (c). (https://www.coastal.ca.gov/coastact.pdf).

restrict, or control the application of biosolids to lands within the local government's jurisdiction.[97]

2. Dredging

The Coastal Act allows for dredging of open coastal waters, wetlands, estuaries, and lakes when there is no feasible less environmentally damaging alternative and where feasible mitigation measures have been provided to minimize adverse environmental effects. Dredging is only allowable for specific types of projects described in Section 30233, and dredge spoils disposal must be planned and carried out to avoid significant disruption to marine and wildlife habitats and water circulation.

Dredged materials may contain plastic pollution, as only a portion of plastic is positively buoyant. In past actions, the Commission has considered how to reduce this plastic pollution through testing of dredged materials and further mitigation measures if the sources of these materials are believed to be heavily contaminated with plastic pollution, particularly if the materials are planned for beneficial reuse on shorelines and beaches or elsewhere in the Coastal Zone.

Examples of Past Commission Action – Below are examples of past Commission requirements for harbor maintenance dredging projects that required removal of plastic debris entrained in dredge spoils deposited on the beach:

- Special Condition 16 of CDP Amendment No. 1-05-039-A1 (Humboldt Bay Harbor, Recreation, and Conservation District). Required a plan for frequent beach cleanups of solid waste (mostly plastic) entrained in the dredged sediment and deposited on the beach.

  Special Condition 9 of CDP No. 4-16-0333-A1 and 4-18-0390-A1 (Ventura Port District and City of Ventura, Ventura Harbor and Ventura Keys Dredging). Required daily inspections and removal of unnatural debris deposited in the dredge spoils, such as plastic, to be conducted during all dredging and subsequent beach grading operations.

3. Roadways

Roadways and vehicles are estimated to be the largest source of microplastic pollution entering the marine environment from land.[98] There are three main sources of plastic pollution

[97] California State Water Resources Control Board. (2024). "Biosolids" webpage (updated Dec. 30, 2024). (https://www.waterboards.ca.gov/water_issues/programs/biosolids/).

[98] Mayer, P., et al. (2024). "Where the Rubber Meets the Road: Emerging Environmental Impacts of Tire Wear Particles and Their Chemical Cocktails." Science of The Total Environment, Vol. 927:171153. (https://doi.org/10.1016/j.scitotenv.2024.171153).

associated with roadways: tire wear particles, road wear particles, and litter. As tires wear during use due to abrasion from the roadway, they shed microplastic particles known as tire wear particles (TWPs), which are a major source of microplastic pollution in both terrestrial and aquatic ecosystems. Road wear particles (RWPs) are generated from the abrasion and weathering of road surfaces and road markings, which can both contain plastics. Finally, roadside plastic litter can be carried into the environment by wind and stormwater runoff, and the plastic and chemicals that leach from the plastic may adversely impact both aquatic and terrestrial life. Strategies for removing plastic pollution and plastic chemicals associated with roadways should be considered, where feasible.

C. Overwater and In-Water Structures

Overwater and in-water structures (such as docks, piers, wharves, bridges, bulkheads, and seawalls) often have several components made from plastic. Plastic-based components may include decking, railings, floats, piles, and sheet piles, as well as pile protection products (pile wraps, sleeves, coatings, and jackets), sealers for wood decking, paint for metal structures, and various accessory products (such as dock bumpers, rub-rails, hinge connections). Weathering, wave action, abrasion, and vessel impact damage may over time lead to plastic pieces breaking off from these components and entering coastal waters. Plastics can also be released into the water during installation and maintenance activities. Furthermore, rainwater, wash water, wave action, and immersion in the water may leach toxic chemicals from some plastic components directly into coastal waters.[99]

As such, non-plastic materials should be given the highest priority consideration for building overwater and in-water structures, whenever feasible. However, when building an overwater or in-water structure, it is important to ensure that the structure will be durable and have a long service life, because replacing such structures (particularly the framework and support components) can be difficult, costly, and disruptive to both the environment and the public. Due to their durability in aquatic environments, plastics may have advantages over other materials. Depending on a project's specific engineering requirements, plastics may therefore be acceptable choices for certain components of overwater and in-water structures.

Monitoring plans are an important consideration for all components of a proposed project's overwater or in-water structures that will be made from plastic-based products. Frequent inspection (e.g., quarterly) of all plastic-based products used to build these structures (including dock floats, decking, piles, pile encapsulation products, sealers, and sheet piles) during the life of the structure can help ensure that the plastic material maintains its structural integrity and identify repair or replacement needs due to damage or degradation. Plastic accessory products

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[99] Metz, V. (2019). "Use of Preservative-Treated Wood and Alternative Materials for Building Overwater and Waterfront Structures." Factsheet on the California Coastal Commission's Water Quality webpage for permit applicants. (https://www.coastal.ca.gov/water-quality/permits/).

(such as dock bumpers, rub-rails, and hinge connections) should also be inspected and replaced as needed to prevent the discharge of plastic debris to coastal waters.

Below are several components of overwater and in-water structures that may be made from plastics, and some potential plastic-free alternatives.

1. **Dock Floats**

Flotation devices for floating docks are commonly made of either expanded polystyrene (EPS) foam, or an air-filled high-density polyurethane (HDPE) shell. Both materials are types of plastic, but they are typically acceptable to use because of the lack of effective non-plastic alternatives. Foam-filled dock floats are generally more durable and stable than air-filled floats. However, exposed foam is vulnerable to impact damage and weathering, leading to plastic foam pieces breaking off and entering the water.

The Commission has required in past actions that EPS foam floats be fully encapsulated by a sturdy shell to protect the foam from degradation. Acceptable foam encapsulation materials may include concrete, galvanized steel, non-treated wood, HDPE, or other industrial-grade plastic coatings.[100] Non-plastic encapsulation materials for foam dock floats are generally preferred, if they meet the project's engineering requirements.

2. **Dock Decking**

Plastic-based decking products for docks, piers, and wharves may include wood-plastic composite boards (such as Trex brand), plastic boards, and plastic grid panels. Some plastic dock floats are designed with an anti-skid walking surface so they can be used directly as decking. Plastics commonly used in these products include Fiber-Reinforced Polymer (FRP), PVC, HDPE, and polypropylene. Plastic-based decking materials have been used as alternatives to preservative-treated wood decking in overwater structures, particularly in locations where coastal waters are impaired by toxic chemicals (such as copper) that leach from common wood preservatives.

However, to prevent plastic pollution, plastic-based decking materials for overwater structures are also preferably avoided unless there is a valid engineering reason to use plastic. For example, for a gangway that moves with the tides, lightweight decking material (such as plastic grid panels) may be needed. Preferable options for overwater decking materials may include naturally decay-resistant untreated wood (e.g., redwood, red cedar, ipe, greenheart, and Douglas fir), concrete, or aluminum.

[100] Oregon State Marine Board. "Boater Information: Foam Encapsulation" webpage (undated). (https://www.oregon.gov/osmb/boater-info/pages/foam-encapsulation.aspx).

3. Wood Decking Sealers and Metal Coatings

Plastic-based sealers, finishes, or coatings (typically polyurethane, epoxy, or polyurea) are often applied to wooden dock decking to help protect the wood from UV damage and decay. Semitransparent penetrating stains (such as polyurethane) have also been shown to reduce leaching and surface dislodgement of toxic chemicals from preservative-treated decking wood into the water below, for up to three years.[101] However, plastic-based sealers wear off over time due to abrasion and weathering, releasing microplastics into the water. The sealer also needs to be periodically reapplied (typically annually), which often entails pressure-washing, sanding, scraping, or using chemicals to remove the old finish. These maintenance activities release additional microplastics from the sealer into the water. Selecting naturally decay-resistant untreated wood or materials such as concrete or aluminum can help avoid the need for wood sealers. If there is a valid reason for requiring a sealer or finish on overwater wood decking, an inert, non-toxic, and water-based marine-grade sealer is typically preferred.

Metal overwater structures such as bridges are typically protected by a plastic-based paint or coating to protect the metal from corrosion. During periodic repainting of the metal, surface preparation for recoating (such as by sandblasting or water jetting) dislodges paint chips and microplastic paint particles. In past actions, the Commission has required that overwater sandblasting debris be contained and collected to prevent the discharge of this plastic pollution into coastal waters.

4. Piles

In past actions, the Commission has discouraged or prohibited the installation of preservative-treated wood piles in coastal waters (including wetlands), unless there is a valid engineering reason to use treated wood (such as replacing a few piles in an existing treated wood piling structure). Preferred alternatives to preservative-treated wood piles have included reinforced concrete, steel, naturally decay-resistant untreated wood (such as Greenheart), or fiber-reinforced polymer (FRP). FRP piles (also called fiberglass composite piles) have a matrix composed of plastic resin (usually polyester, epoxy, or vinyl ester) that is reinforced with fiberglass.

FRP piles have some advantages over some non-plastic piles, such as resistance to corrosion, UV, marine borers, and decay and not leaching wood-preservative chemicals. Because FRP piles typically last at least 20 years and support piles for overwater structures may be difficult to replace, the use of FRP piles may be acceptable if they are determined to be the most effective and least environmentally damaging pile material that meets the project's engineering requirements. However, over time FPR piles can become weathered or damaged, resulting in

[101] Nejad, M., & Cooper, P.A. (2010). "Coatings to Reduce Wood Preservative Leaching." Environmental Science & Technology, Vol. 44(16):6162–6166. (https://doi.org/10.1021/es101138v).

plastic pieces breaking off into the water; thus, non-plastic-based piles may be preferred whenever feasible.

5. Pile Encapsulation Products

Plastic-based pile encapsulation products (i.e., pile wrap, sleeve, or sealant coating) are often applied to wood, concrete, or steel piles to protect against corrosive saltwater and weathering, and to protect wood piles from decay, insects, and marine borers. Plastic pile wraps or sleeves may also be applied to piles to protect from vessel impacts and abrasion. FRP pile jackets may also be installed to repair and reinforce existing wood, concrete, or steel piles that have been structurally damaged. Such plastic pile wraps or coatings typically extend from below the mud line to above the high-water mark. Because pile encapsulation products can significantly extend the service life of piles that are difficult to replace, this may be an acceptable use of plastic in aquatic environments

A steel dock pile with degraded vinyl pile wrap, in Santa Cruz Harbor, California. (Photo: Michael Sandecki)

Pile encapsulation products, and any associated grouts or fillers, should be composed of materials that are inert after they have cured to avoid leaching toxic chemicals into the water. Recommended materials for pile wraps, sleeves, sealant coatings, and jackets may include industrial-grade HDPE, FRP, PVC, fusion-bonded epoxy, and polyurea (also known as polyurethane)—all of which are plastics. Other best practices for pile encapsulation products include application prior to installation of the pile (unless an existing pile is being rehabilitated in place), measures to ensure full containment of the plastic for in-water installations, and installation of protective design features (such as bumpers) on fender piles and floating dock piles to reduce abrasion and protect the pile wrap or coating from vessel damage.

6. Sheet Piles

Waterfront bulkheads and seawalls are often constructed of sheet piles, which are interlocking vertical panels driven into the ground to create a continuous retaining wall for soil or water. Plastic-based sheet piles made of FRP composite or PVC plastic (a.k.a. vinyl) are widely used in waterfront applications. Sheet piles can also be made of steel, reinforced concrete, or wood (typically preservative-treated wood); however, use of preservative-treated wood for sheet piles should be minimized to avoid leaching toxic preservative chemicals into the water. Interlocking vinyl sheet piles can also be installed as a form in which reinforced concrete is poured in place to create a seawall. A sealant (such as polyurethane plastic) is usually required to seal sheet pile interlocks, although steel sheet pile interlocks can be welded.

To prevent plastic pollution, non-plastic alternatives to plastic-based sheet piles should generally be selected for use in or adjacent to coastal waters, whenever feasible. As with plastic-based dock piles, non-plastic alternatives are typically preferred but plastic-based sheet piles may provide advantages over some non-plastic materials, such as not leaching wood-preservative chemicals, and resistance to corrosion, decay, and marine borers. Plastic sheet piles may be acceptable if they are determined to be the most effective and least environmentally damaging material that meets the project's engineering requirements.

Examples of Past Commission Actions – Below are some examples of past Commission requirements for overwater and in-water structures:

- Special Conditions 1 & 4 (modified in addendum) in CDP No. 6-24-037 (Seaforth Marina Dock Replacement, San Diego). Project modified to use ipe wood dock decking instead of wood-plastic composite; prohibited use of wood sealer on decking; addressed plastic dock decking materials and installation BMPs. Required quarterly inspections of HDPE-encapsulated foam dock floats.
- Special Conditions 10 & 11 in CDP No. 5-19-0971 (Dana Point Harbor Docks Replacement, Dana Point). Required construction-phase debris and trash control, including floating booms to contain in-water debris; and required monitoring and maintenance of plastic sleeves on steel piles.
- Special Condition 2 in CDP No. 6-21-0106 (CHSP Mission Bay, LLC, San Diego). Requires monitoring and maintenance of FRP pile jackets installed on concrete piles. Requires that

any paint, coating, wrapping, pile jacket, sealant, adhesive, caulk, or other product be inert when cured, and applied in a manner to prevent leaks and spills.

- Special Conditions 1 & 2 in CDP No. 5-20-0265 (Westchester Bay Homeowners and Seagate Lagoons Associations, Huntington Beach). Bulkhead repair including installation of vinyl sheet piles. Required new or amended CDP if new information becomes available that plastic has harmful effects on the marine environment, and that environmentally superior, feasible alternative(s) are available. Required bulkhead monitoring plan.

D. Long-Term Erosion Protection Products for Slopes, Streambanks, and Coastlines

Several manufactured products that contain plastic are commonly used for long-term erosion protection for slopes, streambanks, coastlines, shorelines, swales, channels, and in-water structures. These products include long-term turf reinforcement mats, geocells (also known as cellular confinement systems), mesh rock bags, and vinyl sheet piles (discussed in the overwater and in-water structures section, above). Long-term erosion protection products made from plastic-free materials should generally be selected, if technically feasible.

Where technically feasible, natural infrastructure, such as building oyster reefs and planting eelgrass beds, and restoring dunes or wetlands are preferable options for shoreline and coastline erosion protection. However, several materials used to create living shorelines may also contain plastic, such as plastic mesh in oyster shell bags used as a substrate to create an oyster reef, and plastic geotextile filter cloth used under oyster shell bags to prevent the oyster shells from subsiding.

Below are several types of manufactured products used for long-term erosion protection that are commonly plastic-based, and some plastic-free potential alternatives.

1. Turf Reinforcement Mats

Turf reinforcement mats (TRMs) are made from synthetic plastic fibers and netting (typically polypropylene) and/or wire mesh that form a three-dimensional matrix with void spaces through which grass or other plants can grow. These non-biodegradable mats are designed to provide long-term protection from erosion to support vegetation on steep slopes, and as armoring for vegetated swales and channels. TRMs are also commonly used in the construction of permanent stormwater management BMPs such as infiltration areas, vegetated swales, sedimentation basins, detention ponds, and vegetated buffer strips.

TRMs are typically used where conditions exceed the capabilities of erosion control blankets but are not severe enough to justify retaining walls on slopes or harder armoring (e.g., articulated concrete blocks or rock riprap) in swales and channels.[102] TRMs are typically buried, and the soil and vegetation help protect the plastic from UV-degradation. Therefore, the lifespan of TRMs typically exceeds 5 years, and some high-performance mats are designed to last for decades in a suitable environment when properly maintained. However, TRMs under soil and grass are not readily visible for inspection, and they are typically not replaced when the plastic eventually degrades, as replacing the mat would damage the vegetation that grows through it. Therefore, non-plastic erosion control materials (such as erosion control blankets, rock riprap, or articulated concrete blocks) may be preferable alternatives to TRMs if they can meet the technical requirements of the project.

2. Geocells (Cellular Confinement Systems)

Geocells (also known as cellular confinement systems) consist of a three-dimensional structure made from synthetic geotextile material formed into honeycomb-like cells that can be filled with soil and vegetation, sand, gravel, or rock. Geocells are used to stabilize soil and control erosion on steep slopes, streambanks, and in channels. They are also used for structural reinforcement to support loads, such as under roads, grass parking lots, driveways, and trails. Because geocells are filled with soil, grass, or other materials, and sometimes covered by a layer of rock, asphalt, or concrete, they are difficult to inspect and to replace when the plastic geotextile material eventually degrades. Therefore, non-plastic materials may be preferable alternatives if they can meet the technical requirements of the project.

3. Rock Bags and Concrete-Filled Bags

Rock bags typically consist of flexible plastic mesh bags filled with rocks. Concrete-filled bags (also known as grout bags) are a similar product, typically consisting of bags made of a woven plastic geotextile with concrete, grout, or sand filling. Rock bags or concrete-filled bags are usually installed in a series to provide long-term protection from erosion and scour on coastlines, riverbanks, and around in-water structures. These bags can be submerged in marine waters or freshwater, installed on the ground surface, or buried under soil and vegetation. Example uses of rock bags or concrete-filled bags include erosion prevention for beaches, stabilizing riverbanks, protecting bridges and culverts from scour damage, stabilizing road embankments, and protecting marine cables and underwater pipelines. These bags can also be used temporarily during construction, such as to create a coffer dam.

The plastic mesh in rock bags is typically made from HDPE or polyester with UV-stabilizers. Manufacturers claim a lifespan of up to 35 years, or up to 50 years when covered either by water or by soil and vegetation. Although durable, the plastic mesh is susceptible to mechanical damage, and eventually the plastic will degrade, releasing plastic fragments into the

[102] Minnesota Pollution Control Agency. (2023). "Erosion prevention practices – turf reinforcement mats" webpage. In Minnesota Stormwater Manual. (https://stormwater.pca.state.mn.us/index.php?title=Erosion_prevention_practices_-_turf_reinforcement_mats).

environment. The mesh also has the potential for wildlife entanglement in the typical 1” to 2” mesh openings. Woven plastic geotextile fabric (usually polypropylene or polyester) is typically used to make the bags for concrete-filled bags.

Plastic-free materials may be preferable alternatives for these bags if they can meet the technical requirements of the project. Potential plastic-free alternatives include gabion sacks or baskets made from steel wire mesh that is filled with rock; however, the optional PVC plastic coating on the wire mesh is likely to be quickly abraded and release plastic debris. The mesh openings on gabion sacks and baskets are also much larger than on rock bags, and thus less likely to entangle wildlife. Natural burlap (jute) bags are an alternative to plastic geotextile fabric for concrete-filled bags.

Another alternative is using Fabric-Formed Concrete (i.e., Concrete Grout Bags) in which a fabric formwork made of woven plastic geotextile fabric (usually polyethylene or polypropylene) is used to cast-in-place large concrete armor units. After the concrete has cured, the plastic geotextile fabric framework can be removed.[103]

Rock riprap (without bags) and articulated concrete blocks are other potential options to armor, stabilize, and protect areas subject to waves and high-velocity water flows from erosion and scour. However, articulated concrete blocks are connected by a plastic grid, and both rock riprap and articulated concrete blocks are typically placed over plastic geotextile fabric to prevent erosional undercutting. Steel sheet piles are another potential plastic-free product for shoreline protection.

4. Oyster Reefs as Natural Infrastructure

Oyster reefs are a type of natural infrastructure that provide long-term erosion protection as well as providing a substrate for the attachment of native oysters. Plastic mesh bags containing oyster shells are commonly used to build an oyster reef. However, examples of alternative non-plastic oyster shell bag materials include, but are not limited to, cellulose-based materials made from beechwood, potatoes, or sugarcane (often referred to by the trade name of "BESE"), galvanized wire mesh, wire mesh gabion baskets, cement-coated jute, and basalt-fiber-based bags. There are also several types of plastic-free manufactured structures made from concrete and/or native materials (such as limestone, oyster shells, and sand) that provide a substrate for oyster attachment in living shorelines.[104] Examples include oyster domes (such as “Reef Balls”), interlocking concrete blocks (such as “Oyster Castles”), table and pillow structures made from

[103] GeoSolutions, Inc. (2024). “Fabric Formed Concrete, Ultimate Guide” webpage article (Jan. 26, 2024). (https://www.geosolutionsinc.com/blog/fabric-formed-concrete-ultimate-guide).

[104] Stephens, A. (2023). “Alternative Material Options: Erosion Control and Living Shorelines in South Carolina.” Coastal Conservation League, Charleston, SC. (https://www.coastalconservationleague.org/wp-content/uploads/2023/07/Living-Shorelines-Alternative-Materials_2.pdf).

cement-infused plant-based fabrics (such as “Oyster Catcher”), or blocks made from limestone and oyster shells (such as “Quick Reef”).[105]

Examples of Past Commission Actions – Below are some examples of past Coastal Commission actions with requirements for long-term erosion protection for slopes, streambanks, and coastlines:

- CDP Amendment 3-19-0020-A1. (San Simeon Community Services District Wastewater Treatment Plant ocean outfall pipeline, San Simeon). Installation of a concrete mattress at the end of the pipeline (to keep it affixed in place on the ocean bottom), and placement of multiple concrete-filled burlap sacks along the ocean bottom under free spanning sections of the pipeline (to ensure stability). The Commission required the use of burlap sacks instead of the proposed woven plastic geotextile sacks for the concrete-filled sacks.
- Special Condition 3.S in CDP No. 1-03-004-A3 (Mad River Slough Levee Repair, Arcata). Amendment for repair of levee using a combination of a steel sheet pile wall and rock slope protection.
- Special Condition 11 in CDP No. 1-11-007 (Union Pacific Railroad Company Remediation Plan, Eureka). After removing contaminated soil, project will install upland soil stabilization structures including a “marine mattress” composed of a rock-filled geogrid container, and a row of steel mesh gabion baskets buried just below final grade.
- Port of San Diego Port Master Plan Amendment No. PMP-6-PSD-20-0001-1 (Pilot Native Oyster Living Shoreline, Chula Vista). Living shoreline pilot project consists of placing oyster “reef balls” made from concrete mixed with local sand and shell aggregate, to study ability of reef balls to protect shoreline from erosion, while providing habitat for native oysters.

E. Recreation and Special Events

1. Marina Facilities for Recreational Boating and Fishing

While Coastal Act Sections 30224 and 30234 encourage increased recreational boating and commercial fishing on the California coast, these activities may result in the discharge of plastic pollution into the marine environment.[106] For example, certain topside and hull boat cleaning and coating practices may result in the discharge of debris including plastic particles; the practice of shrink-wrapping boats in plastic film for winter storage on land may create plastic waste; and solid waste such as trash and fish wastes (which may also include plastic fishing line and paraphernalia) may reach coastal waters if not properly disposed.

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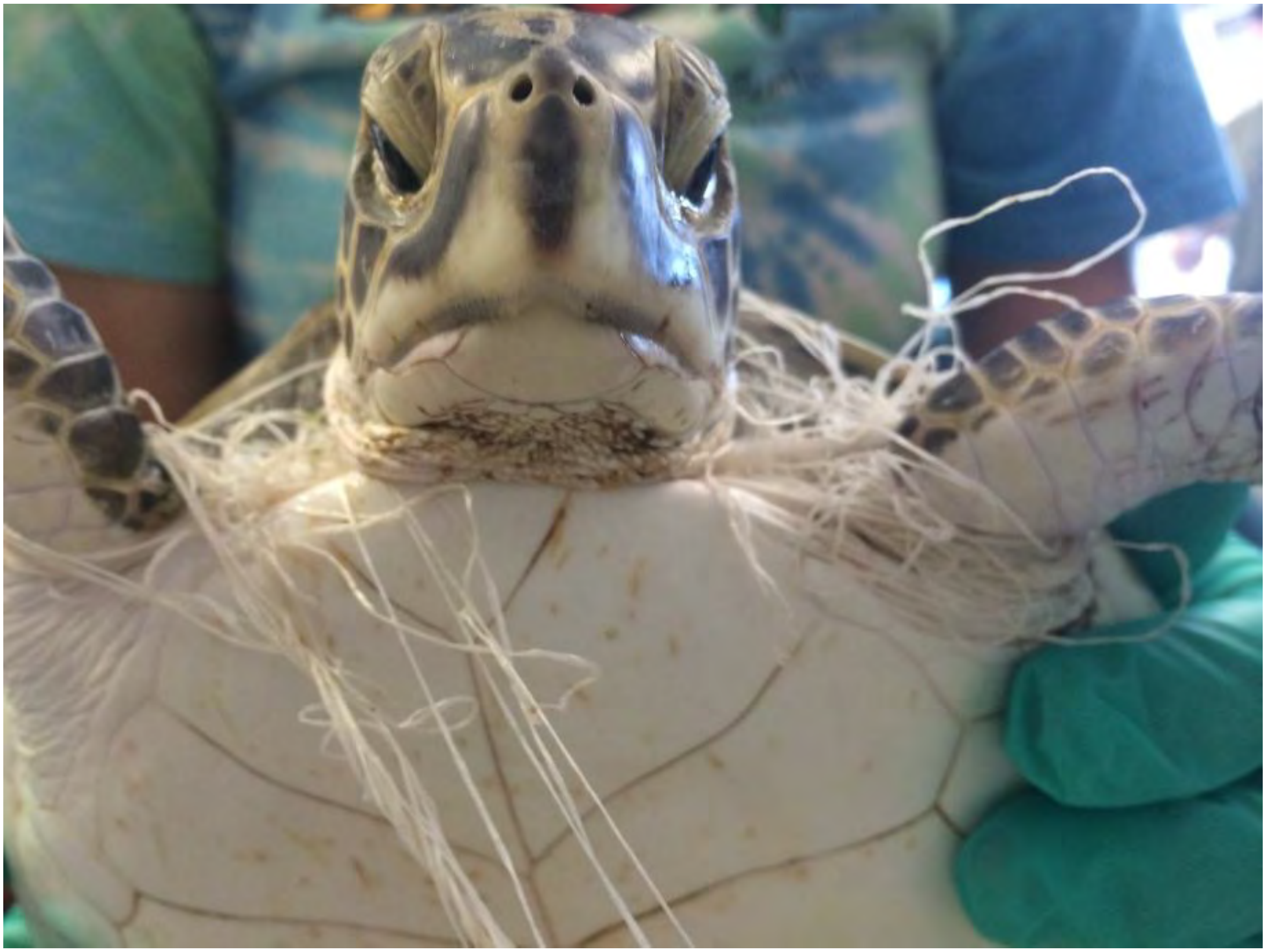
[105] Chesapeake Bay Foundation. “Incorporating Oysters into Living Shorelines.” (Undated factsheet). (https://www.cbf.org/document-library/cbf-guides-fact-sheets/incorporating-oysters-into-living-shorelines.pdf).

[106] See the California Coastal Commission’s Marinas and Recreational Boating webpage for additional information on pollution prevention in recreational boating. (https://www.coastal.ca.gov/water-quality/marina-boating/).



Plastic fishing line and fishing nets can entangle sea turtles and other marine life. (Photo: SeaTurtle, Inc.)

Maintenance of boat hull anti-fouling paint discharges significant quantities of toxic paint particles, which consist of a plastic resin and a variety of additives.[107] Paint particles, classified as microplastics, are discharged directly into the ocean during in-water hull cleaning, or transported into the aquatic environment as airborne particulates or in runoff. If in-water boat hull cleaning is allowed, marinas should employ in-water debris containment devices to prevent the discharge of paint particles. If boat hull maintenance is performed in dry dock, boatyards

107 Turner, A. (2021). "Paint particles in the marine environment: An overlooked component of microplastics." Water Research X, Vol. 12:100110. (https://pmc.ncbi.nlm.nih.gov/articles/PMC8350503/pdf/main.pdf).

could employ effective dust extraction and waste collection systems to capture and properly dispose of paint particles.

The Commission has found in past actions that comprehensive water quality management and boat owner maintenance plans often ensure that recreational boating and fishing associated with development projects (such as in marinas or harbors) can help prevent adverse water quality impacts. Certain measures that the Commission has often required are boat cleaning and maintenance practices, management of solid and liquid waste (including providing fishing line recycling containers), and control of waste discharges and spills, including with controlled bilge pump-out facilities.

Examples of Past Commission Actions – Below are some examples of past Coastal Commission requirements for recreational marina and pier projects that minimize plastic pollution:

- Special Condition 2 in CDP No. 5-21-0681 (Costa Del Sol Marina, Long Beach). Required removal of boats from the water for proper cleaning and disposal of debris; no in-water boat scraping that results in removal of paint/coating from boat hulls; proper disposal of contaminated bilge water and sewage waste; and conspicuous signage near the dock platform that includes a list of water quality and boat maintenance measures.
- Special Conditions 5, 7, & 8 in CDP No. 5-22-0804 (Huntington Beach Pier). Required a bait shop management plan, including fishing line recycling receptacles, and enrollment in Surfrider's Ocean Friendly Restaurant Program (or other acceptable marine debris reduction program) to reduce waste and single-use plastics.
- Special Conditions 15 & 27 in CDP No. 5-19-0971 (Dana Point Harbor). Required proper boat cleaning, coating, and maintenance measures; proper disposal of contaminated bilge water and sewage waste; educational materials for public and boatowners; and required Harbor to be smoke-free and submit a service plan for recycling, trash bins, and compost.

2. Playground Surfacing

Playground surfacing for new or redeveloped public and school playgrounds must comply with government standards for fall safety (i.e., impact attenuation), as well as the wheelchair accessibility regulations of the Americans with Disabilities Act (ADA). There are a variety of playground surfacing options available that meet these requirements, several of which are made from plastics.

Poured-in-Place (PIP) "rubber" playground surfacing is often a popular choice as it requires less frequent maintenance than many other playground surfacing options. However, PIP "rubber" products are not made from natural rubber, but from plastics, and are often not clearly identified as such. PIP "rubber" playgrounds consist of two layers: shredded recycled tires in the base cushioning layer and synthetic rubber granules (typically called rubber, recycled rubber, or virgin rubber) in the top wear layer. The materials in each layer are held together by a polyurethane (plastic) binder.

The materials used to make PIP "rubber" playgrounds contain numerous chemicals and compounds that are known to be hazardous to the environment and human health. Hazardous chemicals in tires include heavy metals (e.g., lead, zinc, mercury, and arsenic), polyaromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), 6-phenylenediamine (6PPD), phthalates, organophosphate esters (OPEs), and per- and poly-fluoroalkyl substances (PFAS), among many others. Many studies have documented that these hazardous chemicals can leach into water and soil, off-gas, and be transported via dust and particles into the environment, causing toxicity in a wide range of aquatic and terrestrial organisms.[108]

Most chemical additives in tires are not strongly bound to the synthetic rubber polymer, which allows these chemicals to be continuously released into the environment during use of the tire, as well as during use of a playground made from shredded tires. For example, the chemical 6PPD is designed to continuously migrate to the tire's surface, where it functions to protect the tire from degradation from ozone. However, the side effect is that this toxic chemical continuously leaches into the environment.[109]

The synthetic rubber granules in the top wear layer of PIP synthetic rubber playgrounds contain many of the same hazardous chemicals, although the chemical concentrations may potentially be lower than in shredded tires.[110] Furthermore, some PIP playground surfacing products use shreds of synthetic rubber (such as EPDM) instead of shredded tires for the cushioning layer of the playground. However, a 2016 federal government report found that research supporting the safety of EPDM and other synthetic rubbers for recreational surfaces was lacking or limited.[111]

Another issue of concern with PIP synthetic rubber playgrounds is that the synthetic rubber granules (classified as microplastics) in the top layer of the playground are continuously dislodged from the playground's surface and discharged into the environment in large numbers. One study documented on average over a million synthetic rubber granules released per

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[108] Mayer, P., et al. (2024). "Where the Rubber Meets the Road: Emerging Environmental Impacts of Tire Wear Particles and Their Chemical Cocktails." (See full citation above).

[109] Massey, R., & Tian, Z. (2023). "6PPD in Tires: A Concern for Playgrounds, Artificial Turf, and More." Collaborative for Health and Environment. (https://www.healthandenvironment.org/join-us/blog/6ppd-in-tires-a-concern-for-playgrounds-artificial-turf-and-more).

[110] Pollard, L., & Massey, R. (2023). "Playground Surfacing: Choosing Safer Materials for Children's Health and the Environment." Lowell Center for Sustainable Production and Toxics Use Reduction Institute, University of Massachusetts Lowell. (https://www.uml.edu/docs/Playground_surfacing_report_Dec2023_tcm18-377890.pdf).

[111] U.S. Environmental Protection Agency, Centers for Disease Control and Prevention, & U.S. Consumer Product Safety Commission. (2016). "Status Report: Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds." (https://www.epa.gov/chemical-research/december-2016-status-report-federal-research-action-plan-recycled-tire-crumb).

playground.[112] For playgrounds near the beach, sand that blows onto the playground can abrade the surfacing materials and increase the release of synthetic rubber granules. Tire shreds (also microplastics) may also be dislodged from the cushioning layer as the playground's surface layer ages and deteriorates. These synthetic rubber granules and tire shreds are transported by wind, stormwater runoff, maintenance sweeping, power-washing, and playground users' shoes and clothing into the environment, where they contribute to microplastic pollution of soil, waterways, and the ocean. UV, ozone, heat, and foot traffic degrade the polyurethane binder in PIP "rubber" playgrounds over time, increasing the dislodgement of synthetic rubber granules and necessitating periodic recoating of the playground surface.

Poured-in-Place rubber playground with deteriorated top green wear layer of synthetic rubber granules exposing the base cushioning layer of shredded waste tires. (Photo: University of Massachusetts, Lowell Center for Sustainable Production)

Other playground surfacing products derived from recycled tires or other synthetic rubbers, such as synthetic rubber mulch, bonded synthetic rubber mulch (i.e., tire shreds or chunks held together with a resin binder), pads or mats made from granulated tires ("crumb rubber") held together with a resin binder, and synthetic grass (i.e., artificial turf) raise similar plastic pollution concerns to PIP "rubber" surfacing. Because of these significant environmental concerns, the Coastal Commission has in recent years sought to avoid the use of playground surfacing materials made from recycled tires and other synthetic rubbers in coastal development projects.

Several alternative playground surfacing options are available that do not contain synthetic rubber (including recycled tires) and do not shed large amounts of microplastics, but that meet

[112] Reef Clean. (2021). "Rubber Crumb Loss Assessment from Play Areas in the Great Barrier Reef Catchment." https://www.tangaroablue.org/wpfd_file/reefclean-ausmap-rubber-crumb-loss-report-2021/.

government requirements for fall safety and wheelchair accessibility.[113] Playground materials made from natural materials include natural cork PIP surfacing (bonded with a polyurethane binder), engineered wood fiber (EWF), and stabilized EWF (bonded with adhesive). In addition, there are several loose-fill natural surfacing materials for playgrounds (such as sand, pea gravel, and wood chips) that meet fall safety standards. Although loose-fill materials do not meet playground wheelchair-accessibility requirements by themselves, accessible pathways to playground equipment can be created by adding roll-out access mats, pads, or interlocking tiles on top of loose-fill materials. Scuff mats or pads can also be placed in high-use areas, such as under swings and slides, to prevent displacement of loose-fill materials. These mats, pads, and tiles are typically made from plastics (such as polyester or PVC); alternatives made of synthetic rubber materials (such as tire crumb rubber) should generally be avoided.

Playground surfacing products made from non-granular plastic materials that are unlikely to shed plastic pieces, and that have documented low aquatic toxicity, may be acceptable if natural surfacing materials are not feasible.[114] Acceptable options may include roll-out beach access mats made of polyester fibers to provide wheelchair accessible pathways in playgrounds; however, these do not provide fall safety protection. Injection-molded PVC interlocking perforated tiles are also acceptable for playground surfacing and can integrate with loose-fill surfacing materials to provide wheelchair-accessible pathways through a playground. These tiles can also be used as scuff mats to prevent displacement of EWF or loose-fill surfacing materials under high-use playground equipment, if installed with a cushioning layer underneath for fall safety. When used on top of a cushioning layer, these tiles can also be used to surface an entire playground. However, it's important to avoid cushioning layers made of shredded tires; non-toxic foam shock pads are a preferred alternative, such as cross-linked polyethylene foam (XPE).

Examples of Past Commission Actions – Below are some examples of past Coastal Commission requirements for playground surfacing projects that minimize plastic pollution:

- Special Conditions 1-4 & Exhibit 8 in CDP No. 5-23-0345 (Newport Mesa Unified School District Playground Replacement, Newport Beach). Prohibited the proposed PIP rubber playground surfacing; applicant changed proposal to PVC tiles with XPE foam padding. Exhibit 8 is a technical memo by Coastal Commission Water Quality staff on the adverse environmental effects of PIP rubber playground surfacing, and recommendations for alternative materials.

[113] Pollard, L., & Massey, R. (2023). "Playground Surfacing: Choosing Safer Materials." (See full citation above).

[114] Metz, V. (2024). "Potential adverse environmental effects of proposed Poured-in-Place rubber playground surfacing product and recommendations for alternative materials." Memo to California Coastal Commission and Interested Parties. June 27, 2024. Exhibit No. 8 in staff report for CDP No. 5-23-0345 (Newport Mesa Unified School District). (https://documents.coastal.ca.gov/reports/2024/7/Th15b/Th15b-7-2024-exhibits.pdf).

- Special Condition 1 in CDP No. 6-23-0627 (De Anza Cove South Comfort Station Playground Renovation, City of San Diego). The City agreed to change the proposed PIP rubber playground surfacing to PVC tiles with an XPE foam shock pad.
- Special Conditions 9-12 in CDP No. 1-22-0509 (Crescent City Beachfront Park Improvements, City of Crescent City). Prohibited the use of playground surfacing materials made from waste tires and synthetic rubber granules. Required final revised playground plans including acceptable alternative materials as indicated. Required frequent inspection and maintenance of any synthetic playground surfacing materials.
- Findings of Approval III.A in Ventura County Channel Islands Harbor Public Works Plan Notice of Impending Development No. CIH-NOID-0001-24 (Harbor View Park, Oxnard). Following coordination with Commission staff, the Harbor Department proposed low-toxicity ADA-compliant playground surfacing materials (i.e., cork PIP surfacing, and PVC tiles with XPE foam shock pad).
- Policy 6.30 in City of San Diego LCP Amendment No. LCP-6-NOC-23-0015-1 (Mira Mesa Community Plan Update). Added a new LUP policy that prohibits synthetic rubber surfacing products made from waste vehicle tires and/or other types of synthetic rubber in the construction of improvements to playgrounds, schools, and public pathways and trails.
- Policy 18 in City of San Diego LCP Amendment No. LCP-6-OMN-23-0053-4 (Otay Mesa-Nestor Community Plan Update). Added a new LUP policy that prohibits synthetic rubber surfacing products made from waste vehicle tires and/or other types of synthetic rubber in the construction of improvements to playgrounds, schools, and public pathways and trails.

3. Artificial Turf Playing Fields

An artificial turf (also known as synthetic grass) playing field typically consists of several plastic-based components: synthetic fiber blades, a backing fabric, a shock pad, and an infill material that holds the blades upright. Traditionally, ground-up recycled tires – known as "crumb rubber" and classified as microplastics- have been used as the infill material. A large amount of crumb rubber particles continuously migrates out of the infill, requiring regular replenishment. For a standard athletic field, an estimated 3-5 tons of crumb rubber must be added annually to compensate for the loss.[115] Plastic fibers from artificial grass blades (commonly made of polyethylene or polypropylene) also break off continuously in large quantities. It is estimated that 5-10 percent of the plastic blades are broken off and released annually, thereby limiting the service life of an artificial turf field to approximately 10-12 years.[116] Research has shown that up to 300 million plastic fibers from artificial turf blades can be lost from a single full-size soccer field each year. A study in Spain found a significant number of plastic fibers from artificial turf

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[115] Lassen, C., et al. (2015). "Microplastics: Occurrence, effects and sources of releases to the environment in Denmark." Danish Environmental Protection Agency. (https://backend.orbit.dtu.dk/ws/portalfiles/portal/118180844/Lassen_et_al._2015.pdf).

[116] de Haan, W.P., et al. (2023). "The dark side of artificial greening: Plastic turfs as widespread pollutants of aquatic environments." Environmental Pollution, Vol. 334:122094. (https://doi.org/10.1016/j.envpol.2023.122094).

blades in river and ocean waters — constituting over 15% of the floating macroplastics found in surveys — and concluded that artificial turf is a major source of plastic pollution in the aquatic environment.[117]

Stormwater BMPs designed to trap discharged microplastics from artificial turf fields have not been shown to be reliably effective. Furthermore, it's estimated that only 16% of plastic blade fibers released from artificial turf enter the stormwater drainage system; the majority are transported off the field by wind, surface runoff, and players' clothing.[118]

Crumb rubber infill has been well-documented to leach numerous toxic chemicals hazardous to both aquatic and terrestrial life. These include heavy metals (e.g., lead, zinc, mercury, and arsenic), volatile organic compounds (VOCs), polyaromatic hydrocarbons (PAHs), phthalates, 6PPD-quinone (shown to kill Coho salmon), among other chemicals.[119,120] The artificial grass blades also pose toxicity concerns, most notably due to toxic per- and polyfluoroalkyl substances (PFAS), known as "forever chemicals."[121] Chemicals in disinfectants and cleaners applied to artificial turf may also pose toxicity concerns.

Artificial turf fields also raise other environmental concerns compared to natural grass. One major issue is the urban heat island effect: artificial turf is 35-60° F hotter than natural grass, as the plastic materials absorb more radiation.[122] Additionally, replacing natural grass with synthetic turf eliminates vegetation that would otherwise remove carbon dioxide through photosynthesis, sequester carbon, and produce oxygen. Other adverse impacts of artificial turf include habitat loss for insects, birds, and soil biota; compromised soil structure and function under the field due to compaction and loss of organic matter; reduced stormwater infiltration and evaporation; and the eventual disposal of large quantities of plastic waste in landfills at the end of the artificial turf's approximately 10-year product life.[123]

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[117] Ibid.

[118] Ibid.

[119] Halsband, C., et al. (2020). "Car Tire Crumb Rubber: Does Leaching Produce a Toxic Chemical Cocktail in Coastal Marine Systems?" Frontiers in Environmental Science, Sec. Biogeochemical Dynamics, Vol. 8. (https://www.frontiersin.org/articles/10.3389/fenvs.2020.00125/full).

[120] Mayer, P., et al. (2024). "Where the Rubber Meets the Road: Emerging Environmental Impacts of Tire Wear Particles and Their Chemical Cocktails." (See full citation above).

[121] Pollard, L., et al. (2024). "Per- and Poly-fluoroalkyl Substances (PFAS) in Artificial Turf: Test Methods." Lowell Center for Sustainable Production, University of Massachusetts Lowell. (https://www.uml.edu/docs/PFAS-in-turf-Test-methods-July%202024_tcm18-385224.pdf).

[122] Massey, R., et al. (2019). "Athletic Playing Fields: Choosing Safer Options for Health and the Environment." Toxics Use Reduction Institute, University of Massachusetts Lowell. (https://www.turi.org/publications/athletic-playing-fields-2/).

[123] Santa Clara County Medical Association. (2024). "Policy Recommendation on the Use of Artificial Turf on Landscapes, Schools and Playing Fields." (https://www.sccma.org/Portals/19/Artificial%20Turf%20Policy%20Recommendation%20SCCMA%20Final%20%206824%20.pdf).

A variety of materials are available as alternatives to crumb rubber infill. Some are made from synthetic plastics (such as EPDM or TPE), while others are mineral- or plant-based (such as cork). Some products combine both synthetic and natural materials (such as sand coated with acrylic plastic, also known as "polymer-coated sand"). Alternative synthetic infill materials still contribute to microplastic pollution and pose toxicity concerns [124], while mineral- and plant-based infill materials may pose respiratory hazards. PFAS-free artificial turf blades are now being marketed; however, standardized testing does not yet exist for all types of PFAS that may be present.[125]

Because of these significant environmental concerns, the Coastal Commission has in recent years sought to avoid the use of artificial turf in coastal development projects. Recently, the Commission approved the use of natural turf grass in lieu of artificial turf for several proposed projects, and it also approved amendments to two LCPs that include a new policy that prohibits the use of artificial turf in the construction of playgrounds and schools.

The need for irrigation water for natural grass can be reduced by selection of grass species with lower water requirements, and implementation of Integrated Pest Management can reduce the need for pesticides on natural grass.[126] A mowed sedge lawn, such as the California meadow sedge (Carex pansa) that is native to the Pacific coast, is another potential alternative to artificial turf for certain uses.[127]

Examples of Past Commission Actions – Below are examples of a recent Coastal Commission actions requiring the use of natural turf instead of artificial turf:

- Special Condition 1 in Notice of Impending Development No. UCS-NOID-0002-23 (Baseball Stadium Turf, University of California at Santa Barbara). Required a Final Revised Project Plan that shows the installation of natural turf, as opposed to the proposed artificial turf, for the replacement of the existing natural turf field.
- Special Conditions 9 & 11 in CDP No. 1-22-0509 (Crescent City Beachfront Park Improvements, City of Crescent City). Prohibited the use of synthetic/artificial turf and required revised plans for installation of natural turf instead.

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[124] Massey, R., et al. (2020). "Artificial Turf Infill: A Comparative Assessment of Chemical Contents." New Solutions: A Journal of Environmental and Occupational Health Policy. Vol. 30(1). (https://doi.org/10.1177/1048291120906206).

[125] Pollard, L., et al. (2024). "Per- and Poly-fluoroalkyl Substances (PFAS) in Artificial Turf: Test Methods." (See full citation above).

[126] University of California, Division of Agriculture and Natural Resources. "Statewide Integrated Pest Management Program" webpage (undated). (https://ipm.ucanr.edu).

[127] Greenlee, J. (2001). "Sedge Lawns: A Sustainable, Low-Maintenance Alternative to Grass" webpage. Brooklyn Botanic Garden. (https://www.bbg.org/article/sedge_lawns).

- Policy 6.30 in City of San Diego LCP Amendment No. LCP-6-NOC-23-0015-1 (Mira Mesa Community Plan Update). Added new LUP policy that prohibits the use of artificial turf in the construction of improvements to playgrounds and schools.
- Policy 18 in City of San Diego LCP Amendment No. LCP-6-OMN-23-0053-4 (Otay Mesa-Nestor Community Plan Update). Added new LUP policy that prohibits the use of artificial turf in the construction of improvements to playgrounds and schools.

4. Special Events

Special events are oftentimes found to be exempt from CDP requirements pursuant to the Coastal Commission's Guidelines for the Exclusion of Temporary Events from Coastal Development Permit Requirements. However, to comply with Coastal Act Section 30610(i)(2) and the Temporary Event Guidelines, the Coastal Commission's Executive Director may find that a CDP is required due to the potential for adverse effects on coastal resources.

Certain special events in particular, such as firework shows, can generate pollution that impairs water quality as well as harm wildlife that may ingest or become entangled in fallout debris. Fireworks debris that may enter the ocean includes fireworks casings, cardboard cylinders, disks, and shell case fragments; paper strips and wadding; plastic wadding, disks, and tubes; aluminum foil; cotton string; and even whole unexploded shells (i.e., duds or misfires). The plastic and aluminum components are likely to persist in the marine environment for lengthy periods if they are not washed ashore or removed by personnel. Moreover, fine microplastic particles from the discharge of fireworks may become suspended in the air and contribute to poor air quality, and they will eventually be deposited into the marine environment.

The Coastal Commission has found that specific pyrotechnic devices, such as those without outer plastic casing and/or other generally biodegradable inner components of the device, could be used instead. The Commission has also explored alternatives to firework shows such as laser light and drone shows.

Likewise, other temporary events located in close proximity to marine environments have the potential to impact water quality through the use and potential discharge of single-use plastics, balloons, and other plastic-derived materials.

Examples of Past Commission Actions – Below are some examples of past Coastal Commission requirements for special events:

- Special Conditions 3-6 in CDP No. 5-24-0399 (Big Bang on the Bay). Required compliance with Fireworks BMPs Plan that includes measures to locate and remove non-biodegradable fireworks waste, including duds, ignited and unignited aerial shells, stars (small pellets of composition that produce color pyrotechnic effects), and packaging; submittal of a marine debris reduction plan that implements recycling, trash bins, and compost; clean-up following the event that includes periodic search and recovery of event waste, especially within firework debris fallout area, and additional debris clean-up to account for 5% estimated firework debris weight.

- Special Condition 5 in CDP No. 5-19-0953 (Los Angeles Jazz Festival). Required waste management during event and post-event BMPs including removal and disposal of accumulated waste/debris, daily clean-ups after any event activities, and prohibitions on smoking.
- Suggested Modifications 24 & 25 in LCP Amendment No. 2-2001-C (Sea World Master Plan). Required monitoring of fireworks shows over five-year period, at the end of all test results will be reviewed by the relevant resource agencies in a coordinated effort to reach scientific conclusions about whether the fireworks produce debris with significant adverse impacts on the marine environment.

F. Permeable Pavements

Permeable pavements are a common strategy to reduce impervious surfaces in development projects and allow stormwater to pass through the pavement surface and infiltrate into the underlying soil.[128] Infiltrating stormwater into the soil provides the dual benefits of reducing stormwater runoff and effectively removing many pollutants. There are several types of permeable pavement products, some of which are made from plastic and therefore pose the risk of plastic debris pollution. In addition, plastic-based sealers, binders, stabilizers, hardeners, and joint fillers are sometimes used in permeable pavement systems. Below are some types of permeable pavements that may include plastics.

1. Reinforced Turf Pavers

Reinforced turf pavers (also known as grass pavers) or gravel pavers consist of a flexible plastic grid that is installed sub-surface, and either covered with turf or filled with gravel. The grid provides stabilization and load-bearing strength, and either protects the grass root system or holds the gravel in place. However, the plastic in the grid (usually PVC or polypropylene) degrades over time, particularly with UV exposure (the typical lifespan is 10-25 years), leading to the release of plastic pieces into the environment. Concrete grid pavers are typically a preferable option to reinforce grass or contain gravel.

[128] Metz, V. (2018, updated 2025). “Permeable Pavements for Stormwater Management in Coastal Development Projects: Project Analysis Tips and Model Permit Conditions.” Factsheet on the California Coastal Commission’s Water Quality webpage for permit applicants. (https://www.coastal.ca.gov/water-quality/permits/).

2. **Permeable Interlocking Concrete Pavers**

Permeable interlocking concrete pavers are concrete blocks separated by permeable joints that are typically filled with small stones that allow water to flow through. However, a variety of plastic-based (usually polyurethane or acrylic) paver sealer products are commonly used to protect the concrete pavers from stains. Plastic-based "joint-stabilizing sealers" are also often used to bind together sand or gravel used to fill the joints between pavers. "Polymeric sand," which is a mixture of sand and polymers (i.e., plastic) that forms a binding agent when mixed with water, is also available to fill the paver joints. Unfortunately, these plastic-based sealing products wear off over time due to weathering and abrasion, releasing microplastics into the environment. Furthermore, paver sealers, joint sealers, and polymeric sand all render the paver joints impermeable, defeating the purpose of using permeable pavers. A preferable option may be to use natural materials to fill the joints between pavers, avoiding the use of plastic-based paver and joint sealers.

3. **Stabilized Loose Rock Paving**

Loose rock materials such as gravel, crushed stone, aggregate, or decomposed granite can also be used as a permeable pavement surface, typically for driveways and pathways. However, a variety of stabilizers, binders, or hardeners are often mixed into the loose rocks to keep them in place. For example, "stabilized decomposed granite" is made from granular weathered granite mixed with a stabilizing agent. Most stabilizers and binders for loose rock are plastic-based (polymers and resins) and unfortunately render the surface impermeable. Over time, as the plastic becomes weathered and abraded, loose rocks coated with plastic can be dislodged, releasing microplastics into the environment. A preferable option would be to use natural stabilizers or binders for loose rock that are plant- or mineral-based (for example, based on psyllium husk). Natural stabilizers and binders often keep the surface permeable and can enable the surface to meet ADA requirements for wheelchair accessibility.

4. **Resin-Bound Paving**

Another permeable option for loose paving materials is "resin-bound paving," which consists of small aggregate stones mixed with a plastic (resin) binder to form a hardened surface, leaving voids for water to pass through. These products typically have a lifespan of 15-20 years, but the material degrades more quickly with heavy traffic. This can lead to cracking and the discharge of plastic-coated stones into the environment. A preferable option would be to use natural non-plastic stabilizers for loose rock.

Non-plastic alternatives for permeable pavement systems are typically preferred, as described above. One exception may be the use of plastic geotextile fabric if needed to separate the layers of a permeable pavement system. However, the use of plastics in permeable pavement systems may not be readily apparent in the description or plans for a proposed project. Terminology that may indicate a proposed use of plastic in a permeable pavement system includes reinforced, stabilized, sealer, binder, hardener, polymer, polymeric, and resin.

Example of Past Commission Actions – Below is an example of past Coastal Commission requirements for avoiding the use of plastic in permeable pavement materials:

- Special Condition 4 in CDP No. 6-24-0216 (UCSD La Jolla Shores Drive Viewing Platform, San Diego). Prohibited plastic resins or other plastic polymer stabilizers, binders, coatings, or hardeners mixed with the granite aggregate used to construct pathways, to minimize the risk of microplastic pollution and ensure the continued permeability of the decomposed granite pavement.

G. Landscaping

1. Synthetic Landscaping Materials

Non-biodegradable plastic mulches, geotextiles, weed cloth, and tree base mats are often more widely used in landscaping than biodegradable alternatives, due to their low cost and high tensile strength and durability. Polyethylene-derived plastics are often the main ingredient for non-biodegradable synthetic landscaping materials.[129] Non-biodegradable polyethylene use in landscaping and agriculture has elicited a significant environmental concern due to the potential for microplastic contamination of soils and receiving waters.[130]

In past actions, the Commission has therefore required that mulch, geotextiles, and landscaping mats be made of non-plastic materials, to the extent feasible. Alternatives may include wood chips, natural fibers, straw, and compost. The specific use of a particular biodegradable, non-plastic material depends on the landscaping activity proposed and the related land use (e.g., residential, commercial, or public). Synthetic geotextiles may be acceptable for some uses that require longevity of the material, such as when used underground to separate the stone aggregate layer from the underlying soil in a rain garden.

Examples of Past Commission Actions – Below are examples of past Coastal Commission requirements for avoiding the use of plastic in landscaping materials (including at public facilities):

[129] Madrid, B., et al. (2022). "End-of-Life Management Options for Agricultural Mulch Films in the United States—A Review." Frontiers in Sustainable Food Systems, Vol. 6. (https://doi.org/10.3389/fsufs.2022.921496).

[130] Khalid, N., et al. (2023). "Impact of plastic mulching as a major source of microplastics in agroecosystems." Journal of Hazardous Materials, Vol. 445:130455. (https://doi.org/10.1016/j.jhazmat.2022.130455).

- Special Condition 1 in CDP No. 4-23-0905 (Ellwood Monarchs, Santa Barbara Co.). Required maintenance of trail to be limited to placement of plastic-free coir fiber erosion control materials, and application of mulch and/or wood chips at trailhead.
- Special Condition 13 in CDP No. 1-20-0560 (Humboldt County Department of Public Works). Required post-construction use of weed-free straw mulch over bare soils; use of biodegradable geotextile fabrics where possible; allowed specific placement of plastic materials under asphaltic concrete paving equipment while not in use to catch and/or contain drips and leaks during the construction phase.
- Special Condition 4 in CDP No. 6-16-0733 (Solana Beach School District). Prohibited use of erosion and sediment control products (such as mulch/compost, fiber rolls, erosion control blankets, netting, and silt fences) that incorporate recycled plastic or plastic netting; required erosion control using natural materials as soon as feasible during construction.

2. Irrigation Pipes and Lines

Irrigation pipes and lines are typically made from plastic resins, such as polyvinyl chloride (PVC), polyethylene (PE), crosslinked polyethylene (PEX), and crosslinked polyvinyl chloride (CPVC). Their widespread use and popularity are due to numerous advantages; compared to metal alloys and concrete, plastic pipes have greater flexibility and resistance to mechanical damage, are easier to install and, most importantly, are not subject to corrosion. Certain plastic resins can also be made more durable and thermoplastic through the addition of stabilizers such as lead and tin, and plasticizers can help create resistance to cracking, ionization, and UV degradation. Nonetheless, these resins do degrade often over longer timespans (10-25 years), leading to the release of plastic pieces into the environment. Recent research has shown that plastic particles may be introduced from plastic piping systems themselves, due to both mechanical wear and chemical aging.[131] Microdamage and exfoliation of these polymers can be particularly pervasive and difficult to detect.

One method to minimize the concentration of microplastics at the point of outflow is to install a filter. However, this can be impractical for large areas of landscaping that require irrigation, and exterior degradation of the irrigation lines could still leach microplastics into the surrounding soils or runoff. Other alternatives to plastic irrigation lines include ceramic and inert metals (such as cast iron), and even certain plastics can be environmentally preferable as compared to others. For instance, high-density polyethylene (HDPE) is often considered “greener” than PVC. For temporary irrigation, it is additionally recommended that the irrigation lines be installed above ground rather than underground, so that their removal is easier to facilitate.

[131] Świetlik, J., & Magnucka, M. (2025). “Aging of drinking water transmission pipes during long-term operation as a potential source of nano- and microplastics.” International Journal of Hygiene and Environmental Health, Vol. 263: 114467. (https://doi.org/10.1016/j.ijheh.2024.114467).

Example of Past Commission Action – Below is an example of past Coastal Commission requirements for avoiding the use of plastics in irrigation materials:

- Special Condition 21 in CDP No. 5-91-286-A13 (Potrero Canyon, City of Los Angeles). Required all new and replacement irrigation to avoid permanent placement of pipes underground and the use of plastic materials (e.g., PVC, HDPE, etc.), which may leach into the surrounding environment.

H. Agriculture

Agricultural soils are often polluted with significant amounts of plastic due to a variety of agricultural practices. Studies have shown that microplastic pollution in agricultural soils has adverse effects on soil quality and fertility, the water-holding and infiltration capacities of soil, the health of soil organisms, and the growth and photosynthesis of plants.[132] Furthermore, toxic chemical additives in plastics can leach into the soil, while environmental pollutants, such as heavy metals, can concentrate on the surface of plastics and be transported throughout the soil ecosystem. Plastic debris from agricultural practices can also be dispersed into the environment by wind and runoff.

The three main sources of microplastic pollution in agricultural soils are the use of plastic film mulch for row crops, the application of municipal sewage sludge biosolids as fertilizer, and the use of composted manure from domestic animals (which ingest plastics from their feed and the environment).[133] On the California coast, other common sources of microplastic pollution in agricultural soils include plastic film fumigation tarps, hoop house and greenhouse plastic sheeting, the breakdown of larger plastic materials (such as drip irrigation tubing and plastic crates), plastic-encapsulated controlled-release fertilizers and pesticides, irrigation with municipal wastewater, and atmospheric deposition.[134]

1. Plastic Mulch Film for Row Crops

The use of plastic mulch film (typically polyethylene) to cover soil for row crops is the largest contributor of microplastic pollution in agricultural soils.[135] The plastic mulch enhances agricultural productivity by conserving soil moisture, suppressing weeds, and increasing soil temperatures. In Monterey County on California's central coast, a study of plastic use in food

[132] Sa'adu, I., & Farsang, A. (2023). "Plastic contamination in agricultural soils: a review." Environmental Sciences Europe, Vol. 35(13). (https://doi.org/10.1186/s12302-023-00720-9).

[133] Ibid.

[134] Krone, P. (2019). "Agricultural Use of Plastic in Monterey County: An Assessment of Plastic Pollution Risk and Reduction for Regional Waterways." California Marine Sanctuary Foundation / Monterey Bay National Marine Sanctuary. (https://awqa.org/wp-content/toolkits/Other/White%20Paper%20V12.pdf).

[135] Sa'adu, I., & Farsang, A. (2023). "Plastic contamination in agricultural soils: a review." (See full citation above).

crop production estimated that when both plastic mulch and fumigation tarps are used, approximately 670 pounds of plastic film are used per acre each year.[136]

Plastic mulch typically has a usable lifespan of about six months, but removal from fields is labor-intensive and its disposal is costly because it is often not recyclable (due to the adhesion of soil and debris to the film). Incomplete removal of plastic mulch is common because the film frequently breaks during removal; one trial in Monterey County found that 10% of the plastic mulch remains in the field.[137] Polyethylene is extremely resistant to biodegradation, but over time it fragments into microplastics that persist in the soil for a long time. A study of farms on California's central coast—where plastic mulch is widely used in food crops—found plastic pollution in surface soils at all surveyed farms, regardless of whether the farms followed standard "best practices" for end-of-season mulch removal.[138]

Left: Rows of strawberry plants growing through plastic mulch film in Monterey, California.

Right: Plastic mulch film covering fields of row crops in Monterey, California. (Photos: Ellie Oliver, California Coastal Commission)

Studies have shown that residual plastic mulch fragments left in the soil can result in fewer earthworms, reduced root growth, and reduced overall plant productivity. These plastic fragments can also be carried by wind or runoff into waterways. In Monterey County, streambank trash surveys found that plastic film fragments made up the highest concentration

[136] Krone, P. (2019). "Agricultural Use of Plastic in Monterey County." (See full citation above).

[137] Ibid.

[138] Tiwari, E., & Sistla, S. (2024). "Agricultural plastic pollution reduces soil function even under best management practices." PNAS Nexus, Vol. 3(10):433. (https://doi.org/10.1093/pnasnexus/pgae433).

of agricultural plastic pollution. While plastic mulch provides short-term benefits for food crop production, its long-term sustainability is questionable.[139]

There are a variety of biodegradable plastic mulches that are designed to be tilled into the soil at the end of the crop cycle, reducing labor costs for removal and alleviating the challenges of disposing used plastic mulch. Biodegradable plastic mulches are either made from conventional fossil fuel-based plastics, bio-based materials (i.e., derived from natural biomass materials or synthesized by microorganisms), or a combination of both. They often contain a variety of chemical additives, dyes, and fillers; however, the types and quantities of these chemicals are currently unknown.[140] The USDA allows the use of bio-based biodegradable plastic mulch in certified organic crop production. However, no such products have been approved for use on organic crops in the U.S. because none of the available products are completely bio-based.[141]

The rate at which soil-biodegradable plastic mulch breaks down under coastal California conditions has not yet been tested, and there are currently no standards for assessing biodegradability under diverse field conditions.[142] In California, a plastic mulch film is considered soil-biodegradable if it meets the international standard EN 17033, which requires that 90% of the plastic breaks down into carbon dioxide and water (with the remaining 10% converted into microbial biomass) within two years in an aerobic incubator at 68-82° F. However, field studies have shown that in-soil biodegradation may proceed much more slowly. One study, using modeling of field data from a Mediterranean climate similar to coastal California, estimated that it could take 21-58 months for soil-biodegradable plastic mulch to reach 90% biodegradation in the soil.[143] When soil-biodegradable plastic mulches are applied annually and tilled into the soil, researchers estimate that the plastic remaining in the soil will reach a steady-state concentration of 3 times the initial plastic concentration (assuming it takes 5 years for the plastic to fully biodegrade).[144]

Furthermore, there are several concerns about the environmental impacts of soil-biodegradable plastic mulches. Although designed to break down over time, fragments of biodegradable

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139 Krone, P. (2019). "Agricultural Use of Plastic in Monterey County." (See full citation above).

140 Campanale, C., et al. (2024). "A critical review of biodegradable plastic mulch films in agriculture: Definitions, scientific background and potential impacts." TrAC Trends in Analytical Chemistry, Vol. 170:117391. (https://doi.org/10.1016/j.trac.2023.117391).

141 Ghimire, S., et al. (2018). "Biodegradable plastic mulch and suitability for sustainable and organic agriculture." Washington State University Extension and the U.S. Dept. of Agriculture. (https://s3.wp.wsu.edu/uploads/sites/2181/2021/07/Biodegradable-Plastic-Mulch-And-Suitability-for-Sustainable-and-Organic-Agriculture.pdf).

142 Krone, P. (2019). "Agricultural Use of Plastic in Monterey County." (See full citation above).

143 Griffin-LaHue, D., et al. (2022). "In-field degradation of soil-biodegradable plastic mulch films in a Mediterranean climate." Science of The Total Environment, Vol. 806(1):150238. (https://doi.org/10.1016/j.scitotenv.2021.150238).

144 Yu, Y., & Flury, M. (2024). "Unlocking the Potentials of Biodegradable Plastics with Proper Management and Evaluation at Environmentally Relevant Concentrations." Nature npj Materials Sustainability, Vol. 2(9). (https://doi.org/10.1038/s44296-024-00012-0).

plastic mulch remain in the soil for several years, potentially harming soil biota and soil function during that period (see IV. Environmental Impacts of Plastic Pollution, above). Biodegradable plastics also fragment more rapidly than non-biodegradable plastics, facilitating the release of potentially toxic additives from the plastic into the soil. In addition, biodegradable plastics have a greater tendency to attract environmental pollutants that bind to the surface of the plastic, and therefore may accumulate a greater concentration of toxic chemicals that can be transported into the food chain.[145] Fragments of soil-biodegradable plastic may also be transported off-site by wind or runoff, entering environments (such as rivers or oceans) where conditions may not support biodegradation.

Given the significant environmental concerns associated with both biodegradable and non-biodegradable plastic mulch in agriculture, it is important to consider alternatives to plastic mulch whenever feasible. Several potential alternatives to plastic mulch exist, including paper mulch, straw mulch, rolled cover crops, deep compost mulch, woodchips, wool mulch, living mulches (such as clover or rye), and cover crops.[146]

2. Microplastics in Sewage Sludge Applied as Fertilizer

Treated sewage sludge (also called "biosolids") from municipal Wastewater Treatment Plants (WWTPs) is commonly applied to agricultural fields as fertilizer, and it is the second largest source of plastic pollution in agricultural soils.[147] In addition to providing nutrients, land application of biosolids serves as a cost-effective disposal method, avoiding the higher costs of alternatives such as landfilling or incineration. Although WWTPs are effective at removing a large percentage of microplastics from the liquid component of wastewater, these microplastics tend to accumulate in the solid sludge. Thus, sewage sludge biosolids often contain an abundance of microplastics, particularly microfibers. When sewage sludge is repeatedly applied to a field for fertilizer, microplastics accumulate in the soil over time. One study found that microplastic abundance in agricultural soils significantly increased by 723 to 1,445 percent following applications of sewage sludge, and that these elevated levels remained constant over 22 years. The study also found that colored microfibers in the sewage sludge may be environmentally hazardous in soil ecosystems due to the toxicity of textile dyes that may leach into the soil.[148]

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[145] Campanale, C., et al. (2024). "A critical review of biodegradable plastic mulch films in agriculture: Definitions, scientific background and potential impacts." TrAC Trends in Analytical Chemistry, Vol. 170:117391. (https://doi.org/10.1016/j.trac.2023.117391).

[146] Hoidal, N. (2021). "Exploring alternatives to plastic mulch" webpage. Fruit and Vegetable News: University of Minnesota Extension. (https://blog-fruit-vegetable-ipm.extension.umn.edu/2021/01/exploring-alternatives-to-plastic-mulch.html).

[147] Sa'adu, I., & Farsang, A. (2023). "Plastic contamination in agricultural soils: a review." (See full citation above).

[148] Ramage S.J.F.F., et al. (2025). "Microplastics in agricultural soils following sewage sludge applications: Evidence from a 25-year study." Chemosphere, Vol. 376:144277. (https://doi.org/10.1016/j.chemosphere.2025.144277).

The application of biosolids to agricultural lands raises several environmental concerns. Studies have shown that microplastic in agricultural soils can adversely impact soil health, soil organisms, the water-holding and infiltration capacity of soil, and plant growth.[149] Additionally, microplastics introduced to soil from biosolids may expose humans to adverse effects from plastics and their chemical additives through food consumption. Furthermore, microplastics in the soil may be transported off-site by wind or runoff, potentially reaching waterways and the ocean.

While the Coastal Commission reviews CDPs for development of municipal WWTPs, the California Water Boards, along with the U.S. EPA, regulate the beneficial reuse of treated municipal sewage sludge (i.e., biosolids) as fertilizer on agricultural lands.[150] To reduce adverse environmental impacts, the U.S. EPA regulates the allowable concentration of metals, microbial pollutants, and certain organic chemicals in biosolids applied to agricultural fields; however, they do not regulate the microplastic content of biosolids.[151] Additionally, there is no standardized method for sampling and analyzing microplastics in wastewater effluent or sewage sludge biosolids.[152]

Given the significant environmental concerns associated with the large quantities of microplastics accumulating in agricultural soils from the application of sewage sludge biosolids, municipalities could consider adding an LCP policy to restrict or prohibit the application of biosolids on agricultural lands within their jurisdiction.

3. Reducing Plastic Pollution from Agricultural Operations

There are multiple opportunities to reduce plastic pollution from agricultural operations, including developing and implementing strong monitoring programs, using alternative non-plastic materials, and eliminating unnecessary plastic use throughout agricultural operations.[153] While ongoing agricultural activities, such as harvesting of major vegetation, are exempt from Coastal Development Permit (CDP) requirements under Section 30106 of the Coastal Act,[154] changes to agricultural practices that generate plastic pollution can still be encouraged through

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[149] Sa'adu, I., & Farsang, A. (2023). "Plastic contamination in agricultural soils: a review." (See full citation above).

[150] California State Water Resources Control Board. "Biosolids" webpage (undated). (https://www.waterboards.ca.gov/water_issues/programs/biosolids/).

[151] U.S. Environmental Protection Agency. "Sewage Sludge Laws and Regulations" webpage (undated). (https://www.epa.gov/biosolids/sewage-sludge-laws-and-regulations).

[152] Hooge, A. (2023). "Fate of microplastics in sewage sludge and in agricultural soils." TrAC Trends in Analytical Chemistry, Vol. 166:117184. (https://doi.org/10.1016/j.trac.2023.117184).

[153] Hofmann, T., et al. (2023). "Plastics can be used more sustainably in agriculture." Communications Earth & Environment, Vol. 4:332. (https://doi.org/10.1038/s43247-023-00982-4).

[154] California Coastal Commission. "Coastal Agriculture" webpage (undated). For permitting information, see "Agriculture in the Coastal Zone: An Informational Guide for the Permitting of Agricultural Development" (2017) and "Flowchart - Permitting Requirements for Agricultural Activities in the Coastal Zone." (https://www.coastal.ca.gov/agriculture/).

policy. Specifically, new or updated Local Coastal Programs (LCPs) could include policies to reduce the use of plastic mulch and sewage sludge on agricultural fields.

Example of Past Commission Action – Below is an example of past Coastal Commission requirements for agricultural activities:

- Recommended Modification G.3.b in Amendment Request No. 3-18C (LCP-5-LOB-18-0100-3-Part C) to the City of Long Beach Certified Local Coastal Program. Although not specific to plastic pollution, staff's recommended modifications to the proposed Urban Agriculture ordinance required implementation of pollutant source control BMPs to minimize the discharge of pollutants resulting from agricultural activities into runoff or coastal waters.