



Phone: (408) 998-8850
Web: www.sccma.org
Address: 700 Empey Way, 2nd Fl
San Jose, CA 95128

Policy Recommendation on the Use of Artificial Turf on Landscapes, Schools and Playing Fields

Santa Clara County Medical Association

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Purpose: To educate and provide recommendations to physicians, officials, school administrators and teachers of the health risks and potential health and environmental hazards of artificial turf and synthetic grass on landscapes, schools, playgrounds and playing fields.

Recommendations: After careful consideration of the current scientific evidence of plastic and chemical contamination, sports injuries, urban heat effects, disposal, potential short and long-term health effects, as well as direct and indirect environmental costs, the SCCMA believes artificial turf is potentially harmful to both human and environmental health and is not a sustainable option when compared with natural grass. Taking a precautionary approach for the long-term protection of the children, the environment and public health, we recommend:

- 1) That artificial turf *not* be used on sports fields, playgrounds, landscaping, residential lawns or in schools, but instead that natural grass turf be used, a choice that will serve to benefit the health and safety of children, athletes and the environment, and
- 2) If artificial turf *is* in place, that at the end of its useful life it be replaced with natural grass and *not* artificial turf.

SCCMA Goals: The support of public health measures to prevent environmentally-related disease is a prime goal and objective of the Santa Clara County Medical Association (SCCMA). This especially applies to children who have greater lifetime exposures to- and accumulation of- toxins, and whose immune, cardiovascular, reproductive and neurologic systems are immature, increasing their vulnerability to acute and chronic diseases related to toxic exposures.

Introduction:

Rethinking Artificial Turf

Artificial turf was introduced into the sports world in 1965. Currently there are approximately 13,000 synthetic turf sport fields in the U.S. While in the past artificial turf initially seemed to be the better alternative due to reduced costs, reduced water usage and lower maintenance, newer information has come to light regarding the direct and indirect environmental and health impacts of synthetic grass, including a full life cycle analysis of costs. As more artificial turf fields are

installed, more long-term problems are being identified. Indeed, the environmental impacts of artificial turf components are now recognized as a global problem (Armada 2022). We think that artificial turf, based on available scientific studies, is not a sustainably safe alternative for landscaping, nor for use on sport fields, particularly for children. In addition, much progress has been made in developing state of the art drought resistant, water conserving grass fields that are sturdy, can be used year-round in California, and can be watered with non-potable recycled water. References follow.

Components of Artificial Turf

Artificial turf is a human-made surface of synthetic fibers, that was invented in the 1960's to look like and replace natural grass on sports fields and residential lawns. It consists of non-biodegradable plastic turf "blades" and a non-biodegradable backing. In the 1990's infill was added between the blades to soften the fields during play. Turf blades are composed of polyethylene, polypropylene or nylon.

The cushioning infill material is most often crumb rubber infill from crushed tires. Other materials have been used, such as silica from crushed quartz, synthetic rubber, polymer-coated sand, and other organic materials (cork and coconut fiber). However, these "eco-friendly" alternatives are typically coated with stabilizers and plasticizers for durability. The primary backing consists of woven or non-woven fabric made from high-strength polyester or polypropylene. The secondary backing is applied to permanently stabilize and secure the tufts of the artificial turf system. The most commonly used coating materials are latex and polyurethane.

Stated Benefits of Artificial Turf

The benefits widely promoted by the Synthetic Turf Council (STC) include less maintenance, less cost, no mowing, none-to-minimal water usage, no discoloration yearlong, no weeds, no allergies, no need for pesticides and durability, as the product withstands harsh weather conditions thus extending the sports season. We will look at some of these issues in the sections below.

Summary: Concerns about Artificial Turf

Chemical and Plastic Pollution

- Artificial turf and infill contain chemicals and heavy metals that are bio-accumulative, and thereby, harmful to humans and to the environment. These include polycyclic aromatic hydrocarbons (PAHs), phthalates, and perfluoroalkyl and polyfluoroalkyl "forever" substances (PFAS) (Ecology Center 2020; New Jersey State 2023; PEER 2024). Chemicals in artificial turf have a variety of biological effects and are known carcinogens, neurotoxicants, mutagens, and endocrine disruptors. Heavy metals such as arsenic, lead, chromium, zinc, antimony, and cadmium are also found in artificial turf components. (Armada 2022; Celeiro 2018; Llompарт M 2013; Zhang 2008; Winz 2023). Some of the incorporated metals are found above regulatory limits (Negev 2022).

- Crumb rubber from crushed used tires is often used as infill, (well as on playgrounds) and has a unique chemical risk profile for humans and the environment (Duque-Villaverde 2024; Frederico 2023; Mayer 2024; Murphy 2022).
- There is close and often repetitive contact of players with artificial turf surfaces and infill, especially for soccer and football players, with particles sticking to shoes and clothing
- There can be direct inhalation and ingestion or dermal uptake of chemicals from the plastic grass and infill (Celeiro 2021).
- There can be leaching of harmful chemicals and microplastics into groundwater, drinking water and soil, causing water contamination, as well as damage to the living soil and organisms beneath them (Celeiro 2021; Armada 2022; Cui 2022; Zhong 2022).
- Many of the chemicals can be volatilized, and thus inhaled, especially with high temperatures (Armada D 2022; Celeiro 2021, Llompart M 2013).
- Biocides and pesticides applied to artificial fields to kill bacteria, mold, viruses and weeds can cause skin sensitization and may pose risks to the health of workers, children, and surrounding ecosystems (Hahn 2010).
- Artificial turf contains microplastics which are considered contaminants of emerging concern as they do not biodegrade, but do bioaccumulate in the environment, thus creating harm at every stage of the plastic life cycle in their production, use, and disposal (Landrigan 2023).
- Microplastics are inflammatory and also found in humans in the blood, brain, lungs, liver, gut, testicular tissue, thrombi and placenta (Gaspar 2022; Leslie 2022; Ragusa 2021; Danopoulos 2022; Wu 2023; Garcia MA 2024; Garcia MM 2024; Saha 2024; Hu 2024). Polyethylene (used in artificial turf) has even been detected in atherosclerotic plaque in 58% of carotid artery specimens showing “visible, jagged-edged foreign particles” that could contribute to vascular inflammation (Marfella 2024).
- Artificial turf adds to the plastic pollution crisis (IUCN 2022).
- Artificial turf microplastics have been found in 50% of urban waterways tested in Spain and comprised 15% of plastic found in the water (deHaan 2023).
- Artificial turf components have been found to be toxic to earthworms (Pochron 2018), aquatic organisms (Kruger 2013) and chick embryos (Xu 2019).
- Artificial turf infill components can reduce sport grass growth (van Kleunen 2019).

Increased Surface Runoff

- Artificial turf is impervious and increases surface runoff that carries microplastics into storm water drains and local water bodies (de Haan 2023).

Increased Sports Injuries

- There is increased biomechanical stress on joints when playing on artificial turf fields versus natural grass, causing an increase in lower extremity sports injuries particularly in football and soccer (Gould 2023) and an increase in concussions because the artificial turf is laid over concrete or compacted earth (Mack 2019) with a resultant increased impact deceleration (Villanueva 2024).
- There is evidence of increased staphylococcus bacterial infections from turf abrasions

- Turf Toe injury is seen largely from artificial turf sports injury (Najefi 2018)

Athletic Preference for Natural Grass

- Athletes from high school to college to professional sports by far prefer to playing on natural grass (Owen 2016; Dumas 2023; NFLPA).
- National Football League (NFL) players prefer natural grass due to increased injuries from artificial turf (NFL Players Association).

Creation of Urban Heat Islands with Risk of Heat Injury

- Artificial turf can create harmful local heat islands with very high field surface temperatures which range from 40 - 60 degrees °F higher than natural grass - even with moderate air temperatures - causing poor athletic performance and heat related injury and illness, such as burns, heat stress, heat stroke and heat exhaustion, making the fields unusable (Mcfarlane 2015; Abraham 2019; Dujanovic 2017). In contrast natural grass fields rarely get above 100 degrees F.
- Cleats can get hot and have been known to melt on artificial turf (Litman 2015; Nazareth 2016).
- High synthetic field surface temperatures increase volatility and absorption of harmful chemicals from the synthetic turf (Armada D 2022; Llompert M 2013).
- A significant amount of water is used to manufacture, clean and cool synthetic sports fields (Alm 2016; Kanaan 2020).
- There is an expected rise in extreme heat events with a rise in heat-related illnesses and deaths in the next 20 years. Climate change will cause this to be more of an issue for athletes and children (California report “Indicators of Climate Change”).
- With rising temperatures artificial turf fields are expected to be increasingly hotter for longer periods, thereby reducing the number of days they can be used in warm or hot weather compared to natural grass.
- Children are physiologically more vulnerable to heat-related illness, due to their greater skin surface area in relation to their bodies, immature sweat glands and higher metabolic rates (Bytomski 2003; Antoniadis 2020; Malmquist 2021). Children can suffer a 24% longer *extreme danger* duration on artificial turf during sunny days than on natural grass (Liu and Kim).
- Parks with grass fields can be cooler than the surrounding urban environment by up to 7°C (Slater 2010).

Not Recyclable: Increasing Plastic Waste

- Artificial turf creates a significant waste problem at the end of its limited lifespan of 8-10 years, and it is difficult to recycle due to its complex plastic mixture. It often becomes landfill waste or is dumped on private land with persistent soil and water contamination leaching from the plastic, or is incinerated with accompanying adverse air quality impacts.

- California does not recycle artificial turf and it has to be sent out of state to an “advanced recycling” plant, however there is controversy over the true recyclability of artificial turf and its carbon cost. Only recently has one plant in Texas opened for recycling, and the results have not been measured. Many decades of artificial turf remain stocked in piles above ground in the U.S. and abroad.
- Industry advertising claims stating that artificial turf is recyclable has been challenged in a formal complaint (PEER 2022, York Daily Report 2019).
- A recent comprehensive report “The Fraud of Plastic Recycling” reveals that the plastic industry and the oil industry knew for decades that plastic was not truly recyclable (The Center for Climate Integrity 2024).
- Typical sports fields are about 80,000 square feet and contain about **40,000 pounds of “grass” turf** along with **240,000 to 720,000 pounds of infill** according to the Synthetic Turf Council.

Water Use

- Valley Water, headquartered in San Jose, notes that water conservation no longer includes artificial turf as they recognize that, “there are healthier and more ecologically sound alternatives”
- California Senate Bill 676, signed into law Oct 8, 2023 by Governor Newsom, specifies “that drought-tolerant landscaping does *not* include the installation of synthetic grass or artificial turf.”
- Water use on hot days is comparable for both natural grass and artificial turf that is cooled with water to allow playability (Kanaan 2020).
- Manufacture of *one* artificial turf field uses the same amount of water needed to maintain one natural grass field for *4 years* (Alm 2016).
- Recycled water may not be suitable for use on artificial turf due to high salt content which can break down artificial turf components (California Coastal Commission 2023). However, natural grass turf can withstand the salts in recycled water (Evanylo 2010; Hochmuth 2022)

Water Quality and Environmental Effects

- As artificial turf is used it degrades with wear and microplastic and chemicals leach into the soil, water and air on fields and in disposal sites (Wik 2009; Bessa 2018; Celeiro 2018 & 2021; de Haan 2023).
- Water contamination from artificial turf is recognized as a global problem with widespread pollutants in the aquatic environment. deHaan (2023) found artificial turf plastics were found in 50% of river samples and comprised 15% of all plastics in the water.
- Artificial turf is associated with a decline in diversity in soil and bird populations (Bernat-Ponce 2020; Sanches-Sotomayer 2022; Valeriani 2019).
- Integrated Pest Management Policies, Programs and Ordinances have been successfully implemented in many municipalities to reduce pesticide use on parks, landscapes and in agriculture (IPM EPA 2023; IPM San Francisco; IPM Santa Clara County; IPM Marin;

IPM-UC; IPM USDA). These programs protect biodiversity, reduce health risks and address long-term indirect consequences of toxic exposures.

Displacement of Green Space

- Artificial turf displaces natural green space, which is important to health, development and the well-being of children.
- California Extreme Heat Action Plan for California encourages natural plants and landscaping to strengthening community resilience.
- Artificial turf replaces natural grass, which provides soil organic carbon sequestration as well as oxygen.

Carbon Footprint

- Artificial turf is made of plastic that is derived from fossil fuels.
- Artificial turf produces greenhouse gas emissions during manufacturing and has been found to emit these gases as it degrades (Royer 2018).
- Natural grass sequesters carbon, especially when organic methods are used to maintain sports fields (Braun 2019; Cumming 2018; Hamido 2016; Kong 2014; Law 2017; Qian 2012; Zhang 2013).
- Turf farms used in industry can create a positive balance for carbon sequestration (Cummings 2018).

Cost is Less for Natural Grass Fields

- Using a Life Cycle Analysis which includes disposal, natural grass fields are less expensive in the long run (Daviscount 2017; University of Arkansas; TURI U of Mass Lowell).
- Cleanup costs for current disposal sites and environmental toxins are not taken into account in the total cost of artificial turf.

Benefits of Natural Grass

- Sequesters carbon
- Groundwater preservation and recharge by preventing runoff
- Restoration ecology, bioremediation and soil restoration
- Maintains healthy soil microbiome
- Water conservation
- Improves wellbeing
- Supports biodiversity in soil and the ecosystem

- Cooler microclimate

Examples of Natural Grass Playing Fields

Note: The Sports Field Management Association gives awards every year to well managed natural grass fields

- Marblehead, MA
- Springfield, MA
- Martha's Vineyard, MA
- Snapdragon Stadium in San Diego
- Woodland Middle School, Portola Valley
- Woodside Priory, Portola Valley

No Proof of Safety for Artificial Turf

- There is a significant data gap in understanding the safety of artificial fields. Gaps remain in understanding the chemicals, their toxicity and concerns about the dosages.
- Long-term human health impacts, such as cancer, remain uncertain with some evidence pointing to a higher risk (Tarafdar 2020).
- There are no studies indicating that artificial playing fields are safe
- In February 2016, the Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds (FRAP) was announced. This multi-agency effort includes the U.S. Environmental Protection Agency (EPA), Centers for Disease Control and Prevention (CDC), and the U.S. Consumer Product Safety Commission (CPSC). The 2019 report released in 2024 discusses crumb rubber only.
- The Consumer Product Safety Commission recommends precautions to limit exposure to chemicals on artificial turf such as hand washing and limiting time on the playground on hot days. (CPSC)

Children are More Vulnerable

- It is well established that children are more vulnerable to toxic exposures due to their immature development that can be permanently disrupted (Carroquino 2012; Landrigan 2001, 2016, 2023; Endocrine Society).
- Children have a longer cumulative time of exposure.
- Children have close and repeated contact with turf surfaces.
- Children are more vulnerable to heat stress physiologically (Bytomski 2003; Antoniadis 2020; Malmquist 2021; Liu and Kim)
- The Mount Sinai Children's Environmental Health Center Position Statement on the use of Artificial Turf Surfaces in Nov 2023, "recommends against the installation of artificial turf playing surfaces and fields due to the uncertainties surrounding the safety of these

products and the potential for dangerous heat and chemical exposures.” (Mount Sinai 2023)

No Regulations on Artificial Turf for Children

- There are no federal safety regulations on artificial turf for children (Zucarro 2022)
- The European Union has banned the sale of products with intentionally added microplastics and products that release microplastics over time, including crumb rubber artificial turf infill (Zucarro 2024).
- Crumb rubber playgrounds and elementary school sports fields are not classified as a children’s product by the Consumer Product Safety Commission (PEER 2015)

Policies to Ban Artificial Turf or Components

The concerns for harmful plasticizers and microplastics in artificial turf, long-term effects on children’s health, as well as life cycle analyses have led to policies to ban artificial turf altogether as well as to ban specific toxic components (Millbrae, San Marino, Boston, Zucarro et al 2022). Millbrae, California, for example, recently passed an ordinance to ban artificial turf, including requiring natural grass replacements once artificial turf installations “begin to show visible signs of wear.” (Millbrae Ordinance 806, Chapter 8.65)

The law allows local governments to ban artificial turf due to well-documented health concerns. Unfortunately, the artificial turf industry does not have to prove safety of their products for humans or the environment in order to market their product. In fact, few studies on human health have been done. Murphy (2022) notes, “The only human epidemiology studies conducted related to artificial turf have been highly limited in design, focusing on cancer incidence.”

Background

1. Chemical Exposures and Contamination

Microplastics and Chemical Pollution: Plastics are now regarded “as a major threat to ecosystems worldwide” (de Haan 2023). Artificial turf is composed of plastic “blades of grass”, a plastic composite backing and cushioning infill. The synthetic green blades are typically made up of polyethylene and polypropylene, and due to its propensity to degrade with UV light, “stabilizers” are added to the mix in the manufacturing process to reduce breakdown. Tire crumb rubber is often used for infill due to cost. All of these components are derived from petroleum products. These components contain microplastics as well as chemicals acknowledged as being hazardous substances, such as polycyclic aromatic hydrocarbons (PAHs), bio-accumulative (“forever”) per- and polyfluoroalkyl substances (PFAS), phthalates, silica (silica crystal infill), polychlorinated biphenyls (PCBs), carbon black and metals such as lead, mercury, cadmium, chromium, cobalt, and arsenic. In addition, pesticides and biocides are used on

artificial fields to reduce bacteria, viruses and weeds, which could cause adverse reactions and skin sensitization.

A study by the United States Environmental Protection Agency (2019) noted, “a range of chemicals (metals and organic compounds) was found on fields,” but no biomonitoring studies on athletes has yet been done.

These chemicals can contaminate water supplies through runoff, as well as leach into groundwater and soil and persist in the environment (deHaan 2023). Children can be exposed via inhalation of off-gassing compounds, or ingestion of infill components. The crushed tire rubber infill adheres to skin, shoes and clothing, and then can enter cars and homes. Based upon the presence of known toxic substances in tire rubber and the lack of comprehensive safety studies the Children’s Environmental Health Center of the Icahn School of Medicine urged a moratorium on the use artificial turf generated from recycled rubber tires. The EPA states in their assessment that “the existing studies do not comprehensively evaluate the concerns about health risks from exposure to tire crumb.” (Marsili 2014). Artificial turf fields are installed on top of a bed of crushed rocks and a drainage system that typically feeds the runoff to storm sewers or surface waterways. As such, artificial turf contributes to the plastic waste crisis.

a. PFAS

High levels of PFAS have been found in artificial turf sold at Home Depot and Lowe’s by the Center for Environmental Health who sent a notice of Violation of the Safe Drinking Water Act on March 4, 2024 (CEH 2024). New health concerns have risen from the ubiquitous chemical group called perfluoroalkyl and polyfluoroalkyl substances (PFAS), which are a class of persistent and highly toxic chemicals with widespread contamination across the United States, and which have been to date found in all samples of artificial turf. PFAS are typically added for water and stain resistance for a myriad of commercial products from packaging to clothes, to food containers and also found in cleaning products and non-stick cookware. Manufacturers of artificial turf state it is used in processing to enhance smoothness and reduce friction during manufacturing.

PFAS in plastics are especially problematic because they are a category of chemicals that contain multiple fluorine atoms bonded to a chain of carbon atoms that makes them resistant to breakdown. This group of chemicals thus bioaccumulates in the food chain and has contaminated water supplies throughout the nation. PFAS are now found in breast milk, blood serum, urine, testicular tissue and placental blood. (ATSDR, Hall, Hu, Wu)

Human health risks include endocrine disruption, adverse effects on the liver and thyroid, as well as metabolic effects, developmental effects, neurotoxicity, and immunotoxicity, with evidence of reduction of effectiveness of childhood vaccinations (Grandjean 2017) as well as developmental harm.

The Mindaroo-Monaco Commission on Plastics and Human Health Report 2023 concludes: “It is now clear that current patterns of plastic production, use, and disposal are not sustainable and are responsible for significant harms to human health, the environment, and the economy as well as for deep societal injustices...The thousands of chemicals in plastics—monomers, additives, processing agents, and non-intentionally added substances—include amongst their number known human carcinogens, endocrine disruptors, neurotoxicants, and persistent organic pollutants. These chemicals are responsible for many of plastics’ known harms to human and planetary health. The chemicals leach out of plastics, enter the environment, cause pollution, and result in human exposure and disease. All efforts to reduce plastics’ hazards must address the hazards of plastic-associated chemicals...to protect human and planetary health, especially the health of vulnerable and at-risk populations, and put the world on track to end plastic pollution by 2040 this Commission supports urgent adoption by the world’s nations of a strong and comprehensive Global Plastics Treaty in accord with the mandate set forth in the March 2022 resolution of the United Nations Environment Assembly (UNEA)” Landrigan (2023).

The Mount Sinai Children’s Environmental Health Center Position Statement on the Use of Artificial Turf Surfaces Nov 2023, “recommends against the installation of artificial turf playing surfaces and fields due to the uncertainties surrounding the safety of these products and the potential for dangerous heat and chemical exposures.” They further state, **“To allow the installation of PFAS-containing surfaces would be extremely short-sighted as further restrictions and regulations on these chemicals are likely to come.”** Noting:

- Studies to assess the safety of artificial turf are ongoing and inconclusive.
- Questions remain about the safety of alternatives to crumb rubber.
- Undisclosed chemicals of concern are present in plastic grass blades and turf pads and matting.
- Chemical hazards escape from artificial turf surfaces to the environment
- Turf materials are transported home.

b. Infill

Infill is used to support synthetic fibers to prevent rippling of the blades, adds weight to the turf to keep it in place, acts as cushioning, assists drainage in high rains. Types of infill that are used include “crumb rubber” (crushed tires), Crystalline Silica sand, and newer alternatives such as coconut husk, walnut, wood and Zeolite.

Crumb Rubber Tire Infill

Crumb rubber from crushed used tires is used as cushioning infill on artificial turf. According the EPA 38 states ban pulverized scrap tires due to their hazardous components and tendency to catch fire, but in 2003 “markets for scrap tires were consuming 233 million, or 80.4%, of the 290 million annually generated scrap tires.” In 2016 the EPA found that 12.5% of all scrap tires were used in crumb rubber infill. (EPA

2016). Crumb rubber was considered an “environmental success story”, according to the Rubber Manufacturers Association (Rappleye 2024).

Crumb rubber, however, exposes humans and ecosystems to a plethora of hazardous chemicals due to the complex mixture of toxic chemicals used in manufacturing. **Celiero (2021)** found, “40 target compounds, including polycyclic aromatic hydrocarbons (PAHs), plasticizers, antioxidants and vulcanization agents were determined in 50 synthetic football pitches of diverse characteristics”. **Duque-Villaverde (2024)** found, “11 compounds of environmental and health concern, including antiozonants such as N-1,3-dimethylbutyl-N'-phenyl-p-phenylenediamine (6PPD) or N, N'-diphenyl-1,4-phenylenediamine (DPPD), and vulcanization and crosslinking agents, such as N-cyclohexylbenzothiazole-2-sulfenamide (CBS), 1,3-di-o-tolylguanidine (DTG) or hexamethoxymethylmelamine (HMMM) from tire rubber... **antiozonant 6PPD [recently linked to acute mortality in salmon]** is present at the highest concentrations up to 0.2 % in new synthetic fields. **Federico (2023)** found, “Trace elements such as Zn, Al, Fe, Cd, Cr, Ni, Hg, and Cu”, as well as a filler called carbon black composing up to 22-40%, or silica for wear resistance. **Lead** has been found in artificial turf as well (**Graca 2022**). A 2020 report by the Ecology Center in Maryland found high levels of lead [up to 30,292 ppm in one sample] in Maryland and Virginia playgrounds made from rubber shred. (**Ecology Center 2020**)

Tire industry workers are subjected to some 50 chemicals, many of which are toxic. Occupational studies of workers in the tire industry reveal an association with emphysema, leukemia, multiple myeloma, as well as cancers of the bladder, esophagus, larynx, liver, lung, pancreas, prostate and stomach. Most chronic diseases caused by occupational toxins don't appear until 10 or more years after first exposure. There are many studies on the toxicity of crumb rubber. (**Murphy 2022**)

Silica Infill

Crystalline silica from crushed quartz rock, also known as industrial sand, is a common alternative to crushed tire infill and contains 95% crystalline silicon dioxide. One manufacturer states: “Silica sand is one of the most ubiquitous forms of infill for the simple reason that it's inexpensive.” [<https://www.purchasegreen.com/blog/silica-sand-what-you-should-know/>] It is also considered a hazardous material. Silica dust has long been known to cause a chronic restrictive lung disease called silicosis and was first documented in 1700 in stone-cutters by Dr. Bernardino Ramazzini, considered the founder of occupational medicine. Symptoms of this progressive irreversible lung disease are persistent cough, shortness of breath and difficulty breathing which may occur years after the exposure as scarring and inflammation progress. Silicosis is the most prevalent chronic occupational lung disease in the world (Upadhyay 2024). Australia banned engineered stone because of silicosis risk that is increasingly found in workers who polish engineered countertops. (Nogrady 2023). A silicosis epidemic was recently noted in the Northeast San Fernando Valley stoneworkers (Norris 2024).

Silica Infill is Not Sand or “Just Dust”

Some people say that silica infill is just beach sand and therefore is safe. Indeed, beach sand is 80 to 95% silica, but is composed of larger particles that do not pose a risk of pulmonary disease. However, silica (silicon dioxide) exists in both crystalline and amorphous forms. A Yale Environmental Health and Safety report points out that beach sand is amorphous silica. Crystalline silica on the other hand is “at least 100 times smaller than ordinary sand found on beaches or playgrounds. It is generated when silica-containing materials are manipulated in such a way that a dust is created, [and] some fraction of that dust may include particles small enough to become respirable.”

The International Agency for Research on Cancer (IARC) Monographs Programme has classified crystalline silica as carcinogenic to humans, while amorphous silica was not classifiable as to its carcinogenicity in humans. The panel emphasized that crystalline silica in the form of quartz or cristobalite dust causes lung cancer in humans. [<https://acsjournals.onlinelibrary.wiley.com/doi/10.3322/caac.21214>]

The American Academy of Pediatrics (AAP) specifically recommends avoiding “Crushed crystalline silica (quartz)” in sandboxes or playgrounds. (American Academy of Pediatrics- Safety in the Sandbox). Some manufacturers state that the silica is contained inside a plastic or acrylic coating. This coating however may break down with use and pose yet more unknown and untested risks. Organic alternatives such as coconut husks or cork may have proprietary ingredients or coatings as well that stabilize the material but create regrettable substitutes with their own hazardous components. The alternative infill, Zeolite, can be toxic to the lungs with inhalation. (Sloan Kettering)

While new artificial infill and plastic technologies may make fields cooler or softer or bactericidal, we still do not know if they are safer. These alternatives may not have independent scientific studies to back their safety when inhaled, ingested or after they enter storm drains. A full toxic life cycle analysis is needed to fully inform a decision to place artificial turf.

Cancer is another concern for athletes and children playing on artificial turf and exposed to infill and a mix of synergistically harmful artificial turf chemicals. Although there are no studies to date associating an increased risk of cancer with artificial turf, questions remain unanswered regarding exposure to carcinogens on these fields.

2. Disposal of Plastic Waste and Recycling

Artificial turf creates an enormous plastic waste problem and recycling is problematic. Sports fields will last 8 to 10 years before disposal. As they are made of a complex mix of plastic and infill ingredients this produces an ongoing challenge at the end of their lifetime. There are over 15,000 artificial playing turfs in the US and about 1,500 are added yearly. The synthetic turf industry repurposes about one-twelfth of the 300 million auto tires that are withdrawn from use each year. An average soccer field of 80,000 square feet can use 27,000 crushed tires for infill at 4-15 pounds per square foot,

equivalent to 320,000-1 million pounds (160-500 tons) of infill along with 40,000 pounds (20 tons) of plastic (Claudio 2008).

Synthetic turf fields are typically under warranty for 8 years and have a lifespan of about 10 years. Thereafter the material must be disposed of and typically it is landfilled. While industry increasingly attempts to reuse or recycle their product, ultimately it is burned or chemically changed into substances that are potentially as harmful and disposed of somewhere later, adding to planetary pollution.

In general, these fields are never completely recycled and are increasingly dumped on unused private land (where owners are paid a rental fee), empty lots and sometimes illegally dumped where they continue to leach hazardous chemicals. Industry advertising claims that artificial turf is recyclable has been challenged in a formal complaint (PEER 2022, York Daily Report 2019). Even if the artificial turf can be recycled there is a substantial carbon footprint as well as economic cost to do so. Moreover, any increased recycling costs will be added on to the price paid by those purchasing artificial turf.

3. Sports Injuries

Injury prevention for athletes and children should be a fundamental objective as youth sports injuries can have not only short-term impacts but also more serious long-term impacts from orthopedic injuries. Many studies show an increased risk of lower extremity sports injuries from artificial turf in **high schools** (Paliobeis 2021; Voos 2019), **colleges** (Loughran 2019) and **professional sports** (Mack 2019; Calloway 2019; Robertson 2022; Gould 2023). It is concerning that Gould (2023) noted that studies showing a higher risk on natural grass were all funded by the artificial turf industry.

Biomechanical studies show there is increased frictional force at the shoe-surface interface with artificial turf compared to natural grass, thus likely explaining an increased incidence of injuries to the foot, ankle and knee. Furthermore, athletes' consistent perception is that natural grass is easier to play on and results in fewer injuries (Taylor 2012). Smeets (2012) concludes, "Torques on external rotational movements were significantly higher with blades [artificial turf]... High rotational torques between the shoe outsole and the sports surface has been correlated with torsional injuries of the lower limb and knee." Balazs (2015) notes this "is potentially relevant for the risk of anterior cruciate ligament (ACL) rupture, where noncontact mechanisms are frequent." Robertson (2022) performed the largest study of rugby player injury risk and surface type. They noted, "a significantly greater mean severity of hip/groin, and foot/toe injuries on artificial surfaces."

Turf toe is an injury initially coined by and most commonly seen on artificial turf. It typically occurs when an already hyperextended metacarpalphalangeal joint at the base of the toe has additional force placed on it from behind by another player contacting the heel or during play. If there is less "give" from the turf then a hyperextension injury occurs, resulting in anything from a minor sprain to a complete tear of the ligamentous complex

supporting the toe joint. (Najefi 2018) Turf toe is a rare but debilitating condition that requires accurate diagnosis and early definitive management to prevent a chronic condition.

Concussion and Playing Field Surface

Surveys of high school and collegiate trainers have shown more serious concussions occur when athletes play on artificial fields that have been built on a concrete foundation (Guskiewicz 2000; Naunheim 2002), or with firm gravel base. Natural grass absorbs physical impacts better. Villanueva (2024) tested this noting that “American football has the highest rate of concussions in United States high school sports. Within American football, impact against the playing surface is the second-most common mechanism of injury.” The authors measured impact deceleration between natural grass and synthetic turf high school football fields and “showed significantly greater impact deceleration on synthetic turf compared to the natural grass surfaces.”

Studies that confirm higher injury rates:

Gould (2022) in a review of 53 articles on sports injuries found a higher incidence of foot and ankle injuries on artificial turf, both old and new generation turf. He also revealed that, “Only a few articles in the literature reported a higher overall injury rate on natural grass compared with artificial turf, and all of these studies received financial support from the artificial turf industry.”

Paliobeis (2021) This study collected data from 26 high schools and found “Athletes were 58% more likely to sustain an injury on artificial turf. Football, soccer, and rugby athletes were at a significantly greater injury risk on artificial turf. Upper and lower extremity and torso injuries also occurred with higher incidence on artificial turf.”

Voos (2019) This review of the above 2019 study from Case Western Reserve University and the University Hospital Sports Medicine Institute analyzed data collected by 26 high school athletic trainers during the 2017-2018 athletic seasons. The authors found, “athletes were 58 percent more likely to sustain an injury during athletic activity on artificial turf. Injury rates were significantly higher for football, girls and boys soccer, and rugby athletes. Lower extremity, upper extremity, and torso injuries were also found to occur with a higher incidence on artificial turf.”

Mack (2019) examined injuries reported during the 2012-2016 regular season NFL games that were played on modern-generation surfaces. The study found that playing on synthetic turf “resulted in a 16% increase in lower extremity injuries per play than that on natural turf.” They concluded, “These results support the biomechanical mechanism hypothesized and add confidence to the conclusion that synthetic turf surfaces have a causal impact on lower extremity injury.”

Loughran (2019) looked at injury data from the National Collegiate Athletic Association American Football: 2004-2005 through 2013-2014 seasons and found a significantly higher rate of knee injuries on artificial turf, finding artificial turf a “risk factor”.

Calloway (2019) looked at injuries over 4 Major League Soccer seasons (2013-2016) and concluded “overall ankle injury, Achilles injury, and ankle fracture were found to have a statistically higher incidence on artificial turf...[and] elite-level athletes prefer to play on natural grass surfaces due to a perceived increase in injury rate, discomfort, and fatigability on artificial turf.”

Najefi (2018) describes “Turf Toe,” which is a “debilitating condition, particularly seen in American footballers after the introduction of harder, artificial ‘turf’ surfaces.” He noted that, “in a survey of 80 active professional American football players, 45% had suffered turf toe injuries in their professional careers, with 83% occurring on artificial turf (Rodeo) .”

Sousa (2013) performed a one-season prospective study of amateur soccer players on artificial turf and found, “Injury incidence in amateur soccer players is higher during matches played on artificial turf than during training sessions.”

Meyer (2005) A 5-year prospective high school football study published in 2005 noted that during higher temperatures there were reported higher incidences of noncontact injuries, surface/epidermal injuries, and muscle-related trauma, reported on artificial fields.

4. Athlete Preference for Natural Grass Playing Fields

Ford and Monsanto Industries joined efforts to make the first artificial turf in 1964 called ChemGrass which was installed in the Houston Astrodome, when the grass died due to issues with the plastic covering of the dome. By the 1980’s athletes were complaining that the turf, then typically made with a base of concrete, was harder and caused more injuries. Indeed, there were more concussions seen on artificial turf fields (Guskiewicz 2000). Earlier turf studies noted, “A number of high-profile professional football players have suffered career-ending concussions.” (Naunheim 2002). Newer materials have been used with more infill placed on fields along with a compacted gravel base to address this issue. A poll by the National Football League in 1995 revealed that 95% of players believed that synthetic turf increased their risk of injuries (Claudio 2008). A recent National Football League Players Association (NFLPA) survey found similar results on newer artificial turf fields. (NFLPA 2020) As noted above, there is both anecdotal and scientific evidence of higher rates of injuries on artificial turf.

College and professional athletes prefer natural grass playing fields by far, due to reduced injuries and ease of play (Owens 2016; Dumas 2023; NFLPA). Players describe artificial turf as “sticky”. The NFLPA has taken a strong public stance against artificial

turf fields, advocating that "NFL clubs should proactively change all field surfaces to natural grass." (J.C. Tretter) The NFL Players Association tracks the league's official injury reports and has consistently found that natural grass fields provide a much lower risk for injuries when compared to artificial surfaces, both during practices and games. The NFLPA analysis shows that players have "a much higher rate of non-contact lower extremity injuries on turf compared to natural surfaces. Specifically, players have a 28% higher rate of non-contact lower extremity injuries when playing on artificial turf. Of those non-contact injuries, players have a 32% higher rate of non-contact knee injuries on turf and a staggering 69% higher rate of non-contact foot/ankle injuries on turf compared to grass." NFLPA President Tretter explained, "When you put so much force and so much torque in the ground, eventually something has to give. When you're on turf, it's going to be your joint."

5. Infections

Methicillin-resistant *Staphylococcus aureus* (MRSA) has been recognized as a significant skin infection in the athletic population, causing minor to serious infections. MRSA is responsible for 33% of infectious outbreaks reported among competitive high school and collegiate athletes. Bowers looked at three Division-I collegiate football programs and found that of the 491 collegiate football players, "33 (6.7%) were diagnosed with MRSA infections. Cutaneous manifestations included abscess (70%), cellulitis (16%), folliculitis, impetigo, and necrotizing fasciitis. Of the infections, 90% underwent surgical drainage, whereas 27% received intravenous antibiotics." The most common areas for infections were in the extremities: elbow, knee and forearm (Bowers 2008).

It is notable that high school football players have a 4-fold increase in MRSA infections than that of the general student-athlete population. While locker room surfaces can harbor MRSA, artificial turf can as well. An EPA study on artificial turf showed that 42% had at least one sample with *Staphylococcus aureus*. Of those, 70% had a least one positive sample for methicillin resistance.

The abrasive nature of synthetic turf along with sheltered MRSA in the turf and infill can make athletes and kids more vulnerable to "turf burn" and infection (Keller 2020). Synthetic turf requires bactericidal chemicals to reduce bacterial growth on fields and infections in players. These liquid turf cleaners can also be toxic and may pose risks to the health of workers, children, and surrounding ecosystems. Bactericides have been shown to act as skin sensitizers (Hahn 2010).

6. Localized Urban Heat Islands and Athlete Heat Stress

Artificial sports fields are known to absorb and retain heat from the sun thus creating significantly higher temperatures, at times 40 to 60 degrees higher than living grass, even

with moderate air temperatures. Studies at Penn State University's Center for Sports Surface Research compared surface temperatures of various synthetic turfs versus natural grass and found "that the maximum surface temperatures during hot, sunny conditions averaged from 140° F to 170°, noting that grass fields rarely get above 100° F due to the cooling effect of natural water evaporation from the living grass (NRPA). These studies have been replicated many times. The heat can be so intense it has been known to melt the plastic (DeSocio 2015).

Heat Injury- These higher temperatures on artificial turf sports fields can cause heat stroke, heat exhaustion, poor athletic performance and skin burns, making these fields potentially unusable under hotter weather conditions. Irrigating the fields with water reduces temperatures; however, the effect lasts for less than 20 minutes, according to research performed by Penn State Center for Sports Surface Research (Abraham 2019; Claudio 2008; NPRA 2019).

The **Consumer Product Safety Commission** notes, "Most adults will suffer third-degree burns if exposed to 150° F water for two seconds. Burns will also occur with a six-second exposure to 140° F water or with a thirty second exposure to 130° F water. Even if the temperature is 120° F, a five-minute exposure could result in third-degree burns." **Note: A hot water heater is set to 120° F, as above that burns can occur.**

Heat stress on artificial turf vs natural grass was reviewed by Liu and Kim (2021). Heat waves and hot weather threaten human health when one is not exercising. Those playing sports or participating in strenuous exercise are at increased risk of heat-related illness. Artificial turf creates a higher temperature microclimate due to heat absorption from the sun. The authors note that **children have been identified as a heat vulnerable group** physiologically compared to adults due to "a higher surface area-to-mass ratio (Cheng, 2020), higher metabolic rate (Fabbri, 2013), higher skin temperature during exercise (Cheng, 2020), quicker rise in core temperature (Vanos, Herdt, Lochbaum, 2017), and lower sweat production (Gomes, Carneiro-Júnior, Marins, 2013). Psychologically, children have less experience coping with or realizing the signs of heat stress than adults (Cheng, 2020). Their findings show that children suffer a 24% longer *Extreme danger* duration on artificial turf on sunny days than natural grass (Liu and Kim 2021).

An urban heat island effect arises when natural land cover, vegetation and trees (greenspaces), which have natural evaporative cooling, are replaced with buildings, pavements and other surfaces, such as artificial turf, also called hardscape, that absorb heat from the sun. These artificial surfaces store heat and upon release can raise air temperatures in adjacent areas or even communities. Urban heat islands can be seen from space and differentiated from natural green landscapes. (ESA) Cities can have temperatures much higher than rural areas with vegetation. Even within cities there is significant variation depending on greenspace, parking lots, and housing density. Urban heat islands are being addressed now in cities such as New York, which has a "Cool neighborhoods NYC" program to plant trees and increase vegetation to cool the surrounding area. (Johnson 2022).

Studies Showing High Heat on Artificial Turf Fields

Brigham Young University: After an athlete suffered a heat burn from artificial turf in Utah, Brigham Young University performed a study on the artificial turf and found that the artificial turf temperature was 87 °F hotter than natural grass (Williams and Pulley 2002). A temperature recorded on an artificial turf was 200°F, well above that which would cause a skin burn. Buskirk (2002) measured temperatures for 24 days on artificial turf, natural grass and in air and recorded turf temperatures that were 50 °F higher than natural grass temperatures and reached 70 °F higher than the air temperatures.

Penn State University Center for Sports Surface: Studies at Penn State University's Center for Sports Surface Research compared surface temperatures of various synthetic turfs and found "that the maximum surface temperatures during hot, sunny conditions averaged from 140- 170° F, noting that grass fields rarely get above 100° F due to the cooling effect of natural water evaporation from the living grass. (NRPA)

University of Missouri: A University of Missouri comparative study showed **with artificial turf** there were both "elevated air temperatures (138 °F) and elevated turf temperatures (173 °F) – while **adjacent natural turf temperatures** were 105 °F and local air temperatures were 98 °F". (Abraham 2019)

University of Tennessee: This study by Thom et al (2014) looked at ten synthetic turf surfaces at the University of Tennessee Centre for Athletic Field Safety with different infills. They noted that maximum temperatures on artificial turf were 187 degrees Fahrenheit with ambient air temperatures of 98.7 degrees Fahrenheit. The authors noted, "Despite differences in infill ratios of crumb rubber to sand (0 kg m⁻² to up to 34.2 kg m⁻² of crumb rubber and sand), synthetic turf surface temperatures varied less than 6 C between the systems suggesting that synthetic turf infill does not affect surface temperature as much as fibers."

Local Heat Island from Artificial Turf at Moffett Park, Sunnyvale, California: Locally the Moffett Park Specific Plan of 2020 also mapped out the local heat island effect and it was evident on the artificial sports fields. **The Twin Creeks Sports Complex**, built in 1985, has 10 all-purpose synthetic turf fields which can be identified in the report as having a temperature in the hottest range (111-138 °F) versus the immediately surrounding area of 102-111°F. Average summer temperatures are "expected to increase in Santa Clara County by ~4°F by 2050 and up to more than 6°F by 2100 (Maizlish et al. 2017), while the number of extreme heat events will double by 2050 and triple by the end of the century." (MPSP, Cal-Adapt.)

Slater (2010) Noted in his study that parks can be cooler than the surrounding urban environment by up to 7°C and this extends up to 100 meters beyond a park borders.

Cooling Methods Used for Artificial turf

Cooling of artificial turf is accomplished through irrigating the field with water. The cooling effect lasts only about 20 minutes (Penn State Center for Sports Surface Research). In arid or semiarid climate zones the amount of water used to maintain artificial turf at temperatures similar to irrigated natural turf grass were comparable (Kanaan 2020). Attempts to alter turf materials to reduce surface temperatures significantly have not been shown to be successful to date. The turf is still significantly hotter. Games can be cancelled if temperatures are too high.

Heat Guidelines for Play on Artificial Turf

National Recreation and Park Association (NRPA) Heat Guidelines for Artificial Turf: For the safety of children public schools have developed heat guidelines for playing on synthetic sports fields due to the higher artificial turf temperatures even with moderate air temperatures. The National Recreation and Park Association (NRPA) 2019 notes that above 120 degrees burns can occur, as well as dehydration with heat stroke, heat exhaustion and poor athletic performance, making these fields potentially unusable under certain weather conditions.

The Montgomery County Public Schools developed the following heat guidelines that apply to and are posted at all its artificial turf fields:

- Anytime the outdoor temperature exceeds 80 degrees, coaches exercise caution in conducting activities on artificial turf fields.
- When outdoor temperatures exceed 90 degrees, coaches may hold one regular morning or evening practice (before noon or after 5 p.m.).
- When the heat index is between 91–104 degrees between the hours of noon and 5 p.m., school athletic activities are restricted on artificial turf fields to one hour, with water breaks every 20 minutes.

It is recommended that artificial turf fields be monitored for temperature and play times adjusted. As global temperatures rise with climate change the heat effects of artificial turf is an ever-increasing concern.

7. Children are More Vulnerable

Artificial turf contains hazardous chemicals and heavy metals. Children are especially vulnerable to all toxic exposures due to their immature biological systems. Scientific evidence (CDC, Landrigan 2001, 2016, 2023) notes that:

- “Children breathe more air, drink more water, and eat more food per pound of body weight than adults.
- Children are more likely to put their hands in their mouth.
- A child’s body may not be able to break down and eliminate harmful contaminants that enter their body.
- Rapid growth can be disrupted easily by toxic exposures

- “Health problems from an environmental exposure can take years to develop.”

On an artificial sport field children and athletes are routinely in close contact with dust and chemicals emitted from the surface of the fields, especially with soccer, football, field hockey and lacrosse, making them more readily inhaled, ingested, and in closer contact with the skin. Thus, it is reasonable to expect that these synthetic turf fields can pose an increased health risk to children. Precaution is thus imperative. (The full list of references is listed below under Children’s Vulnerability to Toxins)

Why Children are More Vulnerable:

- **Children’s ability to metabolize**, detoxify, and excrete chemicals is different from that of adults. Children are less able to detoxify and excrete toxic chemicals (Carroquino 2012).
- **Children undergo rapid growth** and development, and their development phases are perfectly scheduled to achieve complete functional development. If a developmental phase is disturbed at a given time, the correct pathway can be lost, thus causing developmental delay or arrest (brain development, reproductive development, immune development, etc) with permanent and irreversible dysfunction. (Carroquino 2012).
- **Environmental toxicants can harm germ cells** which affect an adult’s own fertility as well as the health of the offspring. (Carroquino 2012).
- **Chemicals can act as endocrine disruptors** that can block or enhance and endocrine effects and alter development at extremely low concentrations (Parts per trillion PPT -Lawson) and according to the OECD 2023, “They can trigger adverse effects at doses below the threshold values of traditional chemical analysis”. Disruption of thyroid hormone changes is especially problematic as this can indirectly alter critical pathways of neural development.
- **The immune system is not mature** up to the age of 7 or 8 (Simon 2015), and beyond that is constantly changing thus is susceptible to toxins causing autoimmune disease even in adulthood, i.e. lead, cadmium and mercury (Kharrazian 2021) and in the case of PFAS even causing reduced immune response to childhood vaccines (Grandjean 2017), as well as reproductive harm (Rickard 2022) and with fetal exposure it is strongly associated with congenital heart disease (Li 2024).
- **The brain and nervous system are not fully developed** until the age of about 26, with different stages of growth and vulnerability. Many chemicals pregnant women and children are exposed are neurotoxic and exposures can lead to neurobehavioral developmental abnormalities. (Grandjean and Landrigan 2014) Lead can cause direct damage to neurons with no safe level of exposure.
- **The reproductive system is complex** and can be disrupted by toxic exposures in utero or even after birth. Male reproduction is particularly susceptible as sperm is constantly maturing. (Lahimer 2023). Female ovaries are partially mature at birth and subject to toxins which can “age” the germ cells in ovaries throughout a lifetime and cause later infertility, also affecting the health of the offspring (Rickard 2022). The measure of cumulative toxic exposure is infertility. (Thomas)

- **Chemicals can act as direct neurotoxins** affecting brain development, i.e. lead causing damage to the hippocampus (memory center) and cerebellum and while nerve cells other than the brain can regenerate, brain cells have limited capacity for regeneration thus are more vulnerable to permanent damage. (Grandjean and Landrigan 2014)
- **Chemicals can also alter sections of DNA** without altering the base sequence i.e. epigenetic changes-and these alter the expression of genes throughout life-altering development and disease. (Ideta-Otsuka 2017)
- **Chemicals can have age dependent rates of absorption** and in one study, lead was absorbed 40-50 times more in younger animals (Sanders 2010)
- **Chemicals can also cause inflammation** of tissues in the body to create or enhance diseases in childhood throughout adulthood (Furman 2019)
- **Longer exposure from childhood-** “There is more time to develop chronic diseases triggered by early exposures...Many diseases, such as cancer and neurodegenerative diseases, are thought to arise through a series of stages that require years or even decades from initiation to actual manifestation of disease. Carcinogenic and toxic exposures, sustained early in life, including prenatal exposures, would then be more likely to lead to disease than similar exposures encountered later.” (Carroquino 2012)
- **Synergistic exposures to multiple chemicals** together can enhance toxicity and adverse health impacts (Gaynor 2022)

8. Cancer and Chemicals Still a Question

While there is no proof that artificial turf causes cancer, scientific evidence shows that many chemicals used on artificial turf and components are carcinogenic, can be endocrine disruptors and can be toxic to aquatic organisms. Murphy (2022) highlights this concern, noting a troubling lack of scientific data noting, “ The only human epidemiology studies conducted related to artificial turf have been highly limited in design.”

While there is an unfortunate lack of independent scientific data on the health impacts of artificial turf, Tarafdar (2020) studied risks of poured rubber surfaces versus classical soil playgrounds in Seoul and noted that the “cancer risk is approximately 10 times higher in poured rubber surfaced playgrounds than in uncovered soil playgrounds. Cancer rates in children and adolescents are rising (Siegel; CDC - Cancer in Children and Adolescents)

9. Environmental Impacts of Artificial Turf: Toxic inputs and Outputs, Water Contamination, Harm to Wildlife, Air Pollution, Carbon Footprint

The components of artificial turf are derived from fossil fuels, which have a number of troubling negative externalities: air pollution, water contamination, and CO2 emissions

contributing to global climate change as well as toxic pollution from short lived as well as “forever” chemicals and microplastics that use petroleum as the base. Adverse effects on soil organisms, birds and biodiversity have also been identified. The true costs of artificial turf have not been added in.

Alms (2016) gathered data for a life cycle analysis (LCA) of artificial turf using data from the Carnegie Mellon “Economic Input-Output Life Cycle Assessment” (EIO-LCA) to identify artificial turfs “unfiltered environmental toll”. She found that during the manufacturing process artificial turf:

- Released multiple air pollutants including carbon monoxide, CO₂, nitrogen oxide, sulfur oxide, PM 10, PM_{2.5} and volatile organic compounds.
- Produced about 143 metric tons of CO₂ released per field
- Used 4,985 kGal of water to produce one synthetic field, while about 1,290 kGal are needed to maintain a grass field per year.

Magnussen (2017) highlights the harmful substances from artificial turf that “may leach to water from infill of both new and recycled material.” The authors also identified increased energy use and greenhouse gas emissions from excavation and transportation of soil and rock materials, production and replacement of infills, maintenance with plowing, brushing and raking of the artificial turf field. Also noted was that the end-of-life emissions from disposal with incineration caused the highest energy use and emissions. They state, “One study found that natural grass was environmentally favorable to artificial turf, however the result was opposite if impacts were divided with the number of playing hours provided (Cheng et al., 2014)”. These facts, notwithstanding, are only estimates and do not take into account differences in playability on sunny days or increasing temperatures with climate change or extreme weather events. They also fail to take into account any health care costs for those injured or ill, or any costs for loss of habitat, degradation of the environment or cleanup costs.

Royer (2018) examined hydrocarbon gas emission from polyethylene, which is the most produced and discarded synthetic polymer globally, and the main plastic used in artificial turf blades. The authors found that as polyethylene ages it emits both methane and ethylene and this increases with time. The authors note that “plastics represent a heretofore unrecognized source of climate-relevant trace gases that are expected to increase as more plastic is produced and accumulated in the environment.” Royer noted in an interview, “**Synthetic turf has a lot more effect on the environment than anything else made of plastic.**”

Celeiro (2018 and 2021) looked at leaching of chemicals from sports fields and found multiple chemicals of environmental concern that were continuously entering the water, as well as chemicals identified in the air. The authors concluded, “The transfer of target chemicals into the runoff water poses a potential risk for the aquatic environment.”

Pochron (2018) found that aged crumb rubber and new crumb rubber posed similar toxic risks to earthworms, noting, “This study suggests an environmental cost associated with the current tire-recycling solution.”

Zhu X (2021) states, in his article, **The Plastic Cycle – An Unknown Branch of the Carbon Cycle**, “It is clear that plastic pollution has become a major environmental issue of our time. Due to the low degradation rates of plastic, almost every piece of plastic that is produced is still somewhere on this planet.” He suggests using the “terminology of biogeochemical cycles” to help scientists address this issue with sinks, reservoirs and fluxes to denote particles moving from one location to another. This would create the “plastic cycle” to better characterize the global nature of this problem.

Sanches-Sotomayer (2022) surveyed 21 parks with artificial grass and 24 parks with natural grass in 18 towns in autumn 2020 looking at differences in bird populations and biodiversity in artificial turf versus natural grass fields. The researchers found “The parks with natural grass always harbored higher gamma diversity, species richness and abundance... the trend of replacing natural by artificial grass in urban parks has harmful effects on urban bird communities and is a threat to bird conservation.” **Bernart-Ponce (2020)** found a similar loss of house sparrows where natural grass has been replaced with artificial turf.

A Report by the Center for Climate Integrity, “The Fraud of Plastic Recycling: How Big Oil and the plastics industry deceived the public for decades and caused the plastic waste crisis,” notes that industry knew for decades that most plastics cannot be recycled and that recycling plastic is neither technically nor economically viable. The report states, “Some types of “advanced recycling” may produce materials capable of being reprocessed into new plastic (plastic-to-plastic)—however, the majority of these processes produce waste or fuel (plastic- to-fuel), which do not qualify as recycling. As such, plastics cannot be meaningfully recycled through either method.”

SB 54- CA 2024-The Plastic Pollution Prevention and Packaging Producer Responsibility Act

The artificial turf industry states that at the end of life at about 10 years, artificial turf will be collected for “advanced recycling”. California bill SB 54 (2022) California mandates recycling of many single-use plastic items but excludes chemical recycling of plastic which means that making fuels from used plastic are excluded as a definition of recycling. Artificial turf thus does not necessarily qualify for recycling. (SB-54)

10. Water Quality and Contamination from Artificial Turf

Artificial turf plastics were found in 50% of river samples and comprised 15% of all plastics in the water. deHaan (2023) Artificial turf blades are typically composed of polyethylene and polypropylene plastic along with a multitude of other chemicals. With wear and tear and UV light this plastic breaks down into micro and macro-plastics. As artificial turf is an impervious substance, the surface water from the fields runs off into storm drains, streams, rivers and the ocean.

Researchers at the University of Barcelona in Spain in 2023 looked at 417 samples of river and surface waters including several waterways entering the ocean and found distinctive plastic from artificial turf in 50% of the water samples. They also found that “artificial turf fibers accounted for up to 15% of meso- and macro-plastic abundance.” deHaan (2023), “**The dark side of artificial greening: Plastic turfs as widespread pollutants of aquatic environments.**”

11. Environmental Benefits of Natural Grass

Benefits of Natural Grass

Water Conservation

Using drought resistant deeper rooted turfgrass, allowing for taller growth on turfgrass, using recycled water and following proper irrigation practices will lead to water conservation, as many fields are overwatered. Recycled water in some areas may contain too much salt to place on artificial turf, which will cause degradation, thus fresh water is needed to irrigate these artificial turf fields (Coastal Commission 2023). Recycled water can be used on natural grass turf, even though the water may have a higher salt concentration, as turfgrass is typically salt tolerant. “Turf grasses, most annuals, and deciduous trees are more tolerant of saline water” and do not accumulate high levels of salt because of frequent mowing. (UCANR)

Groundwater Preservation and Recharge

Dense above ground turfgrass biomass traps and holds water which reduces excess runoff and allows more water to infiltrate into the soil, enhancing groundwater recharge.

Healthy Soil

Organic turf fields which are designed to use few or no pesticides support healthy soil bacteria and earthworm populations, which contribute to “increased macropore space in the soil, resulting in higher soil water infiltration rates, higher water holding capacity, and improved soil structure.”

Restoration Ecology, Bioremediation and Soil restoration

Soil bacteria are also capable of breaking down organic pollutants in the environment, such as pesticides and other manmade pollutants. This concept is now being used in a process known as bioremediation as a less expensive and more effective option for cleaning up contaminated sites. (Alori 2022). Grass fields thus could help restore environmentally damaged areas, and at least prevent further land degradation and chemical pollution. Principles of restoration ecology can be used throughout the conversion of the Santa Clara County fairgrounds to reverse and repair some of the damage done to ecosystems and biodiversity. (Vaughn 2010)

Integrated Pest Management Programs (IPM) to Reduce Pesticide Use

There are many well established IPM programs in the US addressing pesticide use in parks, landscaping and agriculture. These are in cities, counties (Santa Clara County, San Francisco, Marin), universities (University of California, Massachusetts), as well as formulated by the US Department of Agriculture (USDA) and US EPA. All of these programs focus on alternatives to pesticides to reduce harm to the environment and human health. (See IPM in references)

Carbon Sequestration by Natural Grass

Studies have shown carbon sequestration could be higher or the same when one considers energy inputs for maintenance and highly managed fields. A study of turf growers in Australia showed a positive carbon sequestration among other benefits on turf farms.

Zirkle (2011) notes that “Lawns can be a net sink for atmospheric CO₂ under all three evaluated levels of management practices [low to high]” and factoring in mowing, irrigating, fertilizing, and using pesticides.

Tidaker (2017) notes for golf course management the amount of fertilizer, watering and mowing can affect the greenhouse gas emissions and should be addressed to reduce carbon footprint and increase carbon sequestration.

Cumming J (2018). Environmental Assessment of the Australian Turf Industry. The authors state, “The lifecycle assessment involved a review of five turf installation sites over one year. It showed that a well-maintained patch of turf is environmentally healthy, conserves natural ecosystems and will continue to sequester carbon dioxide from the atmosphere through the growth of soil organic matter... This study has also shown that all turf growers were able to provide a carbon positive product with net sequestered carbon dioxide averaging 1.6 kg of CO₂eq per square meter of turf produced... or 48,000 Tonne of CO₂eq per year.”

11. Environmentally Friendly Organically Managed Natural Turf Fields

Natural grass fields can provide a long-term, cost-effective, high-performance surface for athletic activities. Thoughtful management of natural grass organically improves the health of the soil and grass by supporting a rich microbial environment and promoting a strong root system that withstands wear. In addition, there is no need to put synthetic toxic pesticides or fertilizer on the fields. Water use may be reduced as well.

To reduce the risks of chemical exposure and to protect water quality some cities and schools have chosen to rehabilitate or rebuild natural grass turfs or replace artificial turfs with natural grass, learning how to maintain them organically, in a more ecological way with lower water inputs and with longer playability. These playing fields are living carbon sinks which contribute to biodiversity by their non-toxic nature and cooling effect that supports surrounding greenspaces, as well as living organisms such as bacteria, fungi, earthworms and birds. They also protect the health of humans and the environment.

Building an Organic Maintenance Program for Athletic Fields: Guidance from Experts and Experienced Communities. Toxics Use Reduction Institute, University of Massachusetts (TURI).

The key management elements used for increased performance and lower costs include:

- Aeration of the soil
- Proper irrigation and drainage
- Adjustments for mowing
- Soil testing for pH, moisture, nutrients and beneficial microorganisms
- The use of organic fertilizer
- Soil amendments

Examples of healthy safe natural grass turfs

Marblehead, MA: In 1998 the Marblehead Board of Health adopted a policy to reduce pesticides for the health and safety of children and families. Since 2002 all of Marblehead's playing fields have been managed organically, using integrated pest management (IPM) techniques. It was noted that in the past they have only closed the field for high rainfall, however, in 2018 "the fields were closed five times due to rain and twice due to extreme heat. Each was a one-day closure. The heat-related closures were the first that the town has experienced."

Start Date: 2002

Acres: 20 acres

Hours of Use: 1360 hours

Maintenance Cost: \$4,250 - \$4,500 per acre

Cancellations: 7 times

Springfield, MA. In 2014 Springfield received support through a grant to implement organic land care and grass turf management practices on municipal and school properties. The city started with six test pilot cases and grew to 12 organically managed sites by 2019, including multiuse or single use fields. One of the multiuse sports parks, Forest Park Baseball and Soccer Complex, which is open 7 days a week, tallied 3,300 hours per year of use. For strictly soccer use Treetop Park Full-Sized Soccer Field there was 1,051 hours per year of use.

Start date: 2014

Acres: 67 acres

Hours of use: 3,300 for multipurpose and 1,051 for soccer

Total Annual Maintenance Cost: \$98,080 for 12 fields

Cost per acre: \$1,460.

Martha's Vineyard, MA. In 2017, a group of Martha's Vineyard parents established The Field Fund, Inc to provide support to Martha's Vineyard schools and towns to improve their grass playing fields using organic practices. By September 2020 **The Field Fund** was supporting five athletic field complexes. Using organic practices, the schools and parks were able to meet all of their use needs, with only a few cancellations due to weather-related field conditions. In 2019 none of the 5 athletic fields were closed.

Start Date: 2017
Area: 5 sports and recreational fields
Total Annual Maintenance Cost: \$65,600
Cost per acre: \$7620.

Grass Sports Fields on Colleges and Universities

Snapdragon Stadium at San Diego State University was placed in 2022 and is popular with athletes and spectators.

Texas A&M. Ellis Field opened in 1994 and still has natural grass (Tifway Bermuda) .
<https://12thman.com/facilities/ellis-field/9>

University of Arkansas in 2019 replaced artificial turf with natural grass.

The Sports Field Management Association every year presents awards to the best natural grass sports fields that “exhibit excellent playability and safety and whose managers utilize innovative solutions, effectively use their budgets, and have implemented a comprehensive agronomic program. Five sport fields receive awards- baseball, football, softball, soccer, and sporting grounds. These are given to schools and parks, colleges and universities as well as professional fields throughout the Unites States. These awards promote natural grass sport fields for safety, quality and beauty. Prior winners were

- Jack Trice Stadium Iowa State University. Ames, IA
- Ryan Field. Northwestern University. Evanston, IL
- Folsom Field University of Colorado. Boulder, CO
- Ben Hill Griffin Stadium. University of Florida. Gainesville, FL
- Spartan Stadium. Michigan State University. East Lansing, MI
- Scott Stadium. University of Virginia. Charlottesville, VA
- Kyle Field. Texas A&M University. College Station, TX

12. Water Use of Artificial Turf Versus Natural Grass

Water is a limited and precious resource. One argument made to choose artificial turf over natural grass is the low water use compared to natural grass fields. A closer look at this shows that the differences are not as dramatic as claimed when a life cycle analysis is performed that includes manufacturing costs and irrigation for cooling. In in hotter, dryer climates where artificial turf is supposed to be most beneficial more water is used to cool

the field for players to extend use and reduce risks of heat related illness. Kanaan (2020) noted comparable water use for artificial turf and natural grass in hot climates in order to keep the temperature the same.

Alms (2016) looked at Carnegie Mellon 2015 data on lifecycle analysis of production and found that the amount of water used to manufacture artificial turf was 4,985 kGal of water to produce one synthetic field, while about 1,290 kGal are needed to maintain a grass field per year. Thus, the **manufacturing of artificial turf itself equaled 4 years of natural grass irrigation not counting watering in hot weather or surface cleaning.**

Kanaan et al (2020) performed a study at New Mexico State University to evaluate the amount of water required to maintain surface temperatures comparable to those of natural turfgrass areas. They noted that, “In arid and semiarid climate zones the surface temperature of the artificial turf fields can exceed 80°C [176 degrees Fahrenheit during the summer, requiring irrigation and drainage systems to keep them cool enough for use.... The model indicates that over a 24-hr period, **the amount of water (3.00 to 5.00 mm) required to maintain artificial turf at temperatures similar to irrigated natural turfgrass are comparable.**”

Artificial Turf is *Not* Drought Tolerant Landscaping

Regarding water use, the Santa Clara Valley Water District’s Landscape Rebate Program for water conservation no longer includes artificial turf as they recognize that, “there are healthier and more ecologically sound alternatives”. California Senate Bill 676, signed into law Oct 8, 2023 by Governor Newsom, specifies “that drought-tolerant landscaping does *not* include the installation of synthetic grass or artificial turf. [and]... drought-tolerant [natural] landscaping is a viable landscaping alternative that will further the goal of addressing long-term water conservation.”

Recycled Water Can Be Used on Natural Grass but *Not* on Artificial Turf

The California Coastal Commission in 2023 rejected an artificial turf baseball field at University of California Santa Barbara due to water quality impacts. They noted that **recycled water could not be used on the fields** due to its high salt content but recycled water could be used on hardy natural turfgrass.

13. Cost of Synthetic versus Natural Turf: Lifecycle Analysis

As cities and counties struggle with their limited budgets cost considerations become a central concern. Which is cheaper artificial turf or natural grass? While the narrative has been that artificial turf costs less, an analysis of the entire life cycle of artificial turf versus natural grass by Daviscount (2017) shows that using natural grass was cheaper in the long run. For grass fields there is initial equipment costs and it is noted that, maintenance decreases exponentially when additional fields are added. One full time skilled sports field

manager can maintain multiple fields. The disposal and replacement costs for a new field turf about every 8 to 10 years also need to be accounted for. Warranties for artificial turf are typically 8 years.

Identifying a complete lifecycle analysis for artificial turf versus natural grass is challenging due to variables and reviews seem to lack some of the direct or indirect costs, however, many articles provide some estimates. The additional costs for synthetic turf are described below and can be quite significant.

The Toxics Use Reduction Institute (TURI) performed a comprehensive cost analysis of artificial turf versus natural grass fields in 2015. They note that costs vary substantially depending on the type of field and the level of maintenance. They state, however, that “artificial turf fields have a higher life-cycle cost than natural grass fields. Once established, organic management of natural grass can be even more cost effective than conventional management of natural grass.” In addition, nonprofit groups such as The Field Fund have been created to help fund rebuilding or installing natural grass fields in schools and cities.

- **Installation costs** for an artificial turf field was about \$1,223,829. Infill costs varied from \$50,000 for crumb rubber to \$451,000 for “organic infill” .
- **Maintenance costs** varied widely for both with estimates from \$13,720-\$39,220 for synthetic turf to \$8,133-\$48,960 for a natural grass field.
 - **Maintenance of artificial turf systems** includes “fluffing, redistributing, and shock testing infill; periodic static control and disinfection of the materials; seam repairs and infill replacement; field line erasing and repainting; organic matter removal; and watering to lower temperatures on hot days.”
 - **Maintenance of natural grass** can include “irrigation, mowing, fertilizing, replacing sod, and other activities. A soil and grass health assessment of the field is needed to establish an appropriate maintenance program. Maintenance of a natural field may be minimized by substituting full field replacements and seam repairs with spot sod replacements

Daviscourt (2017) study noted, “The results of this case study support what has previously been estimated in the literature: synthetic fields cost more to install than natural turfgrass fields... The average cost of the life-cycle analysis for natural grass was \$821,000 and for synthetic infill was \$1,767,000.”

The initial cost for artificial turf is about \$1,350,000-\$2,000,000. Synthetic soccer turf fields last about 10 years as synthetic turf breaks down and becomes a safety, playability and aesthetic issue. It then needs replacement that costs \$350,000 to \$650,000 per artificial turf field, not counting any work needed on the base layer or drainage (Sports Venue Calculator). This is an added long-term cost for replacement added into the disposal costs. There are typically no replacement costs for natural grass.

The University of Arkansas came to the same conclusion noting increased maintenance costs of artificial turf. The costs for artificial fields included:

- **Installation Costs:** More extensive subgrade work for artificial fields

- **Annual Maintenance:** Additional infill, chemical disinfectants, sprays to reduce static cling and odors removal of organic matter, erasing and repainting temporary lines, irrigation because of unacceptably high temperatures on warm-sunny days.
- **Replacement Costs of synthetic turf vs grass**
- **Disposal costs:** Due to complex plastic components a special disposal fee is often needed.

Sports Field Manager Jerad Minnick, who has managed both natural and artificial playing fields collected data on costs. He states, “Existing turfgrass managers, provided with a few tools, can produce a low-cost, environmentally friendly field. In an age of needed job creation, committing money to maintain grass fields instead of building synthetic will create numerous new environmentally friendly jobs in the sports and park industry.” He also notes that for “grass fields, the cost numbers for maintenance decreases exponentially when additional fields are added.” Below is cost data for different quality of fields. Although this is from 2013 the initial costs for artificial turf as well as disposal fees have increased. Minnick notes there is debate about durability of artificial turf and highlights that artificial turf can fail. This was noted in a WTHR news report showing that some turf fields sold to schools and universities were wearing out more rapidly and had to be replaced. Warranties are typically for 8 years of use.

- Synthetic Professional: \$1,000,000
- Natural Grass Professional*: \$600,000
- Synthetic, Practice/ Tournament: \$850,000
- Natural Grass Practice/ Tournament*: \$350,000
- Natural Grass Youth Field*: \$150,000

Sports Venue Calculator (SVC) also showed that there is a range of costs for both, however, artificial turf is more expensive in terms of construction. Maintenance is generally in the same range to slightly more expensive for natural grass but this does not take into account disposal and replacement fees.

- Construction Costs Artificial Turf- \$700,000 - \$1,500,000
- Construction Costs Natural Grass Field- \$400,000 – \$820,000
- Maintenance Cost Artificial Turf per year \$6,000 - \$10,000
- Maintenance Cost Natural Grass Field per year- \$18,000-\$44,000

14. Year-Round Grass Playing Fields- The Grass is Always Greener

An argument made is that artificial turf withstands all weather and has more playing days. This may be true for winter sports at times, however, natural grass can be maintained with proper management in the winter (Neylan 2021). In hotter spring or even typical summer days artificial turf may be unusable. Artificial turfs must be constantly monitored if the outside air temperature is above 90 degrees and in sunny weather. In even moderate temperatures artificial fields can be unusable. This feature is not always calculated in field use data. Liu and Kim (2021) note the increased

vulnerability of children to heat related illness along with in increased risk of heat related illness on artificial turf. They found children suffer a 24% longer *Extreme danger* duration on artificial turf on sunny days than natural grass.

15. Mental Health and Wellbeing: Synthetic Turf Displaces Natural Green Space

Prior to 1970's all parks and sports fields were natural soft grass. Children and adults sat down on the grass, shared food and chatted. Small flowers often grew in the grass to create meadows. The use of synthetic fields displaces natural green spaces which are also important to the health, development and wellbeing of children. The tactile and sensory benefits of real grass are lost with artificial turf. Natural green spaces can reduce stress and improve wellbeing. (Zhang 2020) notes, "It is evident that time spent in, or exposure to, green space can improve positive mood and emotions, provide a retreat from daily hassles, and reduce the risk of psychological and physiological stress in adolescents. There is also evidence of lasting mental health benefits of green space exposure in childhood."

"Today's children largely grow up in synthetic, indoor environments. Now, with the growing popularity of synthetic turf fields, their experience with nature will be less than ever." (Claudio 2008) Athletes by far prefer playing on real grass (Owen 2016)

16. Policies to Ban Artificial Turf or Components

The concerns for harmful plasticizers and microplastics in artificial turf, long-term effects on children's health as well as life cycle analysis have led to policies to ban artificial turf altogether as well as ban specific toxic components. Zucarro (2022) reviewed policies on synthetic turf and wrote, "While nearly every country acknowledges the potential health risks posed by heavy metals, microplastics, PAHs, and PFAS chemicals, very few have actually implemented artificial turf and crumb rubber infill regulations and/or established adequate surveillance measures to protect those regularly exposed to the fields."

Governments in the US and abroad are restricting the use of artificial fields with crumb rubber or certain hazardous plasticizers (EU and California) due to environmental bio-accumulation of toxic chemicals.

Montgomery County, Maryland banned the use of tire crumb on any newly constructed artificial turf fields due to health concerns in 2015.

[<https://moco360.media/2019/11/18/turf-war/3/>]

Westport, Connecticut banned crumb rubber in 2017 and passed an "Ordinance prohibiting the application of synthetic infill material on playing fields on town property," David Brown, a Westport resident with a doctorate in toxicology from Harvard University, formerly headed up a toxicology group at the state health department. He testified in favor of the synthetic infill ban and stated, "The primary problem with turf is

the off-gas from particles that contain toxic and carcinogenic chemicals. When people ingest the crumb rubber, the toxic chemicals are released in their body.”

In 2021 the European Union (EU) expanded the scope of restriction of the eight polycyclic aromatic hydrocarbons (PAHs) in infill material in synthetic turf use on playgrounds or sports fields.

Boston banned artificial turf in parks due to toxic ‘forever chemicals in 2022.

Holland is banning crumb rubber infill on artificial turf fields due to soil pollution under the turf.

Oak Bluffs Board of Health Banned Turf Fields. Martha’s Vineyard, Massachusetts. April 23, 2024. <https://vineyardgazette.com/news/2024/04/23/oak-bluffs-board-health-bans-turf-fields>

California SB 676 (2023) reverses in part AB 349 (2015) to prevent city or county bans on drought-tolerant landscaping and specifies that “drought-tolerant landscaping does not include the installation of synthetic grass or artificial turf.”

San Marino, California (2023) placed a temporary extended moratorium on Oct 27, 2023 banning the use of artificial turf or synthetic grass within the city (Ordinance No. O-23-1410.)

Millbrae, California (2023) banned artificial turf in 2023 in all areas of the city (Ord. 806, § 1).Chapter 8.65).

Sunnyvale, California in October 2023 rejected a proposal to place artificial turf athletic field in a park renovation.

Conclusion

There has been no proof of safety for artificial playing fields and there are many data gaps. Few studies exist on the health impacts of artificial turf, while numerous chemicals hazardous to human health and the environment are found in artificial turf and its leachate (Murphy 2022). There is growing evidence that significant environmental, as well as, health and safety risks outweigh the presumed benefits of artificial fields. It appears that natural grass is less expensive when a full life cycle analysis is performed. In addition, natural grass prevents storm water runoff of toxins and provides living carbon capture as well. Water use on artificial turf is not as low as stated with a full life cycle analysis. Considering that studies on the risks of long-term health have not been performed, along with absence of comprehensive data on the hazardous chemical components of artificial fields we recommend:

- 1) Not to place artificial turf on playing fields, and
- 2) Should artificial turf already be present, to replace this with natural grass

Children are increasingly exposed to many toxins in the environment. As physicians we advocate for reduction in toxic exposures to reduce individual harm, societal harm, and health care costs which are rising. A precautionary preventative health approach is recommended to avoid unintended consequences and unintended downstream costs.

References

Note: After Legislation and Reports other References are in alpha order as follows- Articles Scientific; Artificial Turf Components and Additives; Bans Artificial Turf; Cancer and Chemical Question; Chemical and Plastic Exposures and Contamination; Children's Vulnerability to Toxins; Climate Change; Costs; Disposal and Recycling; Environmental Benefits of Natural Grass; Environmental Impacts of Artificial Turf; Health and Safety; Heat Related Illness and Urban Heat Effect; Infections; Injuries – Sports (and athletic preferences); Laws and Policy; Lawsuits and Litigation; Letters; Mental Health and Greenscapes; Natural Grass Field Examples; News Articles; PFAS; Videos; Water Use; Water Quality and Contamination.

Legislation, Policy, Position Statements

CA-SB-54 (2023) Solid waste: reporting, packaging, and plastic food service ware. (2021-2022)
https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB54

CA-SB 54 (2023). Plastic Pollution Prevention and Packaging Producer Responsibility Act. Gov. Newsom signs law allowing local governments to ban artificial turf. Oct 28, 2023.
<https://www.nbcsandiego.com/news/local/governor-newsom-signs-law-allowing-local-governments-to-ban-artificial-turf/3339853/>

CA-SB 676 (2023) Local ordinances and regulations: drought-tolerant landscaping. Signed into law Oct 8, 2023. <https://legiscan.com/CA/text/SB676/id/2844684>

CA-SB 676 (2023) - Senate Bill Policy Committee Analysis.
<https://alcl.assembly.ca.gov/sites/alcl.assembly.ca.gov/files/SB%20676%20%28Allen%29.pdf>

CA-AB 349 (2015) (GONZALEZ). COMMON INTEREST DEVELOPMENTS: PROPERTY USE & MAINTENANCE. New protections for homeowners within HOAs installing artificial turf. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB349

CA- AB 1423 (2023) Product safety: PFAS: artificial turf or synthetic surfaces. 2023.
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202320240AB1423

The entire report and citations can be found at www.ncsa.la/artificial_turf



SAFER
CONSUMER
PRODUCTS

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

Technical Document for Artificial Turf Containing Perfluoroalkyl or Polyfluoroalkyl Substances

February 12, 2026

Prepared by

Department of Toxic Substances Control

Safer Consumer Products Program

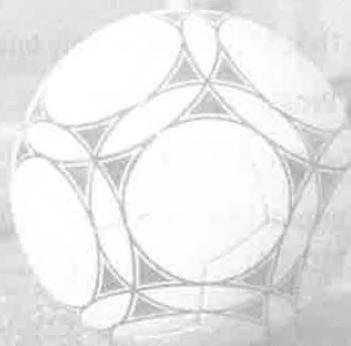
California Environmental Protection Agency



Department of
Toxic Substances
Control



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ABOUT THIS TECHNICAL DOCUMENT

The Department of Toxic Substances Control (DTSC) identifies product-chemical combinations for consideration as Priority Products in accordance with the Safer Consumer Products (SCP) regulations.¹ This technical document (document) outlines the key findings of our evaluation of artificial turf containing perfluoroalkyl or polyfluoroalkyl substances. We are publishing this information to provide transparency about our decision-making process and to highlight the considerable effort that went into evaluating this product-chemical combination.

Readers should consider the following:

1. This document is not a regulatory document and does not impose any regulatory requirements.
2. The document summarizes information compiled by DTSC as of February 2026.

KEY TERMS

Candidate Chemical: A chemical that exhibits a hazard trait and is listed on DTSC's Candidate Chemicals List

Priority Product: A product-chemical combination that has the potential to contribute to significant or widespread adverse impacts to humans or the environment

1. EXECUTIVE SUMMARY

DTSC has determined that artificial turf containing per- or polyfluoroalkyl substances (PFASs) meets the Priority Product identification and prioritization criteria outlined in the SCP Regulations: (1) there is potential for exposure to PFASs in artificial turf; and (2) the exposure has the potential to cause or contribute to significant or widespread adverse impacts. Additionally, artificial turf containing PFASs relates to all of the priorities and considerations for implementation identified in our [2024-2026 Priority Product Work Plan](#).

In 2024, the Synthetic Turf Council informed us that its member manufacturers were proactively engaging with their component and raw material suppliers to ensure that, by 2025, none of their products contain PFAS-based ingredients, including polymeric PFAS processing aids. Our goal is to shift markets away from hazardous chemicals to safer alternatives, and if that shift occurs prior to regulation, we consider this a positive outcome. To verify that a pre-regulatory market shift has occurred, we are pausing listing this product-chemical combination as a Priority Product to gather

¹ California Code of Regulations, title 22, Division 4.5, Chapter 55, Article 3.

additional information from manufacturers and to conduct product testing. If we find that PFASs continue to be present in artificial turf and that regulatory action is appropriate to address potential PFAS exposures and resulting harms, we plan to move forward with regulating this product-chemical combination. The remainder of this section summarizes the evidence to support our determination. Citations and additional details to substantiate the content in this executive summary can be found in the remainder of the document.

PFASs are a class of manufactured chemicals with at least one fully fluorinated carbon atom, as defined in Buck et al. (2011). All PFASs are Candidate Chemicals under the SCP program due to the designation of the entire class as Priority Chemicals for the Biomonitoring California program (Biomonitoring California 2015a).

In regulating PFAS-containing consumer products, DTSC has taken a class approach for several reasons:

- PFASs are a wide and varied group of chemicals used in many applications. All PFASs share one common trait—highly stable carbon-fluorine (C-F) bonds that make them or their final degradation products highly persistent in the environment.
- Persistence is a hazard trait identified in the Office of Environmental Health Hazard Assessment’s Green Chemistry Hazard Traits regulation 69405.3: “Persistence of a chemical in the environment promotes sustained exposure and contributes to accumulation in the environment.”
- Within the overall PFAS class, perfluoroalkyl acids (PFAAs) are the most problematic subclass. They are the most widely and thoroughly characterized subclass and are associated with a number of different health hazards, including endocrine disruption, developmental and reproductive toxicity, and immune dysregulation.
- In the case of PFAAs, their ubiquity in combination with their persistence results in continuous exposure from multiple sources, including contaminated drinking water sources and the food supply. They can accumulate in meat, plants, and drinking water, and ultimately in humans and wildlife.
- The vast majority of PFASs degrade into PFAAs, which typically increases their mobility in the environment, making containment or removal a challenge.
- While persistence alone warrants enough concern to include any member of the PFAS class in product prioritization, the health hazards associated with exposure to PFAAs are additionally concerning and underlie our listing.

For the sake of conciseness, this document does not contain all the supporting information related to all our conclusions, as this material is included in our three previously published PFAS-related Profiles.² These previously published Profiles include information related to the conclusions in the following (sub)sections:

- 3. Candidate Chemical Definition and Properties – introduction and subsections 3.1 to 3.5
- 4.4 Indicators of Potential Exposures to the Candidate Chemical
- 5. Potential for Significant or Widespread Adverse Impacts – introduction and subsections 5.1 to 5.4
- 6. Other Regulatory Programs – introduction and subsections 6.1 to 6.3
- 8. Additional Considerations – introduction and subsections 8.1 to 8.2

1.1. Potential for Exposure

Artificial turf is frequently used in buildings and recreational fields. The use of artificial turf raises concerns due to its potential to expose humans and the environment to PFASs. People who use (e.g., play on) artificial turf can be directly exposed to PFASs through inhalation, ingestion, and dermal absorption. Young children and other sensitive subpopulations are especially vulnerable to the effects of this class of chemicals, some of which are developmental toxicants. In addition to its potential to expose users to PFASs, artificial turf can also release PFASs to the environment. As artificial turf weathers, it can leach PFASs into water.

Once released to the environment during product manufacture, use, or disposal, PFASs become part of a virtually closed cycle leading to chronic human and ecological exposures. PFASs are found in aquatic, atmospheric, and terrestrial environments, including remote locations far from any point source. They are present in indoor dust, drinking water sources, food, wildlife, and humans—including the milk and serum of breastfeeding women. Because persistent PFASs lack a natural degradation route, their levels in the environment, humans, or biota will continue to rise for as long as PFASs are produced and used in consumer products.

In California, most end-of-life artificial turf is disposed of in landfills, which can release PFASs to the environment in leachates and gaseous emissions. Wastewater treatment plants (WWTPs) that collect landfill leachates, surface runoff, and residential and commercial wastewater do not effectively remove PFASs. PFASs in influent partition either to effluent water or sludge. When wastewater effluent is discharged into surface waters, PFASs are released into the environment, contaminating aquatic

² Product-Chemical Profiles for *Carpets and Rugs Containing Perfluoroalkyl or Polyfluoroalkyl Substances*, *Treatments Containing Perfluoroalkyl or Polyfluoroalkyl Substances for Use on Converted Textiles or Leathers*, and *Product-Chemical Profile for Plant Fiber-Based Food Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances*.

ecosystems and drinking water sources. When sewage sludge (which is also referred to as biosolids) is applied to soil, it can contaminate terrestrial ecosystems, drinking water, and human food supplies.

In summary, artificial turf has the potential to contribute to widespread environmental contamination and exposures. Humans and environmental organisms are exposed to PFASs during every point in the product's life cycle (manufacturing, use, and disposal) via inhalation, ingestion, and other routes. Children, a sensitive subpopulation, often play on turf and are potentially exposed to chemicals from this product. Exposures from repeated or frequent recreational activities may have cumulative effects. Industrial workers, installers, recyclers, and those who clean artificial turf may also experience higher PFAS exposure levels than the general population.

1.2. Potential for Significant or Widespread Adverse Impacts

All PFASs display at least one of the hazard traits identified in California's Green Chemistry Hazard Traits Regulations (California Code of Regulations, title 22, section 69401 et seq.): they are either extremely persistent in the environment themselves, or they degrade into other PFASs that are extremely persistent. Most PFASs are mobile in environmental media such as air and water, and thus are widespread in living organisms and the environment. Several PFASs bioaccumulate significantly in animals or plants, including those consumed by humans as food. Certain PFASs also contribute to global warming.

Studies indicate that some PFASs can cause reproductive, developmental, and immunological effects. These effects, which are well established in animal and human studies, include kidney and testicular cancers, thyroid disease, reduced immune response, and pregnancy-induced hypertension. In general, fetuses, infants, toddlers, and young children experience higher relative exposure levels and are more vulnerable to the effects of environmental toxicants; this is true for PFASs. PFASs have also been found to be harmful to plants and animals in the environment; some have been linked to phytotoxicity, aquatic toxicity, and terrestrial ecotoxicity.

Based on the criteria in the SCP regulations, DTSC has determined that artificial turf containing any member of the class of PFASs has the potential to cause or contribute to significant and widespread adverse impacts to sensitive subpopulations, environmentally sensitive habitats, and threatened and endangered species. Given the known hazard traits, replacing currently used PFASs in artificial turf with other members of the PFAS class could constitute a regrettable substitution.

1.3. Proposed Action

Based on the criteria in the Safer Consumer Products Regulations, we have determined that artificial turf containing PFASs has the potential to contribute to or cause both significant and widespread exposure and adverse impacts to Californians—particularly children.

In 2024, the Synthetic Turf Council informed us that its member manufacturers were proactively engaging with their component and raw material suppliers to ensure that their products contain no PFAS-based ingredients, including polymeric PFAS processing aids, by 2025. Our goal is to shift markets away from hazardous chemicals to safer alternatives, and if that shift occurs prior to regulation, we consider this a successful outcome. To verify that a pre-regulatory market shift has occurred, we are pausing listing this product-chemical combination as a Priority Product to gather additional information from manufacturers and conduct product testing. If we find that PFASs continue to be present in artificial turf and regulatory action is appropriate to address the potential PFAS exposures and resulting harms, we plan to move forward with regulating this product-chemical combination.

2. PRODUCT DEFINITION AND SCOPE

This section describes the product, as part of a product-chemical combination.

DEFINITION: Artificial turf is a synthetic surface material engineered to mimic natural grass. It is made of plastic, blade-like fibers woven into a backing.

Common synonyms for artificial turf include artificial grass, synthetic turf, synthetic grass, artificial lawn, synthetic lawn, nylon grass, polyethylene grass

Artificial turf is a synthetic surface material engineered to mimic the appearance of natural grass. Common synonyms for artificial turf include artificial grass, synthetic turf, synthetic grass, artificial lawn, synthetic lawn, synthetic surface, nylon grass, polyethylene grass, and polypropylene grass.

Artificial turf surfaces are intended for athletic, recreational, or landscaping applications. Artificial turf consists of synthetic fibers made of polyethylene, polypropylene, or nylon that are tufted or woven into backing material to provide structural integrity (Figure 1). This document does not examine the makeup of infill material often added to artificial turf but focuses solely on artificial turf itself—the plastic, grass-like blades and the backing they are attached to.

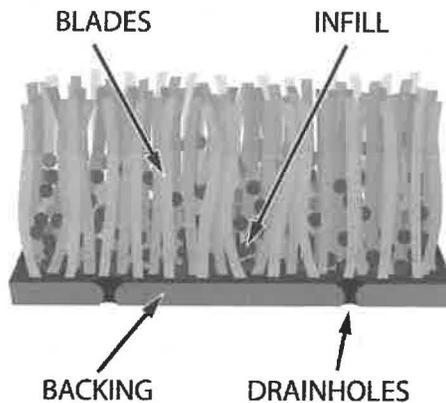


Figure 1. Artificial turf structure.

The Global Product Classification (GPC) system is part of the Global Standards 1 system (GS1), which classifies products to improve the efficiency of supply chain processes and provides a standardized classification of products based on their attributes. GPC codes allow businesses to categorize, search, and compare products globally. GPC categorizes artificial turf by the following codes (GS1 2024):

- Segment: 81000000 – Lawn/Garden Supplies
 - Family: 81010000 – Lawn/Garden Supplies
 - Class: 81011500 – Lawn/Garden Soil/Soil Amendments
 - Brick: 10007009 – Artificial Turf.

GPC defines artificial turf as “...any products that can be described/observed as a ground cover made of artificial grass (also known as astroturf) and is usually designed for the garden or lawn. Typically, these products are made of fabric and plastic, or synthetic materials” (GS1 2024).

While GPC’s definition of artificial turf does not explicitly mention artificial recreational surfaces, for the purposes of this document, we interpret it to include turf manufactured, marketed, and sold for sports and recreation purposes.

3. CANDIDATE CHEMICAL DEFINITION AND PROPERTIES

This section introduces the Candidate Chemical (or Chemicals) in the proposed product-chemical combination.

For the purposes of this document, PFASs are all perfluoroalkyl and polyfluoroalkyl substances in current or future production that meet the definition by Buck et al. (2011).³ In December 2015, all PFASs, as defined by Buck et al. (2011), were added to the Candidate Chemicals List when the scientific

³ Note that U.S. EPA and others use the acronym “PFAS” for this class of chemicals. In this document, we use the acronym “PFASs” to emphasize that this is a class of chemicals and to make it clear when we refer to multiple members of this class as opposed to an individual chemical.

guidance panel for the Biomonitoring California program designated the whole class as Priority Chemicals (Biomonitoring California 2015a). The Biomonitoring California listing is based on the chemicals' potential for widespread exposures, persistence, bioaccumulation, and emerging evidence of toxicity.

PFASs are a class of organic chemicals containing at least one fully fluorinated carbon atom (Biomonitoring California 2015b). PFASs are manufactured and are not found naturally in the environment. All PFASs contain carbon and fluorine atoms, in addition to other elements such as oxygen, hydrogen, nitrogen, sulfur, or chlorine. PFASs vary in chain length (i.e., the number of carbon atoms forming the backbone of their molecule), ranging from a chain of two carbons to large molecular-weight polymers with large numbers of carbon atoms. PFAAs and some of their precursors are frequently subdivided into longer- and shorter-chain PFASs. The longer-chain perfluoroalkyl sulfonic acids have six or more perfluorinated carbons; longer-chain perfluoroalkyl carboxylic acids (PFCAs), perfluoroalkyl phosphonic acids, and perfluoroalkyl phosphinic acids have seven or more perfluorinated carbons (Bowman 2017). The PFAS class includes over 3000 chemicals (KEMI 2015), although fewer may be in current production. The Organization for Economic Cooperation and Development (OECD) has identified 4,730 Chemical Abstracts Service Registry Numbers (CAS RNs) related to individual PFASs or commercial PFAS mixtures available on the global market (OECD 2018). However, OECD's definition of PFASs is broader than the definition by Buck et al. (2011).

We have previously published Product-Chemical Profiles for *Carpets and Rugs Containing Perfluoroalkyl or Polyfluoroalkyl Substances*, *Treatments Containing Perfluoroalkyl or Polyfluoroalkyl Substances for Use on Converted Textiles or Leathers*, and *Plant Fiber-based Food Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances*. For the sake of brevity, we highlight below only the hazards and properties of PFASs that are most relevant to artificial turf, mainly fluoropolymers. Readers should refer to our previously published Profiles for more information.

3.1. Relevant Physicochemical Properties

Reference: California Code of Regulations, title 22, section 69503.3(a)(1)(D).

Physicochemical properties can be helpful in predicting a chemical's behavior. A chemical's behavior in humans, wildlife, ecosystems, and the environment may indicate potential adverse public health and environmental impacts.

PFASs possess unique physicochemical characteristics that confer high stability in extreme temperatures, antistatic properties, and resistance to stains, soils, and corrosion (Buck et al. 2011; Buck et al. 2012). Compared to other organic chemicals, PFASs are very persistent in the environment and biota, partly because fluorine atoms form the strongest known chemical bond with carbon atoms (Kiplinger et al. 1994). Due to its high electronegativity, the F atom pulls the shared electrons of the covalent C-F bond towards itself, which renders it partially negative and the C atom partially positive,

creating a polar covalent bond. This bond requires high energy, up to 544 kJ/mol, to dissociate (Lemal 2004), compared to the 337 kJ/mol needed to separate carbon and hydrogen (Dean 1999). Consequently, PFASs are thermally, chemically, and biologically stable, and resistant to abiotic degradation such as atmospheric photo-oxidation, direct photolysis, and hydrolysis (Wang et al. 2016).

3.2. Environmental Fate

Reference: California Code of Regulations, title 22, section 69503.3(a)(1)(E).

Environmental fate describes a chemical's mobility in environmental media, transformation (physical, chemical, or biological), or accumulation in the environment or biota. A chemical's environmental fate in air, water, soil, and living organisms relates to its exposure potential hazard traits, as defined in the California Code of Regulations, Title 22, Chapter 54.

PFASs persist in both indoor and outdoor environments. They have been found in air, water, soil, and living organisms, including in remote locations such as the deep sea and alpine regions (Lindstrom et al. 2011b; Wang et al. 2016). Their widespread distribution results from their unique physicochemical properties and their ability to undergo long-range transport. Direct emissions from products and indirect formation of PFAAs from PFAS precursors introduce PFASs to the environment (Wang et al. 2014). Longer-chain PFASs tend to bioaccumulate, while shorter-chain variants are more mobile in the aquatic environment due to their high water solubility. Both can be distributed globally through oceanic currents and atmospheric transport (Ateia et al. 2019a; Brendel et al. 2018; Concawe 2016).

Despite extensive studies on PFAS levels in various media, multiple gaps in understanding PFAS sorption/desorption patterns, transport mechanisms, and fate still exist. The environmental fate data available mainly pertain to PFAAs and a few precursors, highlighting the need for further research to fill knowledge gaps regarding PFAS sources, transformation, distribution, accumulation, and trends in wildlife and humans.

Environmental fate of PFASs has been discussed in more detail in DTSC's Product-Chemical Profiles for *Carpets and Rugs Containing Perfluoroalkyl or Polyfluoroalkyl Substances* and *Treatments Containing Perfluoroalkyl or Polyfluoroalkyl Substances for Use on Converted Textiles or Leathers*.

3.3. Degradation, Reaction, or Metabolic Products of Concern

Reference: California Code of Regulations, title 22, section 69503.3(a)(1)(G).

A Candidate Chemical may degrade, form reaction products, or metabolize into other chemicals that have one or more hazard traits. These metabolites, degradation products, and reaction products (which may or may not be Candidate Chemicals) may cause different adverse impacts from those of the parent chemical. In some cases, a Candidate Chemical's degradation or reaction products or metabolites may have the same hazard trait, and may be more potent or more environmentally persistent, or both, than

the parent chemical. In such cases, adverse impacts may be more severe, or may continue long after, the Candidate Chemical's release to the environment.

PFASs that can degrade in the environment typically transform into other, smaller PFASs, such as PFAAs, that do not degrade further under environmental conditions (Buck et al. 2011; D'eon and Mabury 2011; Frömel and Knepper 2010; Krafft and Riess 2015; Wang et al. 2014; Washington et al. 2015). While PFAAs constitute a small subset (approximately 1%) of PFASs, their hazard traits are relevant to the entire class, because they occur in or result from other PFASs—as terminal degradation products, manufacturing aids/raw materials, or impurities. Unlike most other subclasses of PFASs, fluoropolymers cannot degrade to PFAAs under typical environmental conditions. However, certain PFAAs used in fluoropolymer manufacturing can occur as impurities (Lohmann et al. 2020).

Intentional or accidental combustion of PFASs, including fluoropolymers, can also form hazardous chemicals. A literature survey regarding the combustion of various fluorinated polymers reported emissions of C3-C14 PFCAs, ozone-depleting substances such as chlorofluorocarbons, and greenhouse gases such as fluorocarbons when fluoropolymers are combusted at temperatures representative of municipal incinerators (Huber et al. 2009). During incineration at temperatures above 450°C, polytetrafluoroethylene (PTFE) decomposes to ultra-short-chain PFAA tetrafluoroacetic acid (TFA) (Huber et al. 2009) and hydrofluoric acid (Henry et al. 2018), which appears on DTSC's Candidate Chemicals List. An industry-sponsored experimental study in a rotary kiln test facility simulating municipal incinerators found that PTFE polymer pellets begin to decompose at around 500°C, and by around 650°C they completely convert to hydrofluoric acid gas and F-containing ash, with no significant PFAA emissions (Aleksandrov et al. 2019). Other authors report that at lower temperatures, as could occur during accidental landfill fires, fluoropolymers such as PTFE can break down into PFCAs, including potentially perfluorooctanoate or perfluorooctanoic acid (PFOA) (Feng et al. 2015; Schlummer et al. 2015; Lohmann et al. 2020).

3.4. Hazard Traits and Environmental or Toxicological Endpoints

Reference: California Code of Regulations, title 22, section 69503.3(a)(1)(A).

The hazard traits and environmental or toxicological endpoints summarized in this section are defined in the SCP Regulations sections 69501.1(a)(36) and (33), respectively, both of which refer to the Office of Environmental Health Hazard Assessment's (OEHHA's) Green Chemistry Hazard Trait regulations (California Code of Regulations, Title 22, Chapter 54). These include exposure potential and toxicological and environmental hazard traits.

PFASs display multiple hazard traits indicated in OEHHA's Green Chemistry Hazard Traits regulations (22 CCR 69401 2011). These include toxicological hazard traits, (Articles 2 and 3), environmental hazard traits (Article 4), and exposure potential hazard traits (Article 5). Thousands of studies document these hazard traits, many of which can be viewed through the PFAS-Tox Database (Pelch et al. 2022), and have been discussed in more detail in DTSC's *Product-Chemical Profile for Plant Fiber-Based Food*

Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances. Furthermore, recent research continues to identify positive associations between exposure to PFASs, hazards, and mortality (Wen et al. 2022). Below is a summary of some relevant hazard traits.

3.4.1. Exposure Potential Hazard Traits

Environmental Persistence

Environmental persistence is one of the hazard traits identified in OEHHA's Green Chemistry Hazard Traits Regulations. In the Statement of Reasons for these regulations (OEHHA 2012), this hazard trait is explained as follows:

"Persistence of a chemical in the environment promotes sustained exposure and contributes to accumulation in the environment. Because persistence is an inherent property of a chemical in the environment that results in increased exposure to the chemical and consequently potential for health risks, it can appropriately be identified as a hazard trait. Legacy chemicals such as DDT and PCBs remain public health concerns decades after their production was banned because of their ability to persist in the environment."

When chemicals do not degrade in the environment, associated harmful effects have the potential to continue indefinitely. While PFASs vary in chemical structure, they all contain the perfluoroalkyl moiety (Buck et al. 2011), which is extremely resistant to degradation as discussed in section 3.1. Those PFASs that can degrade under specific circumstances form other PFASs that are environmentally persistent (Buck et al. 2011; Cousins et al. 2020). Therefore, environmental persistence is a unifying trait of PFASs and, even absent other hazard traits, would warrant regulating PFASs as a chemical class (Cousins et al. 2020).

Global Warming Potential

A gas's capacity to absorb solar energy and subsequently contribute to warming the Earth is referred to as its Global Warming Potential (GWP). CO₂ has the assigned reference GWP value of 1 (U.S. EPA 2016b). Fluoropolymer processing produces fluorocarbon byproducts with very high GWP. These compounds are volatile and, therefore, difficult to manage once released (Lohmann et al. 2020). For example, hydrochlorofluorocarbon-22 (HCFC-22), which has been used to produce a variety of products including fluoropolymers like PTFE, can release trifluoromethane (HFC-23), a gaseous hydrofluorocarbon (HFC), as an unintentional byproduct during its manufacturing (Stanley et al. 2020). The environmental release of HFC-23 is of great concern because it has an estimated GWP between 12,400 and 14,800, among the highest for gases. This means that HFC-23 is over 12,400 times more effective at trapping heat in the atmosphere than CO₂ and is, therefore, an extremely potent greenhouse gas (Lohmann et al. 2020; Stanley et al. 2020; U.S. EPA 2020). Furthermore, once released,

HFC-23 stays in the atmosphere for about 228 years (Stanley et al. 2020), and, as such, it continues to contribute to climate change for many years after its release.

3.4.2. Toxicological Hazard Traits

Toxicological data are limited to relatively few PFASs, mostly PFAAs. Appendix C from the *Product-Chemical Profile for Food Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances* lists toxicological hazard traits for the PFASs for which data is publicly available. Most toxicological studies evaluate exposure to single PFASs for 90 days or less, which is not representative of real-world exposure scenarios because, due to their ubiquity and persistence as discussed above, humans and animals are chronically exposed to PFAS mixtures over a lifetime.

Potential adverse human health effects from longer-chain PFAS exposure include:

- Increased serum cholesterol (Skuladottir et al. 2015; Winquist and Steenland 2014)
- Thyroid disease (Winquist and Steenland 2014)
- Immune dysregulation (Grandjean and Clapp 2014; Grandjean et al. 2017a; Grandjean et al. 2017b)
- Pregnancy-induced hypertension (C8 Science Panel 2011)
- Kidney and testicular cancers (C8 Science Panel 2012)

Epidemiological studies suggesting links to adverse health effects often include uncertainties in exposure or other confounding factors. A systematic review of 64 epidemiological studies that assessed children's exposure to PFASs and associations with specific health outcomes found association between PFAS exposure and suppressed immune system response, dyslipidemia, impaired kidney function, and delayed first occurrence of menstruation (Rappazzo et al. 2017). Additionally, a recent mixture-analysis study of U.S. adults found a positive association between exposure to PFASs and mortality (Wen et al. 2022).

3.4.3. Environmental Hazard Traits

Appendix C from the *Product-Chemical Profile for Food Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances* lists several studies documenting the following environmental hazard traits:

- Phytotoxicity
- Wildlife developmental impairment
- Wildlife reproductive impairment
- Wildlife survival impairment

Laboratory studies of algae, aquatic plants, terrestrial plants, fish, amphibians, mammals, birds, and important pollinating insects, as well as studies of birds exposed in the wild, show an association between PFAS exposure and several adverse environmental impacts, including developmental,

reproductive, or survival impairment (Annunziato et al. 2019; Eggers Pedersen et al. 2015; Liu et al. 2015; Sanchez et al. 2015; Soloff et al. 2017).

3.5. Structural or Mechanistic Similarity to Chemicals with Known Adverse Impacts

Reference: California Code of Regulations, title 22, section 69503.3(a)(3).

Some chemicals may lack sufficient data to definitively establish presence or absence of harm. In such cases, DTSC may also consider data from other chemicals closely related structurally to the Candidate Chemical to identify potential public health and environmental impacts.

While physicochemical properties and hazard traits for many PFASs are either uncharacterized or unavailable in the public domain, the data available for structurally similar PFASs raise sufficient concerns for DTSC to regulate PFASs as a class in specific consumer products (Bălan et al. 2021). In particular, PFAAs share three key structural and mechanistic properties: their structural similarity to fatty acids (DeWitt et al. 2015), their potential to activate PPAR-alpha (Rosenmai et al. 2018; Wolf et al. 2008; Wolf et al. 2014), and their persistence in the environment (Krafft and Riess 2015). The carbon-fluorine bonds characteristic of the structure of all PFASs endow them with extreme environmental persistence. Recent research continues to highlight the concerns associated with the structural and mechanistic properties of PFASs (Houck et al. 2021; Sørderstrøm et al. 2022).

4. POTENTIAL FOR EXPOSURES TO THE CANDIDATE CHEMICAL(S) IN THE PRODUCT

Reference: California Code of Regulations, title 22, section 69503.3(b).

The SCP Regulations direct DTSC to evaluate the potential for public or aquatic, avian, or terrestrial animal or plant organism exposure to the Candidate Chemical(s) in a product by considering one or more factors for which information is reasonably available.

4.1. Presence of the Candidate Chemical in the Product

Reference: California Code of Regulations, title 22, section 69503.3(b)(2).

This subsection summarizes available information indicating the Candidate Chemical's presence in and release from the product.

For artificial turf to serve its intended purpose and to be commercially viable, it must be durable, resist degradation from oxidation and UV light, and have a grass-like appearance. Achieving these characteristics is challenging with the inherent properties of the polyolefin polymers used in the manufacturing of the blades because they are susceptible to degradation in the presence of oxygen and sunlight and are difficult to dye due to their hydrophobicity (Moody and Needles 2004; Tolinski

2015a). To overcome these challenges and ensure the integrity of the product throughout its lifespan, manufacturers add various additives⁴ to the plastic pellets that make up the foundational material of the blades. The pellets are melted and extruded, forming fibers that are woven into a backing, which typically consists of polyester or polypropylene, and is covered with additional polyurethane or latex as a secondary backing (Kolitzus 2007).

Manufacturers infuse the polymer with various additives and processing aids in three ways (Tolinski 2015a):

- Compound them into the base polymer of the pellets during pellet manufacturing
- Mix them with pellets before the extrusion process
- Feed them directly into the extruder and mix with the polymer when it melts through mechanical action.

When the mixture of ingredients—known as a masterbatch—is complete, the pellets are melted and extruded through a die to form long, thin strands of fibers that are spooled.

To enhance the quality of the fibers and optimize the extrusion process, manufacturers add processing aids and internal lubricants (Tolinski 2015a). Lubricants prevent the extruded plastic from sticking to processing equipment, and processing aids help with melt stability, preventing material buildup and jagged surfaces known as “shark skinning” (Tolinski 2015a).

Available information indicates that fluoropolymer PFASs have been commonly used as extrusion processing aids in the manufacturing of artificial turf fibers, leading to their presence in the finished turf blades. Use of PFASs as processing additives became popular because they increase turf blade quality, prevent dye build-up, and do not negatively impact the performance of other additives (3M 2016). Examples of fluoropolymers used in blade production include PTFE, polyvinylidene fluoride (PVDF), and polyvinyl fluoride (PVF). Some patents on artificial turf manufacturing indicate the use of fluoropolymers as a part of the formulations, specifying the names of processing aids used (e.g., Sick 2022), while others specify the use of any commercially available fluoroelastomer processing aid, at a concentration of 1% by weight (e.g., Bonavoglia et al. 2015).

Examples of fluoropolymer-based additives that are marketed as processing aids for extrusion of artificial turf include 3M’s Dynamar FX5911 and Dynamar FX9613 (3M 2016). FX5911 (CAS RN 25190-89-0) consists of 100% hexafluoropropylene-vinylidene fluoride-tetrafluoroethene polymer (3M 2018a; PubChem 2024). FX9613 (CAS RN 9011-17-0) contains 88-92% by weight vinylidene fluoride-hexafluoropropylene polymer (3M 2018b). In response to regulatory pressure and concerns from

⁴ Additive is “a substance which is intentionally added to plastics to achieve a physical or chemical effect during processing of the plastic or in the final material or article; it is intended to be present in the final material or article” (Official Journal of the European Union 2011).

markets and investors, 3M has pledged to stop manufacturing all PFASs, including fluoropolymers, by the end of 2025 (3M 2022). However, other manufacturers' fluoropolymer-based processing aids will likely remain on the market (Markets and Markets 2024).

Artificial turf can also be sprayed with coatings containing fluoropolymers during or after manufacturing. One patent describes a special coating made of metal oxides that reflect heat. The coating can be applied at any point in the artificial turf life cycle. To bind the coating to inert plastic blades, those applying the coatings must use special binders that are aqueous, polyester, acrylics, or fluoropolymers (Packer et al. 2013). The application of such coatings could also explain the presence of PFASs. However, we have been unable to determine the prevalence of such coatings and the proportion of fluoropolymer binders used in these processes.

The fluoropolymers used in artificial turf may release PFAS monomers and PFAS polymerization aids during manufacturing and product use (Lohmann et al. 2020). Neither monomers nor polymerization aids are intended to be present in the final product: both are contaminants (Korzeniowski et al. 2022; Lohmann et al. 2020).

Lauria et al. (2022) analyzed samples of artificial turf collected in Stockholm, Sweden for total fluorine (TF). Fluorine was detected in all turf components (backing, filling, and blades), indicating the widespread presence of fluorinated substances (Lauria et al. 2022). TF concentrations ranged from 16-313 ppm in backing and 24-661 ppm in blades. Extractable organic fluorine (EOF) and targeted PFASs were detected at low concentrations and in fewer than 42% of the samples (Lauria et al. 2022). EOF concentrations ranged from below the limit of detection to 145 ppb for backing and 192 ppb for blades. These EOF concentrations are more than three orders of magnitude lower than the concentrations of TF and suggest that fluorine in artificial turf is primarily associated with fluoropolymers, which are not extractable (Lauria et al. 2022). However, the presence of EOF may indicate relatively low levels of non-polymeric PFASs in artificial turf blades and backing.

Another study analyzed one sample of brand-new artificial turf blades (with two replicates) for three fluorotelomer alcohols (FTOHs) (Zuccaro et al. 2023). The study's analytes were 4:2 FTOH, 6:2 FTOH and 8:2 FTOH. 8:2 FTOH was measured at a concentration of 1 ng/ μ L (or 1 ppm) and the other two compounds were not detected. The study does not explain the presence of 8:2 FTOH, which is usually associated with the production and degradation of side-chain fluorinated polymers (Buck et al. 2011). Side-chain fluorinated polymers are normally used to produce surfactants and surface protection products (Buck et al. 2011), not turf blades. In the environment, under biotic and abiotic conditions, side-chain fluorinated polymers can release FTOHs, which further degrade into PFAAs. We have identified no other peer-reviewed studies that have attempted to measure PFASs in blades or backing.

Multiple reports on PFASs in artificial turf blades and backing have appeared in the news (Laker 2024). One investigation found 300 parts per trillion (ppt) of 6:2-fluorotelomer sulfonic acid (FTSA) in samples

from newly-installed high school fields in Massachusetts, 190 ppt of perfluorooctane sulfonate (PFOS) in 15-year-old artificial turf installations, and 44-225 ppm of TF in the blades of new samples from eight artificial turf brands (Ecology Center 2019). The Center for Environmental Health, a non-profit organization, also found that in-house Home Depot and Lowe's brands of artificial turf contain PFOS at 0.185-0.264 $\mu\text{g}/\text{cm}^2$ of sample (Diaz Leiva 2024).

The Synthetic Turf Council (STC), an association that represents companies involved in the production, distribution, and installation of artificial turf, has previously acknowledged PFAS use. More recently, in 2024, STC stated that its member manufacturers were proactively engaging with their component and raw material suppliers to ensure that their products contained no PFAS-based ingredients, including polymeric PFAS processing aids, by 2025. According to STC, its members rely on EPA-approved methods to analyze their products and materials for individual PFAS analytes and a total organic fluorine test to verify the absence of any intentionally-added PFAS (STC 2026). Many manufacturers claim on their websites that they do not use PFASs to produce artificial turf and that they have replaced fluoropolymer processing aids to avoid even trace amounts of non-polymeric PFASs (Santos 2024). To reinforce these statements, they provide laboratory reports for multiple PFASs tested (Watersavers Turf 2023). However, the levels of detection are often at tens of ppm concentrations, meaning lower levels of PFASs may still be present.

4.2. Market Presence and Trends

Reference: California Code of Regulations, title 22, sections 69503.3(b)(1)(A-C)

Product market presence information may be used as a surrogate to assess potential exposures to the Candidate Chemical in a product. This information may include statewide sales by volume or number of units, the intended use(s) of the product, and characteristics of the targeted customer base.

Monsanto developed artificial turf in the early 1960s as a substitute for natural grass in football fields (Jastifer et al. 2018). Since then, the product has gone through many modifications and improvements. Today, artificial turf is used in various sports (e.g., football, soccer, baseball, golf, field hockey), commercial and residential landscaping and indoor applications, dog parks, community parks, and playgrounds (City of Los Angeles 2024; Jastifer et al. 2018).

According to STC's analysis, approximately 22 million square meters of artificial turf had been installed in the U.S. by 2020, 63% of which, or 14 million square meters, were sports fields. Of these installations, 62% (9 million square meters) were installed in educational settings, where the synthetic material replaced natural turf (STC 2020).

There are 18,000 to 20,000 artificial turf fields in the U.S. (Chevy Chase DC Advisory Neighborhood Commission 2024), and 1,500 more are installed yearly (Amenabar 2024). While data on the current number of artificial turf fields in California are lacking, the state likely has more artificial turf fields than

most others. That's because California has the largest population (more than 10% of the U.S. population) and the largest economy of any state, and artificial surfaces were intensively promoted as an alternative to natural grass, especially during periods of drought.

Despite higher up-front installation costs than natural turf fields, artificial turf fields reportedly prove cost-effective after approximately three to four years (STC 2022), with estimated lifespans ranging between five and 15 years (Bertling et al. 2021; Sick 2022) depending on usage intensity. Artificial turf for leisure and landscaping is less durable, with warranties focusing on wear and tear and manufacturing defects. Ultimately, the lifespan of any artificial turf installation depends on factors like installation quality, maintenance, climate, and intensity of use (GrassTex 2014).

Manufacturers of sport artificial turf compete based on quality and playing characteristics determined by large sports associations (e.g., FIFA). Manufacturers of landscaping and leisure turf (mainly from China) compete based on price per square foot (Applied Market Information 2022). Replacement of worn-out sports installations drives most of the market growth in North America. In 2021, North American manufacturers, of which TenCate is the largest (Applied Market Information 2022), produced 40.8 million square meters of artificial turf. Production is expected to increase to 52.3 million square meters by 2025 (Applied Market Information 2022).

By comparison, countries in East Asia manufactured more than 214 million square meters of artificial turf in 2021 (Applied Market Information 2022), of which 24.6 million square meters were exported to North America (Applied Market Information 2022). Two Chinese companies led these exports: CC Grass and Bellinturf (Applied Market Information 2022). Most Chinese companies focus on exports for the leisure sector. CC Grass and Bellinturf account for 30% of the world artificial turf market (Applied Market Information 2022). Eight companies—Victory Grass (UK), Sport & Leisure Group (Belgium), Sport Group (Germany), Field Turf (France), along with TenCate Grass and Condor from the Netherlands, and Taishan and Vivaturf from China—accounted for another 25% of the world market, and the remaining 45% are small brands (Applied Market Information 2022).

4.3. Potential Exposures to the Candidate Chemical(s) During the Product's Life Cycle

Reference: California Code of Regulations, title 22, sections 69503.3(b)(3); 69503.3(b)(4)(A-H).

Potential exposures to the Candidate Chemical or its degradation products may occur during various product life cycle stages, including manufacturing, use, storage, transportation, waste, and end-of-life management practices. Information on existing regulatory restrictions, product warnings, or other product use precautions designed to reduce potential exposures during the product's life cycle may also be discussed here.

PFASs are released into air, water, and soil during manufacturing, use, landfilling, incineration, and recycling of artificial turf. Limited research shows that the leachability of PFASs from artificial turf materials may be limited and that the fluorinated substances found in artificial turf blades are not precursors to PFAAs, suggesting a predominance of fluoropolymers (Lauria et al. 2022). However, the lack of standardized analytical methods that identify and quantify PFASs has limited researchers from making an absolute conclusion about PFASs release (Lauria et al. 2022). Administrative and engineering controls are unlikely to address release of PFASs during product use and disposal. PFASs released during the manufacture and use of artificial turf can enter waterways and local environments via direct discharge from manufacturers and runoff resulting from weather events. Meanwhile, users, bystanders, and maintenance and construction workers may be exposed to PFASs in artificial turf during sports activities, leisure, maintenance, and installation.

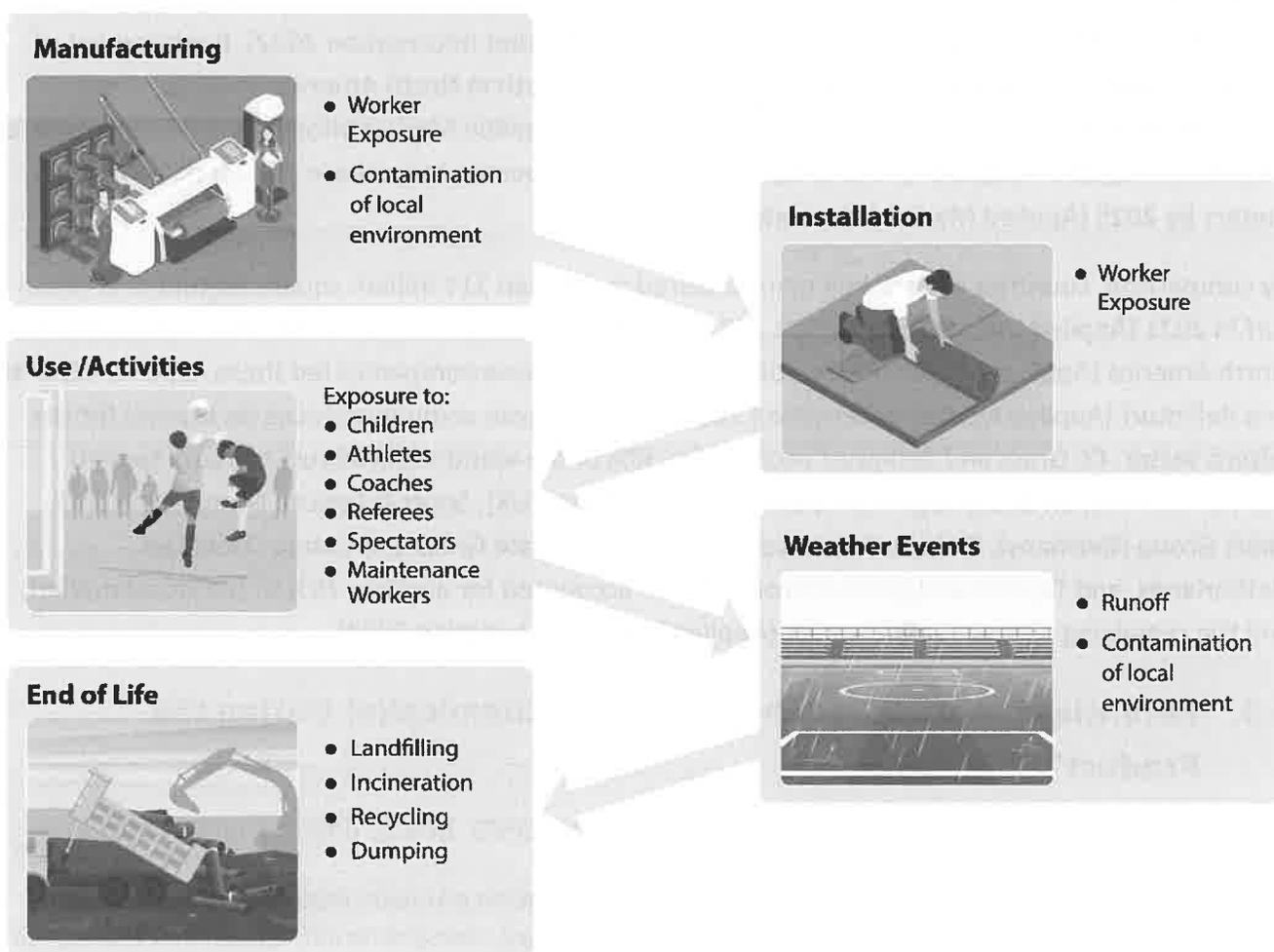


Figure 2. Potential PFAS exposures during the life cycle of artificial turf.

4.3.1. Manufacturing

Exposure to PFASs can occur during manufacturing of artificial turf blades, as fluoropolymers are used in the formulation process. Workers that compound masterbatches, control extrusion of fibers, and clean the machinery have a higher potential to be exposed to PFASs due to direct contact with the chemicals.

The main concerns with the use of fluoropolymers in artificial turf manufacturing processes arise from the manufacturing of the fluoropolymers themselves. The type of fluoropolymers used in artificial turf manufacturing (e.g., finely powdered PTFE and PVDF) are made through a process of emulsion polymerization, which requires the use of low-molecular-weight PFAS-based solvents (Lohmann et al. 2020). These solvents may be released during the manufacture of fluoropolymers, resulting in contamination of the local environment (Dauchy 2023). For example, Dauchy (2023) found high concentrations of long-chain PFCAs in soil and outdoor dust samples collected within about 200 meters of a fluoropolymer processing plant in France. These PFASs likely originate from processing aids used in PVDF production.

We are unaware of any manufacturing of fluoropolymers or artificial turf in California. However, the environmental contamination resulting from the use of PFASs associated with consumer products has become a global problem. PFASs are mobile and can build up in the environment resulting in transboundary pollution and widespread exposure.

4.3.2. Use

Exposure to PFASs can occur during use of artificial turf because unreacted PFAS monomers and residual PFAS polymerization aids may migrate out of the blades. Artificial turf can also generate microplastics made of a mixture of polyolefins and fluoropolymers. These microplastics may be inhaled or ingested during the use of artificial turf. Aquatic organisms can be exposed to Candidate Chemicals in artificial turf when microplastics released from the product are carried to the aquatic environment with runoff and are ingested (Bridson et al. 2021; Li 2019). Plants and soil biota near artificial turf may also be impacted by Candidate Chemicals leaching out of microplastics from weathered artificial turf blades or backing (Ding et al. 2022; Li 2019). Contact with artificial turf surfaces may result in human exposure to PFASs via inhalation, ingestion, or dermal routes (Ragnarsdóttir et al. 2024). Because of the popularity of artificial turf in community, residential, and commercial outdoor areas, all Californians are potentially exposed, directly or indirectly, to PFASs from artificial turf surfaces. Artificial turf sports fields are usually installed and maintained by professional contractors, who may be exposed to PFASs through their work.

In March 2025, OEHHA released a draft report assessing potential health impacts associated with exposures to chemicals released from artificial turf and crumb rubber (OEHHA 2025). It groups users of sports fields covered by artificial turf into three categories of human receptors—athletes,

coaches/referees, and bystanders (OEHHA 2025)—each experiencing different levels of exposure (OEHHA 2025). Athletes experience the highest exposure to chemicals in artificial turf through all three exposure pathways—inhalation, ingestion, and dermal contact. They inhale airborne particles when playing or practicing on artificial turf, their skin comes in contact with these particles, and they ingest them when they then touch their mouths. Coaches and referees are expected to have lower levels of incidental ingestion than athletes. For bystanders, the primary route of exposure is inhalation. However, for bystanders who are infants, toddlers, and young children, ingestion and dermal contact with the field may also be relevant routes of exposure due to their hand-to-mouth behaviors (OEHHA 2025).

In recent years, more schools have chosen artificial turf for their sports fields, increasing the potential for children to be exposed to PFASs (Lam 2024; Purchase Green 2014). As noted previously, children’s potential for exposure to chemicals in artificial turf is exacerbated by their hand-to-mouth behaviors and physiology (e.g., higher absorption rates in the skin and digestive system, and higher respiratory rates) (Levasseur et al. 2021).

Artificial turf is also applied in commercial and residential landscaping, playgrounds, golf fields, and pet parks (The Recreational Group 2024), potentially exposing the general public (of all ages) and pets—especially dogs. Although manufacturers and distributors usually recommend that customers use professional landscaping firms to install artificial turf, people often do it themselves, which increases their potential for exposure to PFASs via skin contact and inhalation.

Artificial turf is also often used in indoor applications, specifically in commercial applications, for indoor sports and in residential applications, for decoration. Through everyday use, artificial turf and other consumer products release PFASs into indoor air and dust, which people inhale or ingest. Indoor installations of artificial turf may result in greater inhalation exposure than outdoor ones because of the lower air exchange rates in enclosed environments. The lack of natural ventilation in indoor settings can result in higher concentrations of airborne particles and chemicals released from the turf materials. However, the stable temperature conditions and lower intensity of use may lead to slower material degradation of indoor artificial turf.

4.3.3. End-of-Life

The average artificial turf football field weighs about 40,000 pounds (STC 2017). Assuming 750 fields are removed each year, the weight of artificial turf sports fields disposed of annually in the U.S., without infill material, is estimated to be about 30 million pounds, or 15,000 tons.

Most waste in California, including end-of-life artificial turf, is disposed of in landfills, where it can release PFASs to the environment via leachates and gaseous emissions (Benskin et al. 2012b; Busch et al. 2010; Eggen et al. 2010; Fuertes et al. 2017; Hamid et al. 2018; Huset et al. 2011; Lang et al. 2017). WWTPs that collect landfill leachates, surface runoff, and residential and commercial wastewater do

not effectively remove PFASs (Arvaniti and Stasinakis 2015; Huset 2007). As a result, when treated effluents are discharged into surface waters, PFASs are released into the environment, contaminating aquatic ecosystems and drinking water sources (Dauchy et al. 2017; Hamid and Li 2016; Pan et al. 2016). During wastewater treatment, some of the PFASs partition to sewage sludge—also referred to as biosolids; when biosolids are applied to soil for agricultural or land remediation purposes, they can also contaminate terrestrial ecosystems, drinking water, and human food supplies with PFASs (Hoffman et al. 2011; Lindstrom et al. 2011a).

Artificial turf can be legally disposed of in any landfill in California that accepts municipal solid waste. However, due to its bulk, landfills often refuse to accept large amounts of artificial turf; this can lead to artificial turf being stored elsewhere under unsuitable conditions (Lundstrom et al. 2019). Some journalistic investigations have reported illegal dumping of artificial turf at such places as the edge of the woods, nearby wetland areas, or empty residential lots across the U.S., including in California (Lundstrom et al. 2019). Such improper disposal may result in PFASs leaching into nearby environments, contaminating soil and local surface waters.

Manufacturers often promote artificial turf as a green solution for sports fields and landscaping, mostly due to lower demand for watering compared to natural turf but also due to the potential recyclability of artificial turf. Recycling efforts aim to repurpose synthetic fibers, backing materials, and infill components. In 2021, only 10%, or 6.2 million m² of the world's end-of-life artificial turf was recycled (Applied Market Information 2022). Even the European Union, the region with the most stringent disposal requirements, recycles only 15% of its volume of artificial turf at the end of life (Applied Market Information 2022). In the U.S., some artificial turf manufacturers have made progress on recycling; however, the demand for recycling outpaces capacity (Applied Market Information 2022). There are currently no artificial turf recycling facilities in California.

4.3.4. Aggregate Effects

Reference: California Code of Regulations, title 22, section 69503.3(a)(1)(B) and sections 69503.3(b)(3).

Multiple sources of exposure to the Candidate Chemical may increase the potential for significant or widespread adverse impacts.

PFASs are found in many frequently used consumer products in households and workplaces, including flooring, furniture, clothing, cookware, cleaning products, personal care products, and electronics (KEMI 2015), as well as in food (Christensen et al. 2017) and drinking water (Boone et al. 2019; Schwanz et al. 2016). This widespread presence of PFASs in products can result in multiple-source exposure to complex PFAS mixtures, including exposures from consumer products other than artificial turf (Bečanová et al. 2016). These other potential exposure sources, in aggregate, contribute to exposure and, consequently, increase the potential for significant or widespread adverse impacts.

4.4. Indicators of Potential Exposures to the Candidate Chemical

Reference: California Code of Regulations, title 22, section 69503.3(b)(2).

The SCP Regulations consider various data that indicate potential for exposure to the Candidate Chemical or its degradation products, including: monitoring data indicating the Candidate Chemical's presence in the indoor and outdoor environment, biota, humans, human food, drinking water, and other media; and evidence of persistence, bioaccumulation, lactational and transplacental transfer.

Reliable information demonstrates the pervasive presence of PFASs in various environmental media, including indoor and outdoor air and dust (DTSC 2021). For instance, dust samples from California childcare centers contained several PFASs, indicating inhalation and ingestion as significant exposure pathways (Wu et al. 2020).

Releases of PFASs have contaminated creeks, rivers, lakes, oceans, and groundwater. For example, PFOS and PFOA have been detected in drinking water sources across the U.S., particularly near industrial sites and military bases (Hu et al. 2016; U.S. EPA 2017). PFASs are also ubiquitous in soils, even in remote locations such as Antarctica and the Arctic Circle (Hanssen et al. 2019; Llorca et al. 2012; Rankin et al. 2016). Sediment samples from rivers and lakes often show high concentrations of PFOS and PFOA, reflecting long-term environmental persistence (Rankin et al. 2016).

PFASs, particularly PFAAs, bioaccumulate in various organisms as they are exposed over time. These include plankton, sea turtles, seals, California sea otters, whales, fish, white-tailed eagles, and bird eggs. Human food sources are also contaminated with PFASs. Human biomonitoring studies show that PFASs accumulate in blood, tissues, and organs, with evidence of transplacental and lactational transfer of PFASs, which poses health risks to fetuses and infants (Cariou et al. 2015; Papadopoulou et al. 2016; Winkens et al. 2017).

Due to the phaseout of longer-chain PFASs, shorter-chain variants have become increasingly prevalent in the environment (Brendel et al. 2018).

5. POTENTIAL FOR SIGNIFICANT OR WIDESPREAD ADVERSE IMPACTS

Reference: California Code of Regulations, title 22, section 69503.2(a).

This section integrates the information provided in the document to demonstrate how the key prioritization principles, as identified in the SCP Regulations, are met.

The policy priorities and considerations listed in DTSC's 2024-2026 Priority Product Work Plan include protecting the health of children and workers from potential exposures to Candidate Chemicals in consumer products, reducing potential release of Candidate Chemicals from consumer products to indoor air and dust, reducing the release of microplastics to the environment during all stages of a

product's life cycle, and protecting California's valuable and limited water resources and aquatic ecosystems from consumer product-derived chemical contamination (DTSC 2024).

DTSC prioritizes the protection of vulnerable populations, such as children, from exposure to and adverse impacts of Candidate Chemicals such as PFASs. Growing evidence continues to highlight the positive associations between exposure to PFASs and adverse impacts in children, including dyslipidemia, asthma, and renal function (Rappazzo et al. 2017). Given their use of artificial turf during sports and recreation, children may be especially vulnerable to adverse impacts associated with PFASs from artificial turf.

Over its life cycle, artificial turf can release PFASs into indoor air and dust, outdoor air, water, and soil. Because they are extremely persistent in the environment, PFASs are now global pollutants that can be found in all environmental compartments. Atmospheric and oceanic currents, as well as international trade, have distributed PFASs to areas of the world far from manufacturing sites (Muir et al. 2019; Stock et al. 2004).

Given the potential for ongoing human and ecological exposures to PFASs throughout the life cycle of artificial turf, and the toxicological, environmental, and exposure potential hazard traits of PFASs, DTSC has determined that exposure to PFASs from artificial turf has the potential to contribute to or cause significant and widespread adverse impacts in humans and other organisms.

5.1. Adverse Impacts Linked to the Candidate Chemical's Hazard Traits

Reference: California Code of Regulations, title 22, section 69503.3(a).

The SCP Regulations direct the Department to evaluate the potential for the Candidate Chemical to contribute to or cause adverse impacts by considering several adverse impact factors for which information is reasonably available.

Artificial turf can contain both polymeric and non-polymeric PFASs. Most non-polymeric PFASs degrade into PFAAs, which persist in the environment, while polymeric PFASs can form microplastics that are of a hazardous particle size and can persist and move throughout the environment (DTSC 2025). Microplastics have been detected in homes and ecosystems throughout the globe. Microplastics' ubiquity gives them high potential to expose people, wildlife, and the environment, and contribute to or cause widespread adverse impacts (DTSC 2025). Non-polymeric PFASs exhibit hazard traits such as persistence, mobility in the environment, bioaccumulation, and lactational and transplacental transfer. These adverse impacts are especially significant for children who are particularly sensitive to the adverse effects from exposure to toxic chemicals, due to windows of susceptibility that occur during the active stages of growth and development (ATSDR 2012; WHO 2006).

The extreme persistence and ubiquity of PFASs, along with the known, significant toxicological effects and cumulative impacts of the better-studied members of the class, underscore the need for regulatory action to mitigate further releases and the consequent adverse impacts on public health and the environment. Persistence has been called “the most important single criterion affecting chemical exposure and risk via the environment” (Mackay et al. 2014). Persistent chemicals may travel longer distances, affect a larger population, and have increased potential for bioaccumulation across food webs (Mackay et al. 2014). They are also very slow to be removed from the environment through natural processes or engineered remediation (Mackay et al. 2014). Extremely persistent chemicals like PFASs are now global pollutants that can be found in all environmental compartments. Once PFASs are dispersed in the environment, there is no practical way to remove them. Their widespread presence has led to contamination of drinking water and human food supplies and growing concern about potential public health impacts (Andrews and Naidenko 2020; APHA 2016).

As discussed in section 3 of this document and detailed in Appendix C of the *Product-Chemical Profile for Food Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances*, better-studied non-polymeric PFASs exhibit several human toxicological hazard traits, including carcinogenicity, cardiovascular toxicity, developmental toxicity, endocrine toxicity, hepatotoxicity and digestive system toxicity, immunotoxicity, nephrotoxicity and other urinary system toxicity, neurodevelopmental toxicity, reproductive toxicity, respiratory toxicity, and ocular toxicity. Their environmental hazard traits also include phytotoxicity and impairment of wildlife development, reproduction, or survival, however data are limited to a very small number of PFASs and organisms (ITRC 2020). Studies have also suggested that PFAAs, including PFHxA, may contribute to mixture toxicity and enhance the adverse impacts associated with other hazardous compounds (see section 5.2 on Cumulative Effects below).

Discharges of PFAS-contaminated WWTP effluents into streams and rivers have led to contamination of water and sediments at concentrations considered potentially hazardous to wildlife and threatening to biodiversity (Rodriguez-Jorquera et al. 2016). The ubiquity of PFASs in aquatic environments and the limited toxicological knowledge about cumulative impacts to aquatic species have led to increasing concern about the potential for irreversible adverse aquatic impacts (Scheringer et al. 2014).

The fluoropolymers in artificial turf are not expected to be highly leachable (Henry et al. 2018), but they can form microplastics when blades and backing disintegrate under various weather conditions and physical abrasion (Lohmann et al. 2020). Microplastics end up in stormwater collection systems during rainfall and runoff events, and they directly discharge into receiving waters without treatment in most urban environments in California. Microplastics are persistent and mobile in the environment and, as a result, they are ubiquitous in virtually all environmental media, ecosystems, and food chains. Microplastics have been reported in drinking water, household dust, and indoor air (Gasperi et al. 2018; Koelmans et al. 2019; Soltani et al. 2021). Fluoropolymer particles have the potential for long-

distance environmental transport, as shown by the detection of PTFE in deep-sea arctic sediment (Bergmann et al. 2017). In the environment, microplastics continue disintegrating into ever smaller particles, ultimately becoming nanoplastics—respirable particles less than 10 µm in size. Laboratory studies show that exposure to micro- and nanoplastics may negatively impact animal’s reproduction and development, cause the dysfunction of the liver and intestine, and induce immune response and neurotoxic effects (Li et al. 2023). Experiments with mammalian cells show that exposure to microplastics may result in cell deaths by oxidative stress and membrane damage (Li et al. 2023).

PFASs are ubiquitous due to their extreme persistence and ability to travel large distances through air and water, leading to multiple exposure pathways in humans and environmental biota and increasing the potential for adverse impacts, both known and as yet undetermined. Increasing reports of toxicity in humans and experimental animals, sometimes at or below common exposure levels, have led to growing public health concern (APHA 2016) and expanded regulatory interest (Scheringer et al. 2024; DeWitt et al. 2024).

5.2. Cumulative Effects

Reference: California Code of Regulations, title 22, section 69503.3(a)(1)(C).

Cumulative effects occur from exposures to the Candidate Chemical and other chemicals with the same or similar hazard traits or environmental or toxicological endpoints.

PFASs have become ubiquitous in peoples’ daily lives and in the environment (Glüge et al. 2020). Humans and non-human organisms are constantly exposed to mixtures of PFASs, leading to cumulative exposure to multiple PFASs. Toxicological assessments typically focus on single PFASs rather than mixtures, leaving the effects of PFAS mixtures undercharacterized. Some research suggests that exposure to PFAS mixtures might result in greater toxicity than exposure to a single PFAS or might result in additive effects (Wang et al. 2011). Evidence from *in vitro* and *in vivo* studies show additive or synergistic effects of PFAS mixtures, including altered cellular lipid patterns, increased oxidative stress, endocrine disruption, and mitochondrial dysfunction (Gorrochategui et al. 2014; Hoover et al. 2019; Rainieri et al. 2017).

Studies also show potential for co-exposure to PFAS mixtures and other chemicals to perturb biological pathways and contribute to disease. In particular, PFAAs may have cumulative impacts with one another and with other hazardous chemicals; however, the specific adverse impacts that may result from such co-exposures are not well characterized and require additional research (Du et al. 2017; Rodea-Palomares et al. 2012; Yeh et al. 2017). For more details on cumulative impacts of PFAS mixtures, refer to the description of cumulative effects found in section 6 of the *Product-Chemical Profile for Treatments Containing Perfluoroalkyl or Polyfluoroalkyl Substances for Use on Converted Textiles or Leathers*.

Besides PFASs, other potentially toxic chemicals that may be present in artificial turf blades include but are not limited to plasticizers (e.g., ortho-phthalates), various colorants (e.g., azo dyes), antioxidants (e.g., various phenols, amines, and thioesters), and UV light stabilizers (e.g., benzophenones, benzotriazoles, and hindered amines) (Tolinski 2015b). The cumulative effects of exposure to various chemicals in artificial turf may be additive or synergistic.

Infill materials are used to provide cushioning in most artificial turf sport fields. These materials can have diverse and complex chemical compositions (Jastifer et al. 2018). The most common type of infill, crumb rubber, which is made from recycled automotive tire rubber, contains many Candidate Chemicals, such as benzo[a]pyrene (a carcinogen), ortho-phthalates (endocrine disruptors), and zinc (aquatic toxicant), to name a few (ATSDR 2019a; ATSDR 2019b). Other infill materials used for cushioning in artificial turf sports fields (e.g., elastomers, polymers, sand, and organic materials like coconut fiber, cork, and ground walnut shells) (Jastifer et al. 2018) may also be of concern due to potential health impacts. Although infill materials are outside the scope of this document, exposure to the chemicals they contain—along with PFASs, which are within the scope—could have cumulative effects.

5.3. Adverse Waste and End-of-Life Effects

Reference: California Code of Regulations, title 22, sections 69503.2(b)(1)(B) and 69501.1 (a)(8).

This section summarizes findings related to the waste materials and byproducts generated during the life cycle of the product and their associated adverse effects, as described in the SCP Regulations. These considerations can form part of the basis for proposing the product-chemical combination.

Historically, recycling of the blades and backing of end-of-life artificial turf has been rare (The Intercept 2019); reuse of infill material (which is outside the scope of the current document) is more common (Zandwijk RTS 2022). Although turf recycling programs have emerged in recent years, they often require the burning or shredding of end-of-life artificial turf, which may lead to worker exposure and continued consumer exposure to PFASs (Ismawati et al. 2023; TenCate 2020).

Artificial turf is most commonly disposed of in landfills after its intended use (Berger 2016). Landfill disposal is a concern because of the large mass of waste involved. Even in a landfill, the roughly 40,000 pounds of turf and 400,000 pounds of infill used in a single average field (STC 2017) may continuously release non-polymeric PFASs and microscopic PTFE particles to leachates and, subsequently, to the environment over time.

Incineration, which is another potential way to dispose of used artificial turf, is problematic because the fluoropolymers in artificial turf blades can form toxic combustion products (e.g., perchlorofluoroalkanoic acids and polycyclic aromatic hydrocarbons) (Myers et al. 2014). Incineration

only accounts for a small portion of overall waste management in the United States (Ng et al. 2019; U.S. EPA 2016b).

PFASs that enter WWTPs are not removed by conventional treatment processes such as sedimentation, flocculation, coagulation, and biological degradation (Ng et al. 2019; Rahman et al. 2014). The enhanced treatment required to remove PFASs is expensive (Arvaniti and Stasinakis 2015; Mudumbi et al. 2017). Adsorption and ion-exchange have recently been explored as methods that could increase the speed and efficiency of PFAS removal (Ateia et al. 2019b; Ji et al. 2018). While the combination of adsorption and separation technologies with destructive technologies shows promise for removing a wider range of PFASs, their large-scale application poses several challenges (Horst et al. 2018), including reliance on chemicals and energy, high cost, and generation of harmful byproducts (Lu et al. 2020). Shorter-chain PFAAs are especially challenging to remove from wastewater and destroy (Li et al. 2020).

Biosolids, especially those from WWTPs that treat leachate from landfills and composting facilities, can be heavily contaminated with PFAAs and precursors that adsorb to organic matter (Arvaniti et al. 2012; Gallen et al. 2018; Kim Lazcano et al. 2019; Sun et al. 2011; Kim Lazcano et al. 2020). Shorter-chain PFAAs have been observed to migrate out of soil following biosolid application, with disappearance half-lives ranging from 88 to 866 days (Venkatesan and Halden 2014). Over time, they can leach into adjacent waterways (Sepulvado et al. 2011), potentially leading to widespread contamination and ecological impacts. Land application of biosolids contaminated with PFAAs and their precursors can lead to bioaccumulation of PFAAs in grasses (Yoo et al. 2011) and food crops (Blaine et al. 2014; Lee et al. 2014). Currently, the concentrations of PFHxA, GenX, ADONA, and other replacement PFASs in land-applied biosolids have shown an increasing trend, while PFOS and PFOA concentrations are generally decreasing (Choi et al. 2019). Unlike many other anthropogenic contaminants in biosolids, which can undergo varying degrees of degradation following land application, PFASs resist breakdown and instead only degrade into other, highly persistent PFASs, as explained in section 3.

PFASs in landfill leachates, land-applied wastewater, and biosolids can contaminate streams, rivers, and other drinking water sources (Hoffman et al. 2011; Lindstrom et al. 2011). Stormwater runoff containing PFASs released from consumer products may be a significant pathway for PFAS transport and release to surface waters (Houtz and Sedlak 2012).

5.4. Populations That May be Adversely Impacted

Reference: California Code of Regulations, title 22, sections 69503.3(a)(1)(F) and 69503.3(a)(2).

This section identifies specific populations of humans and environmental organisms that may be harmed if exposed to the Candidate Chemical in the product. Sensitive subpopulations, environmentally

sensitive habitats, endangered and threatened species, and impaired environments in California have special consideration, as they may be more vulnerable.

Humans and environmental organisms can be exposed to PFASs frequently and from multiple sources over a lifetime. Sources of exposure include placental transfer, breastfeeding, drinking water, food, and contact with consumer products and other environmental media. PFASs have the potential to cause significant and widespread adverse impacts, especially to:

- sensitive subpopulations (which include fetuses, infants, children, pregnant women, some workers, and people with certain preexisting conditions);
- environmentally sensitive habitats; and
- threatened and endangered species.

More than 200 million U.S. residents are estimated to receive PFAS-contaminated drinking water (Andrews and Naidenko 2020). Fetuses, infants, toddlers, and young children experience higher relative exposure levels and are more vulnerable to the effects of toxicants. Artificial turf users (e.g., athletes, children, and people with residential turf installations) may be exposed to PFASs during sport, play, and leisure. People with certain preexisting conditions (e.g., elevated cholesterol, high blood pressure, poor kidney function) may be especially sensitive to PFASs. Pregnant women's exposure to PFASs is of concern due to transplacental and lactational transfer to their offspring. Sensitive habitats and endangered and threatened species in California are vulnerable to contamination of waterways and food webs from PFASs that originate from artificial turf.

A brief discussion of populations that may experience impacts is included below.

Sensitive Subpopulations

Children are a sensitive subpopulation because of their higher ingestion and inhalation rates per unit of body weight, rapid development, immature physiological ability to detoxify environmental contaminants, and behavioral characteristics that predispose them to increased exposures to environmental contaminants (U.S. EPA 2011). These factors result in a higher body burden of PFASs as compared to adults (Rappazzo et al. 2017). Children experience windows of susceptibility during development where they are especially vulnerable to the adverse effects from exposure to environmental toxicants (ATSDR 2023). Pregnant people and fetuses are also sensitive subpopulations because of transplacental migration and the vulnerability of the rapidly developing fetus (Slotkin et al. 2008). Because PFASs can be transferred from the mother's bloodstream into breast milk, nursing infants are susceptible to increased exposure to PFASs (Kang et al. 2016; Kärrman et al. 2007; Mogensen et al. 2015; Mondal et al. 2014; Abdallah et al. 2020). Infants, toddlers, and young children often have increased exposures due to hand-to-mouth behaviors that can lead to increased incidental ingestion of dust and soil with environmental contaminants, and higher doses relative to body weight compared to adults (U.S. EPA 2011).

Exposure to PFASs from artificial turf may disproportionately impact sensitive subpopulations, some of whom may also be exposed to the class through work or contact with contaminated environmental media. Studies demonstrate substantial human exposure in workers at fluorochemical manufacturing facilities (Gao et al. 2018) and communities relying on contaminated drinking water sources (Heydebreck et al. 2016). People living near PFAS chemical manufacturers, or in other areas contaminated by PFASs, have higher-than-average levels of PFASs (Fromme et al. 2009). Individuals with biomarkers of susceptibility for certain health conditions may be unusually sensitive to PFAS exposure (ATSDR 2021).

Residents of low-income communities may be disproportionately impacted by chronic exposures to multiple hazardous industrial chemicals, including PFASs released from artificial turf. These exposures increase the likelihood of cumulative adverse health effects (U.S. EPA 2016a). These residents may also experience aggregate adverse health effects from exposures to the same chemical at multiple points in the life cycle of associated products. For instance, school districts may choose to install artificial turf containing chemicals such as PFASs to save on maintenance costs (Bond 2024), while manufacturing, recycling, and waste facilities, including those that release PFASs, may also be located in these communities (U.S. EPA 2024a).

Release of PFASs from artificial turf contributes to the global environmental burden of this extremely persistent chemical class. PFAS contamination has been documented in far-flung areas, far from manufacturing sites, such as the remote regions of the Arctic. For instance, certain foods that are staples of the traditional diets of the Inuit in Nunavut, Canada, the Nuuk Inuit in Greenland, and the Faroese in the Faroe Islands are heavily contaminated with PFASs that originated from thousands of miles away (Grandjean et al. 2012; Grandjean et al. 2017a; Long et al. 2012; Ostertag et al. 2009).

Environmentally Sensitive Habitats

Environmentally sensitive habitats in California, including estuaries and other wetlands, can be contaminated with PFASs from surface runoff or WWTP effluent. These ecosystems are important breeding, spawning, and nesting sites, and feeding grounds for millions of migratory birds—including threatened and endangered species—that transit California during their annual migration. Since artificial turf exhibits significantly more runoff than natural grass (Simpson and Francis 2021), there is increased likelihood that chemicals associated with artificial turf, such as PFASs, will spread into sensitive habitats during rain events. While studies specifically on leachate from artificial turf have primarily focused on chemicals from crumb rubber infill (Celeiro et al. 2021; Gomes et al. 2021; Halsband et al. 2020; Lu et al. 2021), PFASs, which are not normally associated with the tire rubber from which such infill is made, have been detected repeatedly in artificial turf samples and on users of artificial turf (Amenabar 2024; Bennett 2024; Ecology Center 2019; Naim 2020; Zuccaro et al. 2023). The continued detection of multiple PFASs from artificial turf highlights the potential for these compounds to move throughout the environment.

Threatened and Endangered Species

Exposure to PFASs from artificial turf has the potential to result in significant or widespread adverse impacts to virtually all organisms, including California's endangered and threatened species. As such, release of PFASs from artificial turf could contribute to the current biodiversity crisis in aquatic ecosystems (Abell 2002; Mora and Sale 2011; Valentini et al. 2016). Threatened and endangered species of fish and marine mammals are particularly vulnerable to population-level adverse impacts if they cannot obtain food or avoid predators. Mammals and birds occupying the highest trophic level, including orcas, wolves, eagles and condors, are vulnerable to adverse health effects from ingestion of food and water contaminated with PFASs that bioaccumulate and biomagnify (Kannan et al. 2006; Kelly et al. 2009).

6. OTHER REGULATORY PROGRAMS

Reference: California Code of Regulations, title 22, section 69503.2(b)(2).

DTSC has assessed all applicable state and federal laws and regulations and international treaties or agreements with the force of domestic law related to the product or the Candidate Chemical in the product. DTSC has determined that neither listing artificial turf containing PFASs as a Priority Product, nor any subsequent regulation that may result from such listing, would overlap or conflict with these existing programs.

6.1. Applicable California State Laws and Regulations

In addition to regulation under the Safer Consumer Products Program, California law has generally addressed PFASs contained in or generated by consumer products through direct bans on sales and manufacturing and written warning requirements. The Health and Safety Code (HSC) addresses PFASs in personal protective equipment (HSC 13029), firefighting foam (HSC 13061; HSC 13062), cosmetics (HSC 108981), juvenile products (HSC 108946), menstrual products (HSC 25258.3), food packaging (HSC 109000), cookware (HSC 109000), and textile products (HSC 108970; HSC 108971).

6.2. Applicable Federal Laws and Regulations: Toxic Substances Control Act (TSCA) and Safe Drinking Water Act (SDWA)

Section 5 of TSCA authorizes U.S. EPA to issue Significant New Use Rules (SNURs) for new chemicals or existing chemicals used in a significant new way. A SNUR requires companies to notify U.S. EPA at least 90 days prior to manufacturing, importing, or processing substances for a significant new use and to submit a notification that includes information about the chemical's identity, physical characteristics, processing and use, along with available toxicity data. U.S. EPA has 90 days to evaluate the new use and can request more data, prohibit or limit the manufacture, or allow the use of the chemical. The list

of SNURs related to PFASs proposed or implemented before 2021 can be found in the *Product-Chemical Profile for Food Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances*.

Since 2021, several key federal regulations and actions have been implemented to address PFAS contamination. The PFAS Action Act of 2021 includes several key provisions that aim to address the PFAS crisis. The act mandates U.S. EPA to designate PFASs as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Among many other provisions, the act also requires U.S. EPA to establish national primary drinking water regulations for several PFASs, including PFOA and PFOS, under the SDWA; designates PFOA and PFOS as hazardous substances; and requires “PFAS-free” labeling for some products (Dingell 2021).

U.S. EPA has also taken action on PFASs in drinking water. In April 2024, U.S. EPA established a non-enforceable Maximum Contaminant Level Goal for PFOA and PFOS of zero (88 FR 18638 2023). In addition, U.S. EPA established enforceable Maximum Contaminant Levels for PFOA and PFOS at 4 ppt and for PFNA, PFHxS, and HFPO-DA (GenX Chemicals) at 10 ppt (88 FR 18638 2023). The agency established a Hazard Index of 1 for mixtures of any two or more of the following PFASs: PFHxS, HFPO-DA and its ammonium salt (also known as GenX chemicals), PFNA, and PFBS. Hazard Index of 1 warrants further investigation and potential regulatory actions (88 FR 18638 2023). In 2021, U.S. EPA also finalized a rule under SDWA requiring public water systems that serve more than 3,300 customers to collect data on 29 PFASs (40 CFR Part 141.40 2021).

In 2023, U.S. EPA finalized a rule under TSCA that requires manufacturers and importers of PFASs to report information to the agency, including data on the entity’s PFAS uses, production volumes, byproducts, disposal, occupational exposures, and hazards for each year between January 1, 2011, and December 31, 2022. For the purpose of this rule, the agency has defined PFASs as substances that contain at least one of the following three structures:

- $R-(CF_2)-CF(R')R''$, where both the CF_2 and CF moieties are saturated carbons.
- $R-CF_2OCF_2-R'$, where R and R' can either be F , O , or saturated carbons.
- $CF_3C(CF_3)R'R''$, where R' and R'' can either be F or saturated carbons.

This definition of PFASs is more narrow than the definition by Buck et al. (2011) and may potentially exclude some fluoropolymers from reporting (U.S. EPA 2024b). U.S. EPA states that any TSCA chemical substance meeting this definition is subject to reporting. Based on this definition, the agency estimates that at least 1,462 PFASs that are known to be made or used in the U.S. since 2011 are subject to PFAS reporting (U.S. EPA 2024b).

6.3. Applicable International Treaties or Agreements with the Force of Domestic Law

Stockholm Convention on Persistent Organic Pollutants

There are no applicable international treaties or agreements with the force of domestic law. The Stockholm Convention on Persistent Organic Pollutants (POPs), is a global treaty to protect human health and the environment from chemicals that do not degrade but persist in the environment, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or the environment. However, the U.S. has not ratified the Stockholm Convention, and it has no force of law in the U.S. or in California.

As of 2024, the Stockholm Convention has listed several PFASs in its annexes. PFOA, its salts, and PFOA-related compounds are included in Annex A, which lists chemicals that are subject to elimination, with some exemptions for certain uses. PFHxS, its salts, and PFHxS-related compounds are also included in Annex A, with no exemptions. In 2009, PFOS, its salts, and perfluorooctane sulfonyl fluoride were added to Annex B, which restricts the production and use, as well as the import and export, of listed POPs (SSCCH 2017). However, production and use of chemicals listed in Annex B are still allowed “for acceptable purposes.”

7. POTENTIAL ALTERNATIVES

Reference: California Code of Regulations, title 22, section 69503.2(b)(3).

This section summarizes information available to DTSC regarding alternatives that may or may not be safer than the Candidate Chemical. DTSC does not need to ensure that these alternatives are safer and may summarize their associated hazards to illustrate readily available information. The sections below may include information such as how readily available an alternative is, product functions addressed by the alternative, and implications for manufacturers using the alternative (e.g., use limitations, product reformulation, different equipment needs).

Fluoropolymers are added to artificial turf plastic to increase product quality by preventing ridges from forming when the blades are being formed, a problem called melt fracture, or “sharkskin” (3M 2016). Therefore, alternatives to PFASs in artificial turf must be capable of managing or removing this manufacturing concern. Both nonchemical and chemical alternatives to the current use of PFASs in artificial turf already exist. Potential nonchemical alternatives involve the re-engineering of artificial turf manufacturing processes (NETZSCH Analyzing & Testing 2022; Rauwendaal 2001; TURI 2018). Potential chemical alternatives include the replacement of PFASs with processing aids such as boron nitride, thermoplastic urethane elastomers, silicones, and polyethylene terephthalate, as well as the use of hyperbranched polymers which reduce melt fracture and eliminate the need for PFASs (Hong et al. 1999; Kulikov 2005; Lambert et al. 2008; Pape et al. 1999; Rathod and Hatzikiriakos 2004).

7.1. Nonchemical Alternatives

Engineering strategies may be a promising approach for reducing the presence of melt fracture in artificial turf without the use of PFASs or other additives (NETZSCH Analyzing & Testing 2022; Rauwendaal 2001). The general cause of melt fracture is stress in plastic extrusion die (Rauwendaal 2001), the “metal channels that impart a specific cross-sectional shape to a polymer stream” (Baird 2003). The following methods reduce polymer shear stress without altering the formulation of the resin:

- Reducing the extrusion rate (Giles et al. 2005; Rauwendaal 2001)
- Increasing the die-land temperature with a heater to drop the shear stress below the critical shear stress for the resin’s melt fracture (Giles et al. 2005; NETZSCH Analyzing & Testing 2022; Rauwendaal 2001)
- Streamlining the die’s design by analyzing stresses through the die (Giles et al. 2005)
- Increasing the die gap where the extrusion occurs (Giles et al. 2005; Rauwendaal 2001).

Both conventional and organic natural turf grass, are alternatives to artificial turf containing PFASs. The Toxics Use Reduction Institute (TURI) conducted an alternatives assessment evaluating three turf types—organic turf, conventional turf, and artificial turf—and found organically managed natural grass to be safest and most cost effective when considering the full product life cycle (TURI 2018). Organic turf is natural grass that requires no synthetic pesticides or synthetic fertilizers but requires specific practices to encourage healthy grass growth and reduce irrigation needs (TURI 2016). Unlike organic turf, conventional turf involves the use of synthetic fertilizers and/or pesticides, which may either be applied infrequently in small areas or used routinely (TURI 2016). Artificial turf does not typically require irrigation, though irrigation may be recommended to reduce turf surface temperatures on hot days (TURI 2018). Artificial turf may need to be treated with antimicrobial chemicals to reduce the risk of body fluid contamination and staph infections, something soil microbes typically manage in natural grass (Grassroots Environmental Education 2023).

7.2. Chemical Alternatives

Potential chemical alternatives to the use of PFASs in artificial turf include boron nitride, thermoplastic urethane elastomers (TPUEs), silicones, polyethylene terephthalate, and hyperbranched polymers (Kulikov 2005; Lambert et al. 2008; NETZSCH Analyzing & Testing 2022; Pape et al. 1999; Seth 1997). These chemical alternatives prevent melt fracture in different ways (Kulikov 2005; Lambert et al. 2008; NETZSCH Analyzing & Testing 2022; Pape et al. 1999; Seth 1997).

Boron nitride is a processing aid that can reduce melt fracture in many polymers (Rathod and Hatzikiriakos 2004; Sentmanat and Hatzikiriakos 2004). In contrast to fluoropolymers, which can only mitigate surface melt fracture, boron nitride is also effective against gross melt fracture (Hatzikiriakos and Rathod 2003).

TPUEs delay melt fracture instabilities in polyethylene products (Kulikov 2005). When added in small amounts, TPUEs deposit at the die surface allowing for higher rates of extrusion; however, the efficiency of this process is temperature-dependent (Kulikov 2005). Advantages of TPUEs over fluorinated polymer processing aids include their potential for reduced toxicity, lower price, and reduced environmental impact (Kulikov 2005).

Silicone processing aids reduce melt fracture in polyethylene (Pape et al. 1999). Their performance depends on the structure and concentration of the silicone polymer used. Their effectiveness in reducing melt fracture increases with the polarity of their functional groups (Pape et al. 1999). Silicone processing aids also reduce extruder pressure and current, and they lower the coefficient of friction of the extruded polyethylene surface (Pape et al. 1999).

Polyethylene terephthalate is another potential alternative to PFASs in artificial turf (Lambert et al. 2008). A 2008 patent for polyethylene turf details many additives used in the manufacture of its components such as pigmented tape, fiber, and filaments, as well as additives that lower the friction coefficient of these materials. The patent cites polytetrafluoroethylene (a PFAS) and polyethylene terephthalate as alternatives for lowering friction (Lambert et al. 2008).

A polymer's properties (e.g., viscosity) can be affected by the branching of its chemical constituents (Hong et al. 1999). Hong et al. (1999) found that hyperbranched polymers successfully eliminated melt fracture and reduced the power requirement for extrusion by lowering the viscosity of polymer blends.

Several artificial turf products are marketed as PFAS-free (AstroTurf 2025; SYNLawn 2025). One such product mentions the use of patented polymer processing aids that do not have fluorine (AstroTurf 2025). Other proprietary PFAS-free processing aids have also recently entered the market for a variety of applications and may be potential alternatives to PFASs in artificial turf (Ampacet Corporation 2023; Avient 2024; Mitsui Plastics, Inc. 2024).

8. ADDITIONAL CONSIDERATIONS

This section summarizes other relevant information not captured under the adverse impact and exposure factors named in section 69503.3 of the Safer Consumer Products regulations.

Although chemical manufacturers have been aware of PFASs' potential adverse impacts for decades, national and international action to limit human and ecological exposures has only recently begun. In 2015, more than 200 scientists from 40 countries signed The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs) (Blum et al. 2015), a scientific consensus on the persistence and potential for harm of this class of chemicals, as well as a roadmap for international cooperation to prevent further harm. Since then, many countries and regions have implemented regulations on PFASs. For example, the U.S. and European Union (EU) have introduced or adopted measures to lower exposure to PFASs (DeWitt et al. 2024). In the U.S., Maine, California, and New Hampshire have the

largest number of adopted laws that address the presence of PFASs in products—in firefighting foam, packaging, water, textiles, and personal care products, to name a few (Safer States 2024). Policymakers have been moving toward more comprehensive approaches to PFAS regulation, including addressing PFASs as a class and considering their life cycle, as well as integrating the essential use concept, which is discussed in section 8.1 (DeWitt et al. 2024).

In 2023–2024, legislators across 34 U.S. states introduced more than 330 bills to address PFASs. The three states with the largest number of introduced bills were Minnesota (55 bills), Massachusetts (36 bills), and New York (32 bills) (Safer States 2024). Nine bills (Safer States 2024) were introduced in California. The bills intended to either phase out some specific PFASs or class of PFASs, set the stage for further PFAS research and regulations, or increase producers’ accountability (Safer States 2024). Meanwhile, several states have proposed or enacted laws to ban, require reporting of, or restrict the avoidable use of PFASs in artificial turf: New York, Maine, Minnesota, and Vermont (Safer States 2024).

8.1. The Essential-Use Concept

The essential use concept was based on the Montreal Protocol, which called for the global elimination of the use of ozone-depleting substances (Cousins et al. 2019). To best apply this concept to chemical regulation in North America, a set of three criteria were proposed to determine whether a specific use of a chemical of concern is “essential”: (1) the function of the chemical is necessary for the product; (2) the use of the chemical is the safest feasible option; (3) the use of the chemical in the product is necessary for health, safety, or the functioning of society (Bălan et al. 2023). Legislators have integrated the essential use concept into laws that intend to gradually phase out PFAS use. Example of such proposed or enacted legislation include those in the EU and in Minnesota and Maine in the U.S.

8.2. Relevant Proposed Laws and Regulations in Other Countries

The legislative landscape around PFAS rapidly evolves, with countries taking significant steps toward restricting PFASs, increasing transparency, and funding research. While the bills directly addressing PFASs in artificial turf are limited in number, the general trend toward stricter PFAS regulation suggests that the artificial turf industry might be indirectly affected by broader PFAS legislation in the coming years.

On May 11, 2020, the national authorities of Germany, the Netherlands, Norway, Sweden, and Denmark initiated a call for evidence to inform a joint Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) proposal to limit the human health and environmental risks associated with the manufacture and use of PFASs. The European Chemicals Agency’s (ECHA’s) comprehensive approach includes prohibiting the production, marketing, and use of a broad range of PFASs, except for essential uses where no alternatives are available. The proposal includes two options: a full ban on PFASs and a ban with use-specific derogations. In a six-month comment period

that ended in September 2023, ECHA received more than 5,600 comments from various interested and affected parties. As of July 2024, ECHA's committees for Risk Assessment (RAC) and for Socio-Economic Analysis (SEAC) were evaluating the comments and conducting additional meetings with various industries to update the text of the proposed REACH restriction.

9. CONCLUSIONS

DTSC has determined that artificial turf containing any member of the class of PFASs meets the key prioritization criteria (California Code of Regulations, title 22, section 69503.2(a)) for listing a Priority Product:

- (1) There must be potential public and/or aquatic, avian, or terrestrial animal or plant organism exposure to the Candidate Chemical(s) in the product; and
- (2) There must be the potential for one or more exposures to contribute to or cause significant or widespread adverse impacts.

Artificial turf is widely used across California and can be a significant source of human and ecological PFAS exposures, including human exposures primarily via inhalation and ingestion during product use, and ecological exposures primarily via runoff and weathering.

The PFASs used in artificial turf and their degradation products have the potential to contribute to or cause significant and widespread adverse impacts to sensitive subpopulations, especially young children. They may also adversely impact environmentally sensitive habitats and threatened and endangered species. Given the known hazard traits of all members of the class, replacing currently used PFASs in artificial turf with other PFASs could constitute a regrettable substitution.

Although artificial turf containing PFASs meets the key prioritization criteria outlined in the SCP Regulations, DTSC has determined that the market is shifting away from using PFASs. We consider a pre-regulatory market shift a positive outcome. To verify this has occurred, we are pausing listing this product-chemical combination as a Priority Product to gather additional information from manufacturers and conduct product testing. If we find that PFASs continue to be present in artificial turf and that regulatory action is appropriate to address the potential PFAS exposures and resulting harms, we plan to move forward with regulating this product-chemical combination.

ACRONYMS AND ABBREVIATIONS

Individual PFASs

ADONA	4,8-dioxa-3H-perfluorononanoic acid
GenX (HFPO-DA)	Hexafluoropropylene oxide-dimer acid
FTOHs	Fluorotelomer alcohols
FTSAs	Fluorotelomer sulfonic acids
PFAA	Perfluoroalkyl acid
PFBS	Perfluorobutanesulfonic acid
PFCAs	Perfluorinated carboxylic acids
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoate or perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate or perfluorooctane sulfonic acid
TFA	Tetrafluoroacetic acid

Other Abbreviations Used in This Document

C	Carbon
CAS RNs	Chemical Abstracts Service Registry Numbers
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CO ₂	Carbon dioxide
DDT	Dichlorodiphenyltrichloroethane
DTSC	Department of Toxic Substances Control
ECHA	European Chemicals Agency
EOF	Extractable organic fluorine
EPA	Environmental Protection Agency
EU	European Union
F	Fluorine
FIFA	Federation Internationale de Football Association
GPC	Global Product Classifications
GS1	Global Standards One
GWP	Global Warming Potential
HCFC-22	Hydrochlorofluorocarbon-22
HFC	Hydrofluorocarbon
HFC-23	Trifluoromethane

HFP	Hexafluoropropylene
HSC	Health and Safety Code
<i>in vitro</i>	Within the living
<i>in vivo</i>	In glass
O	Oxygen
OECD	Organization for Economic Cooperation and Development
OEHHA	Office of Environmental Health Hazard Assessment
PCB	Polychlorinated biphenyl
PTFE	Polytetrafluoroethylene
POPs	Persistent organic pollutants
PPAR	Peroxisome proliferator-activated receptor
PVDF	Polyvinylidene fluoride
PVF	Polyvinyl fluoride
RAC	Committee for Risk Assessment
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
SDWA	Safe Drinking Water Act
SEAC	Committee for Socio-Economic Analysis
SNUR	Significant New Use Rules
STC	Synthetic Turf Council
TF	Total fluorine
TFE	Tetrafluoroethylene
TPUE	Thermoplastic urethane elastomer
TSCA	Toxic Substances Control Act
TURI	Toxics Use Reduction Institute
U.S.	United States
U.S. EPA	United States Environmental Protection Agency
UV	Ultraviolet
VDF	Vinylidene fluoride
WWTPs	Wastewater treatment plants

Units

%	Percent
°C	Degrees Celsius
kJ/mol	Kilojoules per mol
µm	Micrometer
m ²	Square meter
ng/µL	Nanograms per microliter
µg/cm ²	Micrograms per square centimeter

ppb	Parts per billion
ppm	Parts per million
ppt	Parts per trillion

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APPENDIX A: REPORT PREPARATION*

Preparers and Contributors

Armeen Etemad, M.S., P.E., Senior Hazardous Substances Engineer, Safer Consumer Products

Nicole Macatrao, M.S., Senior Environmental Scientist, Safer Consumer Products

Alyssa Demko, Ph.D., Senior Environmental Scientist, Safer Consumer Products

Elena Galkina, M.S., Environmental Scientist, Safer Consumer Products

Alicia Lim, M.S., Environmental Scientist, Safer Consumer Products

Mia Yamagiwa**, Environmental Services Intern, Safer Consumer Products

Reviewers

Simona Bălan, Ph.D., Regulations and Policy Branch Manager, Safer Consumer Products

Thomas Bruton, Ph.D., P.E., Supervising Hazardous Substances Engineer, Safer Consumer Products

André Algazi, Chemical and Product Evaluation Branch Manager, Safer Consumer Products

Robin Christensen, M.S., Deputy Director, Safer Consumer Products

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** No longer works for the Department



CLIMATE EMERGENCY MOBILIZATION OFFICE



DATE: February 19, 2025

TO: The Honorable Members of the Energy and Environment Committee
c/o Eric Villanueva, Legislative Assistant
Office of the City Clerk
Room 395, City Hall
Los Angeles, CA 90012

SUBJECT: **Climate Emergency Mobilization Office and Chief Heat Officer Report Relative to Council File No. 24-0602: Synthetic Grass / Artificial Turf / Polyfluoroalkyl Substances (PFAS) / Forever Chemicals / Health and Environmental Risks / Drought-Friendly Landscaping**

Background

The City of Los Angeles is engaged in efforts to mitigate the impacts of extreme heat on public health and infrastructure, improve our heat and climate resilience, and reduce exposure to toxic materials. Extreme heat is the primary and most lethal climate hazard for the City of Los Angeles, with increasing severity of extreme heat events that are breaking records every year and are longer in duration and frequency, with higher temperatures. One of our roles as the Climate Emergency Mobilization Office (CEMO) includes transitioning and investing in more climate and heat-resilient infrastructure and materials that first do no harm which complement our zero emissions goals. Our City can create criteria that identifies neutral impact materials with zero or close to zero emissions and avoids contamination to our soil and water while also being cost effective. This would include uses of these materials for infrastructure, buildings, roads, parks, and overall built environment in order to avoid unintended consequences, liabilities, and costs.

In response to the City Council adopting the CF 24-0602 substitute motion on September 17, 2024 including instructions for the CEMO, this report summarizes the environmental, health, and heat impacts of synthetic grass/artificial turf, summarizes policies of other jurisdictions with respect to these products and provides recommendations for next steps.

Recommendations for the City Council:

1. **Cost-Benefit Analysis:** Identify funding and financing for a comprehensive independent study that includes a cost-benefit analysis and prioritizes and takes into account public health impacts, injury liability to the City, water contamination, the impacts of climate hazards such as extreme heat and rain storms, the costs of remediation, waste management and costs to our waste stream of artificial turf versus natural grass playing fields to then also provide a phased plan for such removal of synthetic turf, and any additional unforeseen unintended consequences, that is feasible to the City of Los Angeles.

2. **Community and Subject Matter Expert Engagement:** Involve public health experts and community subject matter experts in considerations related to alternatives to artificial turf, its installation, and maintenance. Consider the funding of a future independent report from public health experts. This effort should involve scientific experts from state agencies such as: CalEPA's Department of Toxic Substances Control (DTSC) and Office of Environmental Health Hazard Assessment (OEHHA), local research universities and public health experts such as UCLA Geffen School of Medicine, Fielding School of Public Health and the Labor Occupational Safety and Health Program (LOSH), USC Keck School of Medicine, and local advocacy groups such as the Climate Reality LA Chapter, Los Angeles Neighborhood Council Sustainability Alliance (LANCSA), Sierra Club Water Committee, as well as community partners, and labor unions.
3. **Develop an agreed upon strategy for assessing risks to the public,** and seek benign solutions that align with our climate resilience goals that are cost-effective alternatives to artificial turf products that don't use petroleum based products or any harmful chemicals. The alternatives should also reduce the impacts of extreme heat, another primary climate hazard the city is addressing. The CEMO recommends that the city develop a general strategy for assessing risk reductions and climate hazards such as extreme heat that artificial turf poses, phasing out this class of products, and as practicable and via council approved funding, replacing it with sustainable, eco-friendly alternatives such as natural turf and native plants. The city should also create protocols for evaluating the possible unintended consequences of untested technologies, solutions, and materials overall that appear to solve certain issues (drought, maintenance, demand for playing fields) but can have long-term impacts (public health, heat, environmental costs) and may not even solve the short-term issues (such as the requirement to water and maintain artificial turf).

Summary of products, health risks and environmental impacts

Artificial turf athletic fields have been promoted over the past several decades for their reduced maintenance costs, presumed water conservation benefits, and energy savings, and they have been installed at many public and private facilities. The terms synthetic grass and artificial turf are similar and often used interchangeably, but the purpose and installation process differ. Synthetic grass is used for general aesthetic purposes such as landscaping (as a replacement for natural turf or shrubs), pet relief areas and miniature golf courses, and consists of longer synthetic fibers and a plastic or rubberized backing. Artificial turf is a more durable product used for higher contact activities, such as sports fields and playgrounds, and usually comprises three layers: synthetic fibers, backing, and a rubber, zeolite (mineral-based) or plant-based infill (PBI). The fibers of synthetic grass and artificial turf products are made with polypropylene and/or nylon (petroleum-based plastics), the rubber infill commonly from vulcanized used tires, and the backing can be from plastic or urethane mesh, depending on the turf's application.

Both the synthetic fibers and infill are components that can contain per- and polyfluoroalkyl substances (PFAS). PFAS are a category of complex synthetic chemicals with bonded fluoride and carbon atoms. Thousands of different PFAS are used to manufacture a wide variety of products, including artificial turf. The United States Environmental Protection Agency (EPA) is considering the environmental and health effects and regulations around this class of chemical

compounds.¹ California law prohibits juvenile products, textiles, and food packaging containing specified levels of PFAS from being distributed, sold, or offered for sale in the state, and requires the DTSC to adopt regulations for the enforcement of PFAS prohibitions and to ensure compliance with those provisions and regulations.² The DTSC is evaluating artificial turf for possible listing as a Priority Product under the Safer Consumer Products Regulations; a listing could result in removal of the product from the California market or removal or replacement of one or more chemicals of concern in the product.³

PFAS persists in the environment and can bioaccumulate, meaning that they can concentrate in plants, animals, and people. Exposure can be direct via skin contact or inhalation of volatilized compounds emitted by the material, which can be amplified with increased temperatures, especially during extreme heat incidents. Certain turf manufacturers in Southern California and elsewhere advertise that their products contain no PFAS. However, these claims have yet to be independently and completely verified. Much research has focused on the variety of contaminants found in artificial turf and the different types of infill used in its manufacture.^{4 5 6} Concerns have been raised about the polyaromatic hydrocarbons (PAHs), heavy metals (lead, zinc), PFAS, microplastics and other substances contained in these products and their effects on long-term sustainability, environmental contamination, human health hazards, and adverse impacts on wildlife. There is substantial research demonstrating that PFAS are a chemical component in synthetic turf, and that even when not carcinogenic as a stand-alone chemical, they can act synergistically and cause cancer through cumulative impacts and multiple pathways.⁷

Artificial turf products also create higher surface temperatures and contribute to higher thermal air temperatures as compared to natural grass, impacting exposure and injury to the users in various ways, while also exacerbating the urban heat island.⁸ The plastic and rubber components of the products have low albedo (reflectivity), which means they absorb solar radiation (heat energy), stay hotter for extended periods, and then release the radiated energy as heat back into the environment. The dozens of artificial turf athletic fields installed in the City of Los Angeles may contribute to increased local temperatures and potential increased heat health risks to our vulnerable communities. Local community groups, such as the LANCSA, and national environmental organizations have compared the risks and benefits of artificial turf to natural grass for playing fields and have documented concerns about the risks posed by

¹ *Per- and Polyfluoroalkyl Substances (PFAS)*. United States Environmental Protection Agency (EPA). <https://www.epa.gov/pfas>.

² Assembly bill No. 347 (AB-347). Ting. *Household product safety: toxic substances: testing and enforcement*. September 30, 2024. https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=202320240AB347

³ California DTSC. *Background Document on Candidate Chemicals in Artificial Turf*. August 2024. <https://dtsc.ca.gov/wp-content/uploads/sites/31/2024/07/Background-Document-on-Candidate-Chemicals-in-Artificial-Turf.pdf>

⁴ *Organic Contaminants in Tire Crumb Rubber*. Collaborative on Health and the Environment (CHE). January 27, 2022. <https://www.healthandenvironment.org/assets/images/Webinar%20Highlights%20Organic%20Contaminants%20in%20Tire%20Crumb%20Rubber.pdf>.

⁵ *Tire Crumb Exposure Characterization Report (Volumes 1 and 2)*. United States Environmental Protection Agency (EPA). <https://www.epa.gov/chemical-research/tire-crumb-exposure-characterization-report-volumes-1-and-2>.

⁶ Cheng, H., Hu, Y., and Reinhard, M. (2014). Environmental and Health Impacts of Artificial Turf: A Review. *Environmental Science & Technology*, 48(4), 2114-2129. <https://pubs.acs.org/doi/abs/10.1021/es4044193>.

⁷ *Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)*. United States National Institute of Environmental Health Sciences (NIEHS). <https://www.niehs.nih.gov/health/topics/agents/pfas>.

⁸ *Artificial Turf and Your Health* (Podcast). U.S. National Institute of Environmental Health Sciences (NIEHS). May 20, 2024. <https://www.niehs.nih.gov/research/supported/translational/peph/podcasts/2024/artificial-turf-and-your-health>.

artificial turf products.^{9 10 11}

Research warns of increased health impacts to workers engaged in manufacturing and installing these products as well as the general public utilizing artificial turf surfaces.¹² The relatively unyielding surface can lead to increased lower-body injuries when an athlete falls, slides, or pivots. Injuries can include sprains, torn ligaments, blisters, and burns. Plastic-based surfaces such as artificial turf and synthetic grass do not contain the beneficial indigenous microbes and of natural grass and soils, leading to potential harboring and transmission of viruses and bacteria harmful to humans. Children can be more susceptible to heat illnesses and chemical and pathogen exposure, as well as injuries to feet, ankles and knees.¹³

Synthetic grass and artificial turf also contribute to environmental degradation in several ways throughout the product's life-cycle. The manufacturing processes contribute to the continued use of petro-chemicals and release of hydrocarbon by-products. PFAS from these products can contribute to surface and groundwater contamination. Watering of artificial turf fields is still necessary for maintenance especially in summer and fall months to cool the surfaces in the Southern California climate. Significantly, the products have a finite life-cycle of a decade or so and need to be replaced; industry and environmental groups claim opposing views regarding how readily the components break down. Independent research shows they are difficult or impossible to recycle, leading inevitably to landfilling and impacts to the waste stream.¹⁴

Summary of Policies in other Jurisdictions

To date, no state, county or major city in the U.S. Southwest or West Coast has enacted an outright ban on the sales or installation of synthetic grass/artificial turf. The California state legislature has enacted several laws that would restrict the installation of artificial turf or synthetic surfaces. Several jurisdictions have restricted the use of synthetic grass for specifically water conservation purposes. At the state level, California SB 676¹⁵ was enacted on October 8, 2023 and amends Section 53087.7 of the Government Code to specify that the definition of "drought-tolerant landscaping" does not include the installation of synthetic grass or artificial turf, in effect allowing cities to prohibit artificial grass as an alternative as part of turf replacement and water-use reduction landscaping programs. During session year 2023-24, AB 1423¹⁶ would have prohibited a person or entity from manufacturing, distributing, selling, or offering for sale in the state any covered surface that contains regulated PFAS, including artificial turf or synthetic grass, commencing January 1, 2026. This bill was approved by the legislature but vetoed by the Governor.

⁹ SoCal Stop Artificial Turf Fact Sheet. The Climate Reality Project and LANCSA. <https://tinyurl.com/57u63s3t>

¹⁰ Safe Healthy Playing Fields. <https://www.safehealthyplayingfields.org/>

¹¹ Public Health Risks of Artificial Turf. Sierra Club. <https://www.sierraclub.org/loma-prieta/public-health-risks-artificial-turf>

¹² Chemicals: Synthetic turf fields contain a wide array of chemicals that are potentially harmful to young children and young athletes. Partnership for Healthy Playing Surfaces. <https://www.healthyplayingsurfaces.org/chemicals>.

¹³ Op. cit. *Artificial Turf and Your Health* (Podcast). U.S. NIEHS.

¹⁴ *Environmental Health Impacts of Synthetic Turf and Safer Alternatives* (Webinar). Collaborative on Health and the Environment (CHE). January 27, 2022. <https://www.healthandenvironment.org/che-webinars/96595>.

¹⁵ Senate Bill No. 676 (SB-676). Allen. *Local Ordinances and regulations: drought-tolerant landscaping*. October 10, 2023. https://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=202320240SB676.

¹⁶ Assembly Bill No. 1423 (AB-1423). Schiavo. *Product safety: PFAS: artificial turf or synthetic surfaces*. September 14, 2023. https://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=202320240AB1423.

Two additional failed bills, SB 499 and AB 2947 were held in Committee and would have impacted the future installations of synthetic turf products. SB 499,¹⁷ the School Facilities: School Extreme Heat Action Plan Act of 2023, proposed to replace all low specific heat surfaces (asphalt, concrete, artificial turf) with high specific heat surfaces (natural grass, cool pavement and other natural systems) that can absorb heat energy without transferring the heat to the surrounding area and raising local temperatures. AB 2947,¹⁸ the “Water: turfgrass conversion” bill was introduced in early 2024 and would have prohibited turf replacement programs from funding conversions to artificial turf for water conservation purposes.

Among the few smaller California cities that have enacted restrictions, the City of Millbrae, California adopted Ordinance 806, § 1 in October 2023 to prohibit all installation of synthetic grass and artificial turf, effective January 1, 2024.¹⁹ Residents will have to replace all existing artificial turf by January 2028. The Ordinance comes after a two (2) year temporary ban while Millbrae did an assessment on the environmental impact of artificial turf.²⁰ The City of San Marino adopted Ordinance No. O-23-1410²¹ in October 2023 which established a temporary moratorium on artificial turf installation. The City of San Marino later adopted Ordinance No. O-24-1413²² in September 2024, extending the moratorium and prohibiting the installation of artificial turf and synthetic grass. The decision was based on studies which included an EPA July 2019 report²³ and an ongoing study by the California OEHHA.²⁴

In 2024, the County of Santa Clara Board of Supervisors and the City of Sunnyvale City Council voted separately to proceed with studies comparing the use of artificial turf with natural groundcovers. To date these studies have not been released and therefore results and conclusions are pending. In April 2024, the County of Santa Clara commissioned a report^{25 26} on environmental health and safety ramifications of artificial turf, and a proposed vote on banning artificial turf for athletic fields failed in January 2025.²⁷ In the interim, the Santa Clara County Medical Association (SCCMA) issued a policy letter in June 2024, recommending that due to

¹⁷ Senate Bill No. 499 (SB-499). Menjivar. *School facilities: School Extreme Heat Action Plan Act of 2023*, Sec. 2, Art. 5, § 17615.2(b). May 19, 2023. https://leginfo.ca.gov/faces/billCompareClient.xhtml?bill_id=202320240SB499.

¹⁸ Assembly Bill No. 2947 (AB-2947). Lackey. *Water: Turfgrass Conversion*. April 8, 2024. https://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=202320240AB2947&search_keywords=artificial+turf

¹⁹ City of Millbrae Municipal Code Title 8, Chapter 8.65. *City of Millbrae Synthetic Grass and Artificial Turf Ordinance*. Ordinance No. 06, § 1. October 24, 2023. <https://ca-millbrae.civicplus.com/276/Prohibition-of-Artificial-Turf>.

²⁰ *Millbrae bans new artificial turf: Council votes unanimously to prohibit synthetic grass and enact maintenance requirements for current installations*. Alyse DiNapoli, The San Mateo Daily Journal. Archived from original publication (October 30, 2023). https://www.smdailyjournal.com/news/local/millbrae-bans-new-artificial-turf/article_c325995c-7688-11ee-8e80-bb4d2a753170.html.

²¹ City of San Marino Ordinance No. O-23-1410. *Temporary moratorium on the installation of artificial turf and plastic grass*. <https://cms9files.revize.com/cityofsanmarino/O-23-1410%20E-extending%20the%20Term%20of%20Ordinance%20No%20O-21-1385-U.%20Establishing%20a%20Temporary%20Moratorium%20on%20the%20Installation%20of%20Artificial%20Turf%20and%20Synthetic%20Grass.pdf>.

²² City of San Marino Municipal Code Secs. 14.18.07, 23.16.03, and 23.16.24. Ordinance No. O-24-1413. September 27, 2024. [https://cms9files.revize.com/sanmarinoca/planning/O-24-1413%20Artificial%20Turf%20\(Signed\).pdf](https://cms9files.revize.com/sanmarinoca/planning/O-24-1413%20Artificial%20Turf%20(Signed).pdf).

²³ *July 2019 Report: Tire Crumb Rubber Characterization*. United States Environmental Protection Agency (EPA). July 25, 2019. <https://www.epa.gov/chemical-research/july-2019-report-tire-crumb-rubber-characterization-0>.

²⁴ *Synthetic Turf Studies*. California Environmental Protection Agency (Cal EPA), Office of Environmental Health Hazard Assessment (OEHHA). <https://oehha.ca.gov/risk-assessment/synthetic-turf-studies>.

²⁵ *Santa Clara County to study ban on artificial turf*. B. Sakura Cannestra. San José Spotlight. April 17, 2024. <https://sanjosespotlight.com/santa-clara-county-to-study-ban-on-artificial-turf-athletics-sports-fields-grass/>.

²⁶ Santa Clara County Board of Supervisors, April 16, 2024 meeting, Board referral #24-5361. *Prohibiting Artificial Turf Installation on County Property*. <https://santaclaracounty.primegov.com/Portal/viewer?id=0&type=7&uid=19708cbc-a495-4ca0-94a9-13ccd8b80976>
Meeting minutes: santaclaracounty.primegov.com/Public/CompiledDocument?meetingTemplateId=1404&compileOutputType=1

²⁷ Sheynar, G. *Push to phase out synthetic turf fields meets resistance*. Palo Alto online. January 31, 2025.

<https://www.paloaltoonline.com/santa-clara-county/2025/01/31/push-to-phase-out-synthetic-turf-fields-meets-resistance/>

health effects, injury concerns and environmental impacts, artificial turf not be used on playing fields or other types of landscaping and that existing artificial turf be replaced with natural turf at the end of its useful life. The policy letter follows several years of research and issuance of recommendation letters from SCCMA to local jurisdictions and schools in Santa Clara County warning about the health risks, environmental dangers and costs of artificial turf.²⁸ Santa Clara County Supervisor District 3 maintains a “Plastic Turf FAQ” webpage.²⁹ In September 2024 the City Council of Sunnyvale in Santa Clara County voted to fund a study on the impacts of artificial turf used for athletic fields.³⁰ No conclusions can be drawn from this study as research and benchmarking for the study is currently underway and a scope of work has yet to be released.³¹

The States and local jurisdictions of Arizona, Nevada and Colorado focus on water conservation methods for residential and commercial properties: reducing outdoor irrigation, utilizing desert-adapted plants, and eliminating non-functional natural turf, rather than restricting or banning artificial turf/synthetic grass for its environmental and public health risks. At the state level, Arizona passed HB 2131³² in 2022, which prohibits planned community and homeowner associations (HOAs) from banning artificial grass if the community allows natural grass. In 2023 the Scottsdale City Council approved Ordinance 49260 that bans new homes from having real grass in yards³³ and the City of Tucson, Arizona passed Ordinance 12005 in 2023 which prohibits all non-functional grass to strictly focus on water conservation.³⁴ In 2021 the State of Nevada legislature passed AB 356³⁵ which prohibits watering nonfunctional turf, grass areas not providing functional use, and requires the removal of all nonfunctional turf by the end of 2026. The Southern Nevada Water Authority encourages residents to change non-functional grass areas into drought-tolerant landscaping,³⁶ and prohibits new installations of natural turf requiring irrigation. Similarly inspired solely by water conservation measures, the State of Colorado legislature passed SB 24-005³⁷ which as of January 1, 2026, will prohibit local governments from allowing the installation, planting, or placement of nonfunctional turf and artificial turf on commercial, institutional, or industrial property, common interest community property, or a street right-of-way, parking lot, median, or transportation corridor as well as at state facilities. Residential properties and artificial turf used on athletic fields are exempted from the legislation.

Considerations for Risk Reduction

The following are considerations from CEMO for measures regarding the current and future use of artificial turf and synthetic grass at City facilities.

²⁸ *Environmental Health*. Santa Clara County Medical Association. <https://www.sccma.org/programs/environmental-health.aspx>.

²⁹ County of Santa Clara, Supervisor Otto Lee District 3. *Plastic Turf FAQ*. <https://d3.santaclaracounty.gov/take-action/plastic-turf-faq>

³⁰ *Sunnyvale to Study State of its Grass Fields*. Silicon Valley Voice. svvoice.com/sunnyvale-to-study-state-of-its-grass-fields/

³¹ City of Sunnyvale. *Study issues underway*. (webpage) n.d.

<https://www.sunnyvale.ca.gov/your-government/governance/city-council/study-issues-and-budget-proposals/study-issues-underway>

³² Arizona House Bill 2131. <https://legiscan.com/AZ/text/HB2131/id/2470213>

³³ City of Scottsdale Municipal Code. Sec. 49-260. - *Prohibition of Mandatory Turf Conditions by Owner's Associations*.

https://library.municode.com/az/scottsdale/codes/code_of_ordinances?nodeId=VOLII_CH49WASESEDI_ARTVIIWACO_DIV2DRMA_S49-260PRMATUCOOWAS

³⁴ City of Tucson Muni Code 7.6. https://codelibrary.amlegal.com/codes/tucson/latest/tucson_az_udc/0-0-0-5860

³⁵ Nevada Legislature AB 356. <https://www.leg.state.nv.us/App/NELIS/REL/81st2021/Bill/7910/Overview>

³⁶ Southern Nevada Water Authority. <https://www.snwa.com/>

³⁷ Colorado General Assembly SB24-005. <https://leg.colorado.gov/bills/sb24-005>

Environmental, Safety and Health Considerations:

- **Chemical Runoff and Off-gassing:** Artificial turf has been shown to release harmful chemicals, including heavy metals and PFAS, into soil, air, and water. These chemicals can be harmful to human health and are non biodegradable.
- **Water Usage:** Consider the amounts and costs of water use to cool and clean artificial turf athletic fields in comparison to natural grass fields. Water may be used several times a day, especially during athletic games usage, to prevent skin burns and other injuries.
- **Urban Heat Island effects:** Consider impacts from large installations of artificial turf on the urban heat island effect, increasing energy demand for cooling and reflected heat in the most heat-risk impacted communities. Research shows artificial turf has higher surface temperatures as compared to natural grass.
- **Climate Budget-GHG Inventory:** Consider including emissions from all phases of product life-cycle (manufacturing, installation, transport, and disposal) in the city's GHG Emissions Inventory.
- **Evaluate Environmental Impact:** Conduct assessments to compare the water and air contamination and toxic exposures generated by artificial turf versus natural grass.

Health Risks and Injury Considerations:

- **Heat Stress and Injury:** Measure and monitor temperatures on artificial turf fields, especially during hot weather in comparison to natural grass fields. Artificial turf temperatures may increase the risk of certain injuries, particularly burns and abrasions and may also contribute to increased risk of heat exhaustion or heat stroke.
- **Harder Surfaces and injuries:** Artificial turf can be harder and less forgiving than natural grass, increasing the risk of injuries such as sprains, joint pain, and concussions.
- **Pathogen and chemical exposure:** Artificial turf can harbor bacteria and other pathogens, which can lead to transmission to humans using the fields, causing skin infections and other health problems. Synthetic fibers and their by-products may cause negative health impacts through contact and exposure.

Conclusion

Artificial turf, while often marketed as a low-maintenance solution, poses significant risks, costs, and both environmental and health concerns. There is enough evidence that points to serious concerns for health and sustainability from these products that warrants consideration of an immediate ban or at least serious limitation of new installation and use at city facilities, especially athletic fields used by children. It is important to note that while these are some of the potential health risks associated with artificial turf, the extent of the risk can vary depending on factors such as the specific type of turf, the frequency of use, and individual susceptibility. The City of Los Angeles should consider a moratorium on artificial turf installations, until these costs and environmental and public health concerns are studied and verified by independent sources.



Dear Colleagues,

In 2015, Governor Jerry Brown signed a law that prohibited municipalities from banning artificial turf. At that time, very little was widely known about the health and safety risks associated with artificial turf, and it was thought to be an effective solution for severe drought.

Unfortunately, the panacea of artificial turf has not brought about water savings, and instead has created many unintended consequences. We now recognize that artificial turf is manufactured with petrochemicals, and the manufacturing process uses harmful per- and polyfluoroalkyl (PFAS) substances and other hazardous chemicals. PFAS “forever chemicals” are associated with cancer and linked to growth, learning, and behavioral problems in infants and children; fertility and pregnancy problems; thyroid disease; asthma; and more. Children and athletes who play on artificial turf are at increased risk, and because PFAS chemicals bioaccumulate, it is especially harmful to children who are still developing.

Toxic runoff from artificial turf contaminates drinking water, rivers, lakes, and oceans with microplastics as well as PFAS. The EPA has recently reported that there is no safe amount of PFOA or PFOS (types of PFAS) in drinking water, and both have consistently been found in artificial turf. Recent studies have found that 12 to 15% of microplastics in rivers, lakes, and oceans are from artificial turf.

Artificial turf must also be regularly cleaned of contaminants. Cooling and cleaning of artificial turf can require more water than would be used for the maintenance of natural, drought-tolerant grasses.

Artificial turf has been shown to reach temperatures much higher than natural grass, readily reaching 160 to 180 degrees F or more, creating heat-island effects, and causing heat-related injuries and illnesses such as skin burns and heat stress. This is particularly hazardous for disadvantaged communities where there are already too few natural green spaces. Additionally, artificial turf leads to increased sports injuries.

Artificial turf is an impervious surface that contributes to flooding when rain water is not absorbed for groundwater recharge. It kills the biome below and takes away critical food and habitat from insects, birds, and local wildlife, contributing to species loss. This is the opposite of what we should be doing during a biodiversity crisis when we have lost 95% of our local pollinators and our fire season has moved from three months of the year to a year-round phenomenon. We can no longer think of our urban green spaces as a separate element from nature. Ornamental artificial turf should be replaced with native plant species that are the most cost-effective measure to battle the urban heat-island effect while supporting butterflies, local songbirds, and other wildlife. Artificial turf playing fields should be upgraded to drought-tolerant turf grasses that are safer for athletes while supporting soil health and flood-risk mitigation.

Finally, because it is made of mixed plastic materials, artificial turf will never be economically viable for recycling. At the end of its 8-to-15-year lifecycle it is sent to a landfill, illegally dumped, or sent out of state to be incinerated.

Artificial turf is a danger to the health and safety of our community and our environment, and it fails to produce promised water savings. Therefore, we, the undersigned, support a ban on new and replacement installations of artificial turf in both public and private applications.

For further information visit:

https://www.ncsa.la/artificial_turf

Respectfully,

Terry Saucier, Chair
SoCal Stop Artificial Turf Task Force

Lisa Hart, she/her, Executive Director
Los Angeles Neighborhood Council Sustainability Alliance

Kathy Schaeffer, Legislative Coordinator
Climate Reality Project, San Fernando Valley Chapter

Charles Miller, Chair
Climate Reality Project, Los Angeles Chapter

Antonina Markoff, Coordinator
Climate Reality Project, California Coalition

Anne LaForti, Biomimic and Soil Nerd
Nature Know

Lynn Fang, Soil Scientist
Soil Wise

Shawn Maestretti, Founder
Studio Petrichor

Dr. Diana Zuckerman, President
National Center for Health Research

Annette Mercer, President
Westwood Greenway

Janet Cox, CEO
Climate Action California

Ben Stapleton
USGBC California

Diana Conway, President
Safe Healthy Playing Fields, Inc.

Melanie Winter, Founder and Director
The River Project

Elise Kalfayan, Board Member
Glendale Environmental Coalition

Eugenia Ermacora
Surfrider Foundation, Los Angeles Chapter

Kelly Shannon McNeill, Associate Director
LA Waterkeeper

Azita Yazdani, CEO
Exergy Systems, Inc.

Conner Everts, Executive Director,
Southern California Watershed Alliance

Katherine Pease, Director of Science & Policy
Heal the Bay

Marianne Simon
G3 Green Gardens Group

Pamela Berstler, CEO
Flower to the People, Inc.

Jonathan Galindez, CEO/Founder
N8tive Roots Landscaping

Kristy Pace, Artist/Educator, Founder
Save This Place for Me

Jack Eidt, Co-Founder
SoCal 350 Climate Action

Francesca Corra, Owner
Dirt Diva Designs

Aurora Corona, Secretary, Quality of Life & Safety Committee
Pico Union Neighborhood Council

Kay Hartman, President
Palms Neighborhood Council

Rosalind Haselbeck, PhD, Executive Director
Dwelling on Carbon Nonprofit

Aleksandar Pavlovic, Board President
Resilient Palisades

Coach Ron, CEO
Fun Zone Fundamentals Sports Camp For Kids

Belén Bernal, Executive Director
Nature For All

Joanne D'Antonio, Chair
Los Angeles Community Forestry Advisory Committee

Jackie Nuñez, Founder
The Last Plastic Straw

Dianna Cohen, Co-Founder and CEO
Plastic Pollution Coalition

Studio City Residents Association, SCRA Board

Sophie Pennes, Founder
Urban Farms LA

Duncan McIntosh, Director
Earth-Riders

Suzanne Hume, Educational Director & Founder
Clean Earth 4 Kids

Diana Carpinone, President
Non Toxic Communities

Susan Keefe, Founder
Eco Forward

Susan Keefe
California Green Business Network

Jon Tsuchiyama, Owner
West Valley Nursery

Katie Tilford, Interim Executive Director
Theodore Payne Foundation

Miles Lewis, Director
Valley Art Workshop

Claire Bloom
The Tarzana Community & Cultural Center

Daniel Tamm, Deacon
Los Angeles Faith and Ecology Network

Pat Bates, Treasurer
San Fernando Valley Audubon Society

John Garside, Director of Policy and Development
Crop Swap LA

Manny Gonez, Director of Policy Initiatives
TreePeople

North Westwood Neighborhood Council, Board

Nan Joo Kim
LA Native Plants

Travis Longcore, President
Los Angeles Audubon Society

Stephanie Bartron, Secretary
Silver Lake Reservoir Conservancy

Jerry Yang, President
North Hollywood High School
Environmental Leadership Club

Allison Waliszewski, Director of Regional Policy & Program Development
5 Gyres Institute

Bahram Fazeli, Director of Research & Policy
Communities for a Better Environment

Tevin Hamilton
Environmental Justice Communities Against Plastics (EJCAP)
Coalition Coordinator at Physicians for Social Responsibility-LA

Andrea Wald, Co-Founder
Community for Natural Play Surfaces

Brian Averill, President
Venice Neighborhood Council

Patricia Wood, Executive Director
Grassroots Environmental Education

Ruth Abbe, President
Zero Waste USA

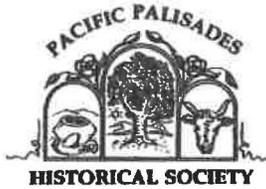
Randy Booker, Owner
Turfevolution, Inc.

Robert P. Sjoquist, Director
Soils Solutions, Inc.

Sam Pearse
The Story of Stuff Project

Mariam Moore and Mihran Kalaydjian
The Climate Corps Initiative (TCCI)

Scott Culbertson, Executive Director
Friends of Ballona Wetlands



To: Los Angeles Recreation and Parks Commissioners:

Pacific Palisades News Letter – Spring 2026

Striving to Save a Community Center

By DONNA VACCARINO, AIA
PPHS President

In our November newsletter, we argued that the historic Palisades Recreation and Parks building should be adaptively repurposed to serve the Community at large, in conjunction with the massive restoration project proposed by Steadfast LA. Their \$40-million plan shows the demolition/removal of the “Old Gym,” built in 1947 and designed by the prominent Pasadena architectural firm Bennett and Bennett.

Alas, on January 15, the Recreation and Parks Commission, at a regularly scheduled meeting, voted unanimously to approve Board Report No. 26-017.

In summary, this premature vote allows the preliminary Steadfast Park Plan to move forward without any alternative considerations. The Commission also approved making the project “statutorily exempt” from the California Environmental Quality Act (CEQA).

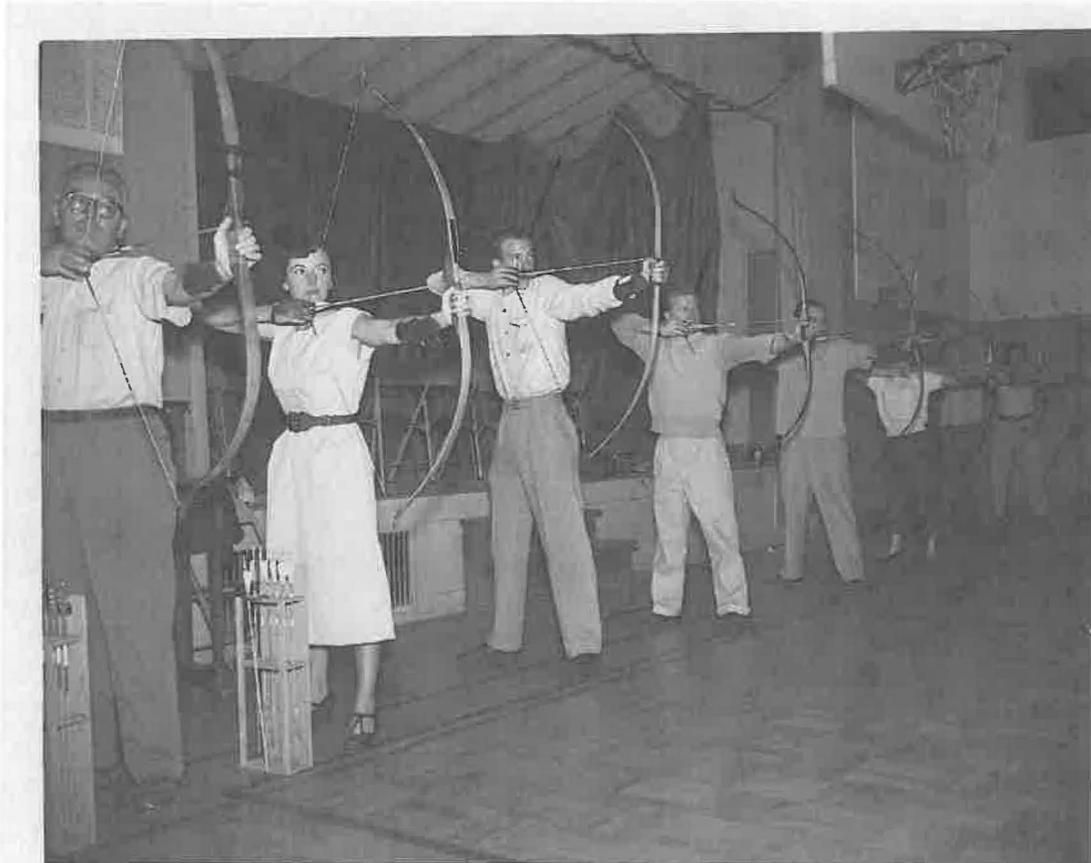
No more review, no more community input required.

Per the written staff report: “The Proposed Steadfast Project contemplates improvements to a portion of the total area of the Recreation Center and excludes the baseball fields and the tennis courts. The Project will demolish the smaller recreation center and replace the two recreation centers (which had a total footprint of approximately 18,000 square feet) with an expanded structure featuring two indoor basketball courts with bleachers, two indoor pickleball courts, a lobby, a multipurpose room, office space, storage rooms and restrooms; the total footprint of this expanded facility is expected to be roughly 28,000 square feet....” The Project also includes the relocation of two outdoor basketball courts and new amenities, including “an outdoor community meeting area, new shaded outdoor community pods, a new multipurpose field and terraced seating west of the tennis courts and north of the baseball fields.”

WOW!! Sounds great – but wait, we see disturbing misrepresentations and a titanic change of use in the proposed park plan. The new building will no longer be a multipurpose building serving the local community. It will be a *sports complex* with no room for a Senior Center or community activities other than *ball-related* sports. The overall massing of the building footprint is not 28,000 sq.ft. but actually 35,000 sq.ft., thanks to the enormous roof overhang on the south side of the building. The structure is five times bigger than the existing “Old Gym” with no community space for non-sport programs. The designated multipurpose room is smaller than the bathrooms and one-third of its area is an exit corridor.

The proposed building is massively out of scale and out of character with the existing park and neighborhood. It will forever change the nature of the park setting and surrounding neighborhoods.

Opened in 1950 and originally painted white, the gym building at the Palisades Recreation Center was a multipurpose gathering place that served the community as a nucleus for park activity. Photo: Courtesy the PPHS Image Archives



The “old gym” was a voting center for decades and hosted beauty pageants, high school prom dances, art classes, Halloween parties, roller skating, basketball leagues, yoga classes, theatre and music performances, Scouting ceremonies ... and even indoor archery (!). Photo: PPHS Image Archives

February 18, 2026
Donna Vaccarino, AIA
President, Pacific Palisades Historical Society
www.pacificpalisadeshistory.org



PARENTS AGAINST SANTA SUSANA FIELD LABORATORY

LOS ANGELES | VENTURA COUNTY



SCHOOL OF PUBLIC HEALTH
DEPARTMENT OF EPIDEMIOLOGY
109 OBSERVATORY STREET
ANN ARBOR, MICHIGAN 48109-2029

OFFICE OF THE CHAIR
HAL MORGENSTERN, PH.D.
734-764-5435 FAX 734-764-3192
halm@umich.edu

April 15, 2007

Senator Joe Simitian, Chair
Committee on Environmental Quality
State Capitol
Sacramento, CA 95814

**Re: The Boeing Company Statement in Opposition to SB 990 (Kuehl)
April 2007**

Dear Senator Simitian:

It has recently come to my attention that the Boeing Company has submitted a statement to your Committee, regarding Senator Kuehl's bill dealing with the cleanup of the Santa Susana Field Laboratory in Ventura County.

Their statement contends, "In contrast to the accusations made against The Boeing Company that falsely claim increased cancer rates in the communities surrounding SSFL, a recent study conducted by the University of Michigan School of Public Health just concluded the opposite." Although the authors of the Boeing statement do not cite the source of that study, they then quote three brief passages from my final research report on *Cancer Incidence in the Community Surrounding the Rocketdyne Facility in Southern California*, which was submitted in March to the Eastern Research Group and the Agency for Toxic Substances and Disease Registry (ATSDR).

I would like to make it clear to your Committee that Boeing's claim made about the conclusion of our study is false. We did *not* conclude that there was no excess cancer in the communities surrounding SSFL. Furthermore, Boeing's quotes from our report were taken out of context, and they failed to report our specific findings that contradicted their claim.

In the main analyses of our study, we compared the incidence rate of specific cancers in adult residents living within 2 miles and 2-5 miles from SSFL with adult residents living more than 5 miles from SSFL in both Ventura and Los Angeles Counties. For the period 1988 through 1995, we found that the incidence rate was more than 60% greater among residents living within 2 miles of SSFL than among residents living more than 5 miles from SSFL for the following types of cancer: thyroid, upper aerodigestive tract (oral and nasal cavities, pharynx, larynx, and esophagus), bladder, and blood and lymph tissue (leukemias, lymphomas, and multiple myelomas).

For the period 1996 through 2002, we found that the incidence rate of thyroid cancer was more than 60% greater among residents living within 2 miles of SSFL than for residents living more than 5 miles from SSFL. The magnitude and consistency of the thyroid finding for both periods is especially provocative because of evidence from other studies linking thyroid cancer with environmental exposures originating at SSFL and found in the surrounding communities.

In their statement, Boeing ignored these results and focused instead on our discussion of the methodologic limitations of our study. It is true that we did not measure environmental exposures, relying instead on residential distance from SSFL, and that we were not able to link excess cancer rates with exposures originating at SSFL. Nevertheless, it does not follow—as implied by Boeing’s statement—that we did not find excess rates of cancers near SSFL, nor can we conclude that Boeing-related exposures did not cause cancers in the nearby communities. For the record, the conclusion in our summary of the final report (p. 4) starts as follows:

“Despite the methodologic limitations of this study, the findings suggest there may be elevated incidence rates of certain cancers near SSFL that have been linked in previous studies with hazardous substances used at Rocketdyne, some of which have been observed or projected to exist offsite.”

We went on to acknowledge that further research would be necessary to determine whether these provocative findings reflect the effects of environmental exposures originating at SSFL and that it is not clear at this time whether such additional analyses or studies would be sufficient to resolve the matter.

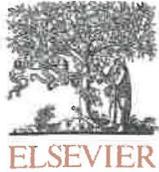
In summary, Boeing’s assertion that we found no increased cancer rates in the communities surrounding SSFL is false. We did, in fact, find increased incidence rates of certain cancers associated with proximity to the facility, the significance of which would require further research.

Please let me know if I can be of further assistance to your Committee.

Sincerely,

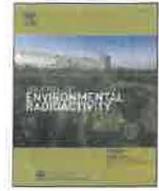


Hal Morgenstern, Ph.D.
Professor and Chair



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Radioactive microparticles related to the Woolsey Fire in Simi Valley, CA

Marco Kaltofen^{a,*}, Maggie Gundersen^b, Arnie Gundersen^b^a Worcester Polytechnic Institute, Dept. of Physics, 100 Institute Road, Olin Hall, Worcester, MA, 01609, USA^b Fairewinds Energy Education, 520 Folly Road, Ste. 25-344, Charleston, SC, 29412, USA

A B S T R A C T

In November 2018, the Woolsey Fire burned north of Los Angeles, CA, USA, potentially remobilizing radioactive contaminants at the former Santa Susana Field Laboratory, a shuttered nuclear research facility contaminated by chemical and radiochemical releases. Wildfire in radiologically contaminated zones is a global concern; contaminated areas around Chernobyl, Fukushima, Los Alamos, and the Nevada Nuclear Test Site have all experienced wildfires. Three weeks after the Woolsey Fire was controlled, sampling of dusts, ashes, and surface soils ($n = 360$) began and were analyzed by alpha- and beta-radiation counting. Samples were collected up to a 16 km radius from the perimeter of the laboratory. Controls and samples with activities 1σ greater than background were also examined by alpha and/or gamma spectroscopy or Scanning Electron Microscopy with Energy Dispersive X-ray analysis. Of the 360 samples collected, 97% showed activities at or close to site-specific background levels. However, offsite samples collected in publicly-accessible areas nearest to the SSFL site perimeter had the highest alpha-emitting radionuclides radium, thorium, and uranium activities, indicating site-related radioactive material has escaped the confines of the laboratory. In two geographically-separated locations, one as far away as 15 km, radioactive microparticles containing percent-concentrations of thorium were detected in ashes and dusts that were likely related to deposition from the Woolsey fire. These offsite radioactive microparticles were collocated with alpha and beta activity maxima. Data did not support a finding of widespread deposition of radioactive particles. However, two radioactive deposition hotspots and significant offsite contamination were detected near the site perimeter.

1. Introduction

The Santa Susana Field Laboratory (SSFL), a former center for nuclear research, is located in the Simi Hills area of Ventura County, California, USA. The Simi Hills are a low rocky mountain range. SSFL was developed during the late 1940s and 1950s on a 1152-ha site approximately 48 km northeast of Los Angeles in what was then a rural area. The research site hosted rocket engine tests, conducting 17,000 engine tests during the 60-year life of the site (Boeing 2021). The site hosted multiple atomic reactors for nuclear research under a U.S. Department of Energy (DOE) license. One of the site's test reactors, the Sodium Reactor Experiment, experienced a partial meltdown and vented an unmonitored amount of radiation into the environment in July 1959 (US DOE 2020a). Other unmonitored documented radiation releases from other test reactors and burn pits occurred, ending in 1988 when all nuclear research at the site was terminated (EPA 2012a).

Since the end of SSFL operations, studies by the US Environmental Protection Agency (EPA) have detected SSFL-specific radioactive contaminants, including cesium-137, cobalt-60, radium-226, and technetium-99. EPA investigators have also detected the more commonly found isotopes of uranium and thorium and their daughters above naturally-occurring background concentrations. These

investigations confirmed that some radioactive contaminants from SSFL had migrated to areas outside the site perimeter (EPA 2012b; EPA 2012c). Uranium and thorium and their decay products have alpha- and beta-emitting isotopes and may be naturally-occurring or of industrial origin (ATSDR 2013; Kaltofen 2019).

During the three decades following the 1988 closure of operations at the SSFL site, the Los Angeles suburbs have encroached on the Simi Hills's once-rural land. Changes in regional and global climate favoring increased drought along with actual weather conditions on the day of the fire start meant that "The conditions for a large-scale fire incident were perfect" (LA County 2019). Today, 500,000 people live within 16 km of the SSFL site. In early November 2018, a fire began on the SSFL site (US DOE 2020b). This fire, which became known as the Woolsey Fire, was spread by winds gusting more than 70 km per hour and rapidly engulfed 39,500 ha, devoured 1500 structures, killed three people, and spread as far as coastal California at Malibu. The fire spread as much as 25 km SW of SSFL, which is a formidable spread. In addition, an area adjacent to the SSFL was the origin of the wildfire. Financial losses exceeded \$1.5 Billion (LA Times, 2018).

"Wildfires typically mobilize lead-210, bismuth-210, and polonium-210," all of which are decay products of naturally-occurring radon (Los Alamos 2000). In addition, wildfire, and climate change-driven wildfire

* Corresponding author. ,

E-mail address: mpkaltofen@gmail.com (M. Kaltofen).

in particular, has been a driver of radioactive contaminant transport in forest fires at Chernobyl in Ukraine (Evangelidou 2015) and the Cerro Grande Fire at Los Alamos that transported cesium-137 and strontium-90-contaminated materials (Los Alamos 2001). The potential impact of climate change on radionuclide transport is two-fold, as increasing drought, fire frequency, and increased precipitation intensity result in greater post-fire stormwater transport of contaminated sediments. This increase is over and above the typical increase in runoff and sediment yield after wildfires (ibid). At the Hanford Nuclear Reservation in Washington State, the Wautoma wildfire detected elevated gross alpha and gross beta activities in fire plume air samples not attributable to natural radon (WADOH 2008). Multiple wildfires have ignited in the restricted zones surrounding the Fukushima Dai-ichi Nuclear Power Station in Japan. An April 2017 forest fire in a radioactively-contaminated part of Namie, Fukushima Prefecture, Japan, was extinguished using fire suppressing helicopters (Mainichi 2017). The fires resulted in a localized increase of cesium-137 activities of 3–9 times at distances of up to 8 km from the wildfire (Safecast 2017). In May 2021, the Cherrywood Wildfire at the Nevada (USA) National Security Site approached the portion of the site impacted by surface nuclear material contamination, requiring plans to evacuate firefighters (PVT citing BLM 2021).

This study's objective was to determine if a low-cost crowdsourced sampling method could be rapidly initiated to establish whether SSFL-specific contaminants had migrated beyond the site boundary into the surrounding community because of Woolsey Fire-related ash and dust transport. This study used community-volunteer Citizen-Science methodology previously developed worldwide and applied at other radiologically contaminated nuclear power plant and nuclear waste sites and communities surrounding them. Citizen-Science is not a new phenomenon; it began more than 2000 years ago in ancient China to monitor and track migratory locusts that destroyed harvests (Nature 2018).

Worldwide, Citizen-Science is now a crucial scientific method that enables real-time scientific data to move beyond corporate scientists and into the hands of those most impacted who must design and implement environmental and health mitigation projects (IAEA 2016). Moreover, Citizen-Science work is open-source. As a result, locally impacted communities, states, provinces, prefectures, and national governments may realize the magnitude of ecological and public health impacts of chemical, radioactive, and other human-made detritus to arrange remediation procedures and public financing (Silverton 2011).

There has been an uptick in the use of Citizen-Science during the last decade due to the wide availability of internet access and accurate, inexpensive GPS (Global Positioning Systems). It is a low-cost solution that allows large-scale sampling despite limited funding for scientific and health studies. Citizen-Science fosters international cooperation and enables scientists to get timely answers that would have been unaffordable with any other methodology, as exhibited in the analysis of air quality Citizen-Science in Antwerp Belgium. This Flemish Environmental Protection Agency and Citizen-Science partnership included a team of 50,000 non-academic volunteers (Nature 2018).

In the United States, federal statutes note that “crowdsourcing and Citizen-Science projects have additional unique benefits, including accelerating scientific research, increasing cost-effectiveness to maximize the return on taxpayer dollars, addressing societal needs, providing hands-on learning in STEM, and connecting members of the public directly to Federal science agency missions and each other;” (USC 2021). Citizen-Science has been instrumental, for example, in studies of the Fukushima Dai-ichi region and at control sites in the U.S. (Kaltofen 2018).

Typically radiological migration studies look at gross measures of radioactivity in bulk materials such as soils and sediments. However, this study also included data on microparticles of dust or soil. These particles contain sufficiently-high concentrations of radioactive elements to exert an internal radiation dose if the microparticle is inhaled via radioactive dust particles suspended in the air or incidentally

ingested from contact with soil or dusts containing radioactive microparticles. Once radioactive microparticles enter the body by either pathway, the body will continue to be exposed to radiation until the material is excreted via urine or feces (Japan MOE 2021). The radioactive isotopes detected in bulk samples and microparticles are alpha-emitters, including primarily uranium-234, 235, and 238; thorium-228, 230, and 232; and radium-226 and 228; as well as beta-emitters, of which cesium-137 was the most prevalent beta-nuclide found at the SSFL site (DOE 2005).

These alpha-nuclides occur both naturally and industrially. For example, thorium occurs naturally as thorium-232, a primordial radionuclide. Typically this radioactive element is found as monazite, a crystalline mineral composed of cerium, lanthanum, rare earth elements, calcium, phosphorous, plus thorium, and occasionally also uranium (Kaltofen 2018). Thorium also occurs as a decay daughter of uranium-234 and 238. Fertile thorium-232 is also used as a refined metal in nuclear materials and in industrially-produced monazite-type materials as a nuclear waste form (Ibid). This study uses the activity, location, and elemental composition of particulate matter that contains uranium, radium, and thorium to distinguish between natural and industrial alpha-emitters.

The large number of samples collected was possible given the involvement of Citizen-Science volunteers. Given the low percentage of dust samples ultimately found to contain significant activity, citizen-scientists were essential to getting a sufficiently large number of samples from which to draw conclusions regarding this site.

2. Methods

A total of 360 samples of house dust, surficial soils, and ash were collected for this study. Sample collection began in December 2018 (less than one month after the Woolsey Fire began) and ended by February 2019. Samples were collected from private residential properties (with property owners' permissions), public areas, and public areas directly adjacent to the SSFL site fence line. The samples were collected using community-volunteers from the Los Angeles area. These community-volunteer citizen-scientists had received training in sample collection and safety protocols before collecting samples. The locus of areas sampled extended to a radius of approximately 16 km around the perimeter of the SSFL-site. This area encompasses rural, urban, suburban, and undeveloped mountainous locations.

The samples collected came from the Woolsey Fire zone (Fig. 1) and unaffected areas generally easterly and upwind of the fire zone. Fig. 2 shows the Woolsey Fire burn area overlaid with the prevailing Santa Ana winds. This represents wind direction and speed for the fire period (NASA 2018).

Each sample was assigned a unique identifier and tagged with latitude and longitude data acquired using a handheld Global Positioning System (GPS). No radiation monitoring devices were employed to bias sample collection. One sampling team used a b-Geigie® rate counter with an integrated data-logger to produce a record of gamma readings and GPS coordinates during the SSFL site perimeter sampling. These data were not reviewed until after the completion of sample collections. All bulk samples (n = 124 of 360) were collected in double Ziplock® bags with GPS and identification data affixed to both bags. Depositional dust and ash samples were collected from residential locations using Zefon® Biotape® microscope slides with a 4-cm² adhesive area that collected a thin layer of dust, soil particles, or ashes (n = 236 of 360). Lift-tape samples were prepared by contacting the sampled surface with the adhesive portion of the Bio-Tape slide, removing it, and then returning the slide to its individual case (Barbieri, 2009). Samples were assigned a suffix (A, D & S) for ashes, surface dusts, and soils, respectively.

When packed for shipping, samples were placed inside two boxes with a gap between the boxes to create a geometry that reduced the potential for any radiation exposure during transit. Prior to final



Fig. 1. Map of the sampled area showing Woolsey Fire (2018) extent and SSFL (DTSC, 2020) (low-res version, actual is high-res).

shipping, all samples were prescreened using an International Medcom Inspector rate counter that could detect alpha, beta, and gamma activity (using a halogen-quenched Geiger-Mueller tube with an effective diameter of 45 mm and a mica window density of 1.5–2.0 mg/cm²).

All samples were analyzed using the same geometry by preparing lift-tape (Bio-Tape®) samples. The samples were collected directly onto lift-tapes in the field or as a monolayer from the air-dried and homogenized bulk samples in the laboratory. There was no sieving or other type of particle size adjustment during preparation. Slides were counted for three 1-h counts using a Ludlum Model 3030 two-channel alpha-beta rate counter. Bulk samples with alpha and beta counts greater than 1 σ above the respective means were also analyzed by alpha and gamma spectroscopy and/or Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy analysis (SEM/EDS).

On selected samples, alpha spectroscopy (with pretreatment by digestion and chemical separation of approximately 1.0 g samples, followed by planchet counting for radium, thorium, and uranium alpha decays) was performed by Eberline Analytical Corp, a commercial testing laboratory in Oak Ridge, TN. Eberline also performed a high-resolution gamma analysis using quantitative high-purity Germanium [HPGe] spectroscopy (for cesium-137, cesium-134, and uranium/thorium decay products using air-dried bulk samples).

SEM/EDS analysis was performed by Microvision® Laboratories of Chelmsford, MA, using a Bruker® X-Flash® Peltier-cooled silicon drift detector (SDD). The electron beam current was 0.6nAmperes, accelerated to a voltage of 0.5–60 keV. Air-dried Biotape® slides were carbon-coated before X-ray analyses. A Robinson Detector was used to scan for

high-Z materials among the particles. The SDD detector can quantify the elemental composition of particles with an approximate limit of detection of 0.2%. SEM/EDS does not detect radioactive decays but will efficiently detect high-Z elements such as uranium and thorium that contribute to the alpha activity. Prior to the SEM analysis, slides were weighed, preloaded, and post-loaded, and were found to contain (on average) 4.4 ± 2.1 mg of the material, based on the mass gain over the tare value for the Bio-Tape slides (Kaltofen 2020).

3. Results

3.1. Alpha count rate

The complete set of study samples had a mean net alpha count rate of 7.6 ± 3.0 counts per hour (CPHr) for each 2 cm \times 2 cm slide (α CPHr 4 cm⁻²). The mean of background samples (soils/dusts east and upwind of SSFL and the fire zone) was 7.4 ± 4.4 CPHr 4 cm⁻². The two means are not significantly different, attesting to the scattered nature of the elevated activity samples. One outlier was neglected in calculating σ for the mean. The collection points of samples with notable alpha count rates and other detections are shown in Fig. 3. Samples with alpha count rates that were about 2 σ greater than the mean are shown in Table 1. Only seventeen of the 360 samples collected had alpha count rates about 2 σ greater than the mean, with σ based on counting variability, not assuming the actual count data were normally distributed (Figs. 1–6).

Of the 360 samples collected, twenty (20) were sampled from the perimeter (fenceline) of the SSFL. The mean alpha count rate for the

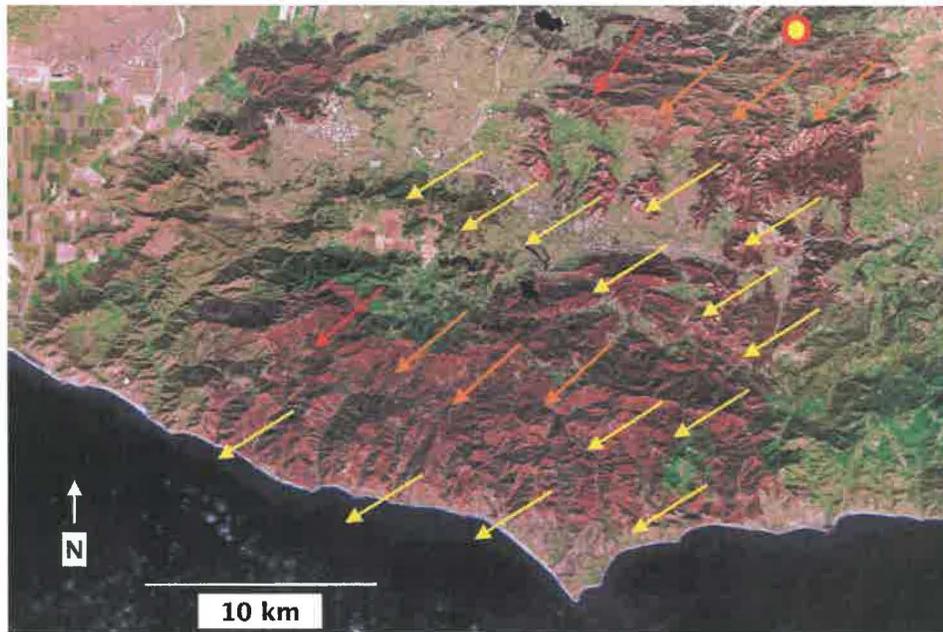


Fig. 2. Map of Woolsey Fire extent with wind pattern overlay (NASA, 2018) showing approximate fire origin (circle), wind direction, and maximum wind gust speeds (yellow 30 mph, orange 30-40 mph, red >40 mph). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

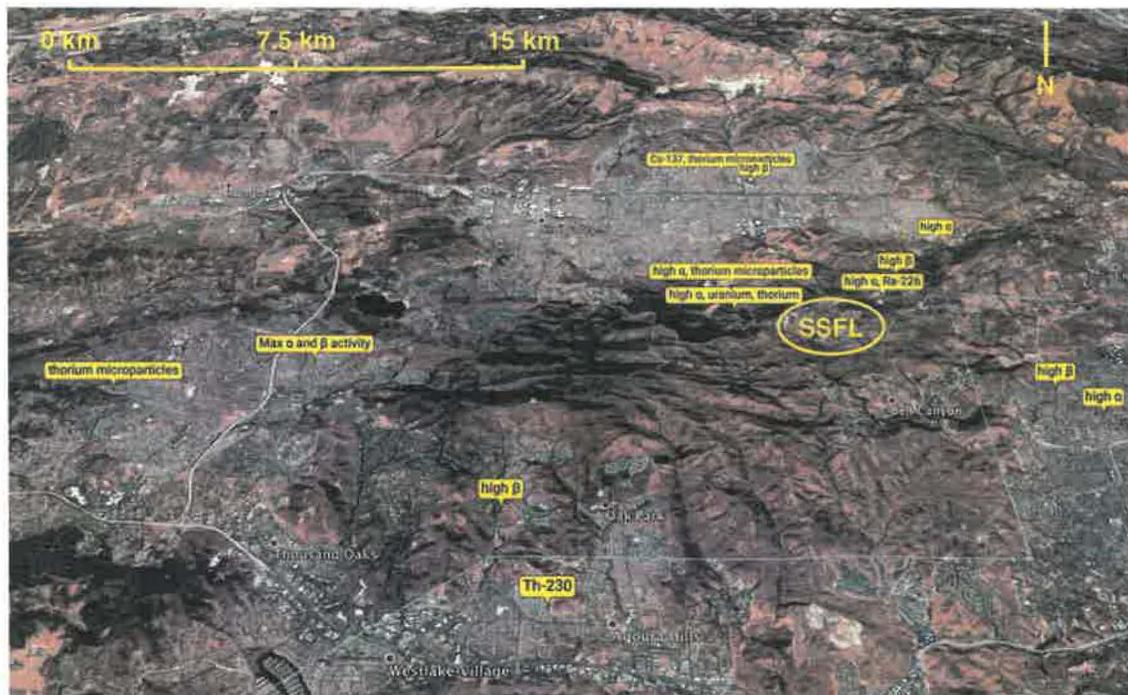


Fig. 3. Map of the notable alpha, beta, gamma, and SEM/EDS results, adapted from Google Earth (2020) (low-res version, actual is high-res).

fenceline sample set was 11.4 ± 3.5 CPHr 4 cm^{-2} . This mean is significantly higher than the means for the background and total sample set results.

A deposited ash sample (180 A) collected 15 km from the SSFL perimeter (in Thousand Oaks, CA) had the highest alpha count rate of the entire sample set. X-ray microanalysis (described later in the SEM/EDS results) detected multiple thorium-bearing radioactive

microparticles in this same ash sample. Thus, the data for sample 180 A is consistent with fire-transported radioactive microparticles. In Table 1, samples taken nearest the SSFL fenceline had generally higher alpha count rates and were therefore over-represented compared to the rest of the sample set.

Table 1
Net Alpha counts per hour (α -CPHr) over instrument background [ID identifier: A = Ash, D = Dust, S=Soil, Control = pre1945 wood samples].

ID	α -CPHr	km to SSFL	direction to SSFL
180 A	140.4 \pm 15.1	15 km	SSW
020 S	23.1 \pm 2.1	<0.5 km ^a	N
150 S	20.7 \pm 2.5	<0.5 km ^a	N
332D	20.4 \pm 1.0	4.4 km	SE
126 A	20.1 \pm 3.8	<0.5 km ^a	W
129 S	19.7 \pm 6.4	<0.5 km ^a	W
169 S	18.4 \pm 4.4	11.6 km	ESE
161 S	17.4 \pm 3.1	5.5 km	N
218D	16.4 \pm 1.0	12.7 km	W
206D	16.4 \pm 4.0	15 km	W
025 S	15.7 \pm 5.5	<0.5 km ^a	N
170 S	15.4 \pm 2.1	1.7 km	NW
148 S	15.4 \pm 3.8	9.5 km	SW
021 S	15.4 \pm 6.1	<0.5 km ^a	N
024 S	15.1 \pm 4.5	<0.5 km ^a	N
122 S	15.1 \pm 6.4	6.1 km	NW
All samples	7.6 \pm 3.0	–	–
Fenceline only	11.4 \pm 3.5	–	–
Background (S)	7.4 \pm 4.4	varies	E
Control	0.5 \pm 1.0	NA	NA
Control (ashed)	4.2 \pm 3.1	NA	NA

^a Fenceline sample adjacent to SSFL.

3.2. Beta count rate

The complete set of study samples had a mean net beta count rate of 87.7 ± 51.8 CPHr for each 2 cm \times 2 cm slide (CPHr 4 cm^{-2}). The instrument background net beta count rate was 0.0 ± 79 CPHr 4 cm^{-2} . The mean of background samples ($n = 47$, soils/dusts east and upwind of SSFL and the fire zone) was 84 ± 42 CPHr 4 cm^{-2} . For the twenty (20) samples from the perimeter (fenceline) of the SSFL, the mean beta count rate was 123 ± 39 CPHr 4 cm^{-2} . The three means are not significantly different, further confirming the elevated activity samples' isolated and

geographically-separated nature. This result may also reflect that of the beta-emitting radioisotopes found at SSFL itself, only one, cesium-137, exists at significant levels above background. None of the radioactive microparticles detected in the study included any form (radioactive or stable) of cesium. This result is consistent with the finding that beta counts for the fenceline set were, on average, within 1σ of the whole set (see Table 2).

The beta count rate geographical distribution was similar to that for alpha count rates, with the same maximally-elevated results for sample 180 A (the Thousand Oaks, CA ash sample) and a preponderance of SSFL fenceline samples in this elevated count rate group. Some degree of correspondence between alpha and beta results is anticipated given the radioactive decay chains for thorium, uranium, and radium. These are identified SSFL contaminants of concern (EPA 2012b; EPA 2012c). All yield both alpha and beta decays in their respective decay chains (ATSDR 2013). Many higher beta count rate samples cluster to the west and southwest of the Santa Susana Field Lab (SSFL) in an area within the fire zone. Excluding fenceline samples, only 3 of 22 samples in the high-count rate group are located in the eastern and generally upwind non-fire zone. While these findings mirror the location fire zone, it also reflects the greater sampling density in the fire zone compared to areas located to the east of SSFL ($n = 305$ fire zone or downwind vs. $n = 55$ upwind, non-fire zone and easterly).

3.3. Isotopic data

As with the alpha and beta count data, the highest isotopic activities were found in samples collected nearest the SSFL site, several additional scattered detections above the background levels in the fire-impacted areas. The highest activities for sampled uranium and thorium isotopes originated from an ash sample collected near the western edge of Santa Susana Field Lab, indicating that the Woolsey fire produced ashes contaminated by radioactivity, whether natural or industrial, from the material at SSFL. Table 3 summarizes the highlights of the alpha and gamma spectroscopic analyses. This study's maximum sample activity of radium-226, $648 \pm 307 \text{ Bq kg}^{-1}$, was more than 18 times the DOE

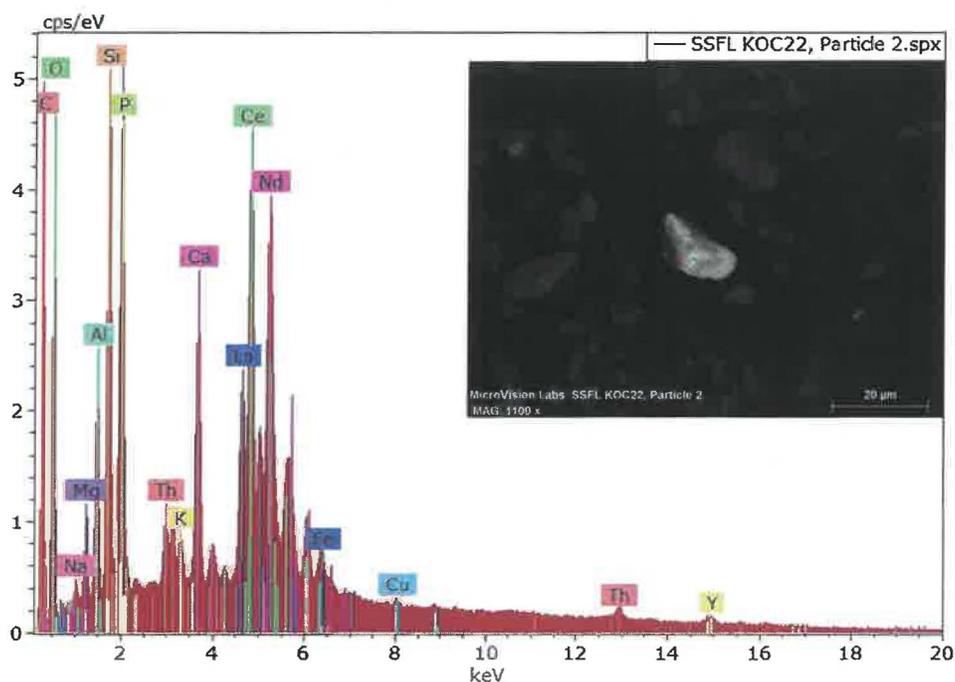


Fig. 4. SEM/EDS Data Particle SSFL22S.2 with 19- μm long axis diameter and with elemental composition of 2.1% Th, 11.6% Ce, 6.2% P, 5.8% La, 5.1% Nd, and 3.1% Ca. The sample was collected at the SSFL fenceline.

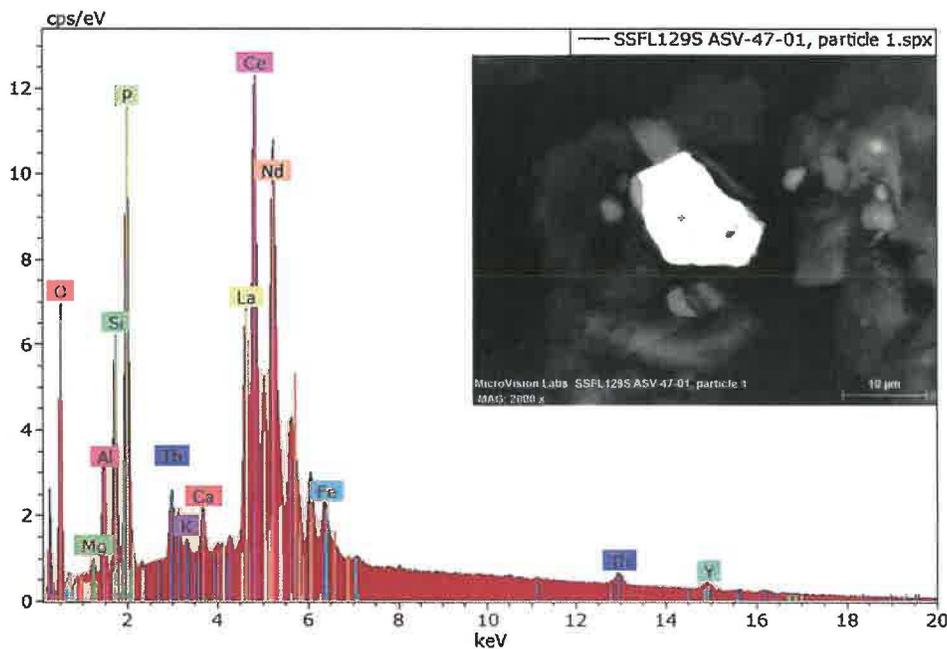


Fig. 5. SEM/EDS Data Particle SSFL129S.1 with 16-µm long axis diameter and with elemental composition of 5.0% Th, 29.9% Ce, 16.6% La, 15.3% P, 12.6% Nd, and 1.2% Ca. The sample was collected at the SSFL fence line.

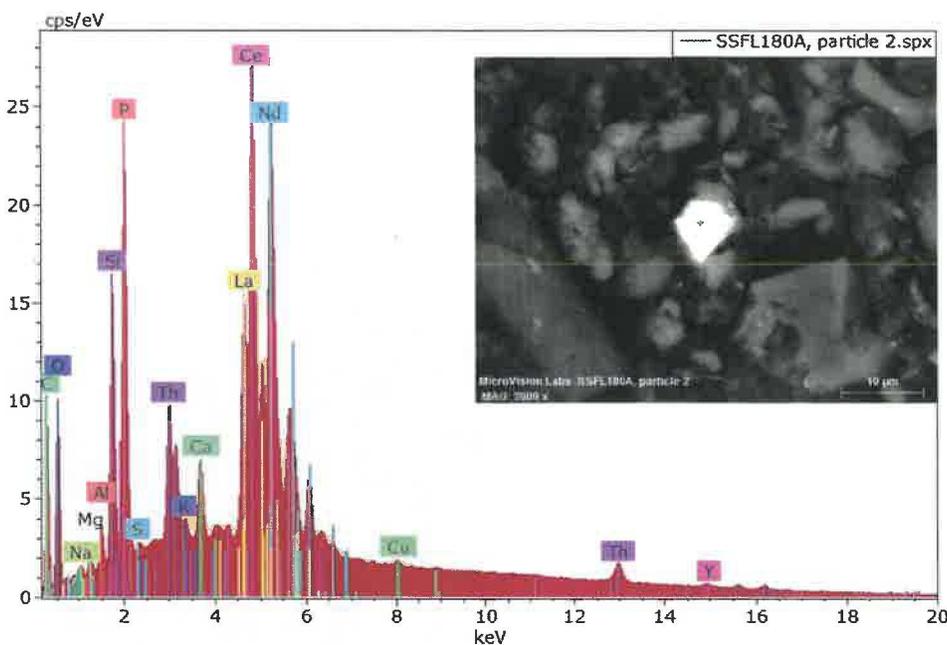


Fig. 6. SEM/EDS Data Particle SSFL180A.2 with 8-µm long axis diameter and with elemental composition of 9.6% Th, 29.8% Ce, 15.2% La, 15.0% P, 10.9% Nd, and 1.9% Ca. This ash sample was collected 15 km SSW of the SSFL in Thousand Oaks, CA. This ash sample also had the maximum alpha and beta count rates of the entire 360-sample set.

reported background activity, $27 \pm 10.4 \text{ Bq kg}^{-1}$ (DOE 2005). This surface soil sample was collected just outside the fenced perimeter north of SSFL. Therefore, radium-226 is an SSFL-specific contaminant of concern (EPA 2012c).

Similarly, the highest activities for uranium-234, uranium-238, thorium-228, and thorium-232 were all found in the ash sample collected at the west-side fence perimeter immediately outside of SSFL. The elevated cesium-137 activity of sample 161 S was eight times

background and came from Simi Valley, CA. This same 161 S sample also contained thorium monazite particles. The elevated thorium-230 activity of six times background was found in a sample collected in Agoura Hills, CA.

3.4. SEM/EDS results

Of the thirteen radioactive microparticles detected, nine were in the

Table 2
Net Beta in counts per hour (β-CPHr) over instrument background [ID identifier: A = Ash, D = Dust, S=Soil, Control = pre1945 wood samples].

ID	β-CPHr	km to SSFL	direction
180 A	322 ± 21	15 km	SSW
012	221 ± 38	<0.5 km ^a	N
023	188 ± 49	<0.5 km ^a	N
020	185 ± 32	<0.5 km ^a	N
317D	184 ± 16	8 km	SW
021	182 ± 78	<0.5 km ^a	N
171 S	179 ± 79	3 km	N
210D	175 ± 21	11 km	SSW
220D	175 ± 28	5.6 km	WNW
289D	168 ± 15	10 km	SE
170 S	168 ± 98	1.7 km	NW
182D	167 ± 23	7 km	SSE
168 S	165 ± 13	4.6 km	NW
311D	164 ± 16	12.7 km	SW
259D	164 ± 19	4.1 km	NW
110 S	163 ± 8	16 km	NW
108 S	162 ± 56	14 km	NW
173 S	157 ± 28	10.6 km	SW
164 S	156 ± 23	5.4 km	S
109 S	153 ± 39	14.5 km	NW
176 S	152 ± 13	5.5 km	SW
239D	152 ± 45	4.1 km	E
134 S	151 ± 24	3.3 km	NNW
197D	151 ± 27	8.3 km	NNW
231D	150 ± 65	12.5 km	SW
161 S	149 ± 19	0.5 km	W
All samples	96 ± 45	–	–
Fenceline only	123 ± 49	–	–
Background	84 ± 42	varies	E
Control	13 ± 53	NA	NA
Control (ashed)	115 ± 39	NA	NA

^a Fenceline sample adjacent to SSFL.

Table 3
Site-specific background activities (US DOE, 2005) vs. SSFL sample maximums. Data are in Becquerels per kilogram (Bq kg-1). Sample IDs and matrices are also shown.

Isotope	Background	Sample set max.	Note	Location	
Cs-137	1.96 ± 1.85	16.7 ± 11.8	161 S	high β	Simi Valley
U-234	27. ± 7.8	91 ± 25	126 A ash	high α	<0.5 km (W)
U-235	1.63 ± 0.74	4.1 ± 3.3	122 S	high α	Simi Valley
U-238	27 ± 7.8	72.5 ± 21.8	126 A ash	high α	<0.5 km (W)
Th-228	32.2 ± 9.2	82.9 ± 27	126 A ash	high α	<0.5 km (W)
Th-230	27 ± 10.4	164 ± 49	148 S	high α	Agoura Hills
Th-232	32 ± 9.2	74.4 ± 24.8	126 A ash	high α	<0.5 km (W)
Ra-226	25 ± 11	648 ± 307	021 S	high α & β	<0.5 km (N)

fence line area (<0.5 km from SSFL), four were found 5.5 km north of SSFL in Simi Valley, or 15 km west of SSFL in Thousand Oaks. The range of thorium compositions in detected monazite particles was 0.8–11.2 percent thorium by mass, with a mean of 5.3% ± 3.9% (Table 4). Thorium was used extensively at SSFL, including in the Sodium Reactor Experiment Complex, where the reactor used 93% uranium-thorium metal alloy fuel (EPA 2012a).

All thirteen radioactive microparticles contained percentage thorium concentrations as thorium monazite (Figs. 4–6). Monazite is a naturally occurring radioactive calcium-phosphate mineral containing 3%–11% thorium, rare earth elements including La, Ce, Pr, Nd, Sm, Eu, and Gd; and (typically) less than 1% uranium (Tew 1968; Hayaton 2019). Thorium monazite may also originate from industrial wastes. This mineral is a source of thorium and uranium for the nuclear industry, a byproduct of metal refining, and monazite has also been used experimentally as a waste storage form for actinides (Boatner 1980; Paschoa

Table 4
Radioactive microparticles detected [ID identifier: A = Ash, D = Dust, S=Soil].

Sample ID	Particle composition	Location
206D	11.2%	Th as monazite Thousand Oaks, CA
180 A	9.8%	Th as monazite with Lead (Pb) Thousand Oaks, CA
161 S	2.7%	Th as monazite Simi Valley, CA
126 A ^a	9.8%	Th as monazite
129 S ^a	9.0%	Th as monazite
129 S ^a	5.0%	Th as monazite
129 S ^a	4.4%	Th as monazite
129 S ^a	2.2%	Th as monazite
021 S ^a	2.1%	Th as monazite
021 S ^a	0.9%	Th as monazite
021 S ^a	0.8%	Th as monazite
022 S ^a	1.4%	Th as monazite
022 S ^a	0.9%	Th as monazite

^a Fenceline sample adjacent to SSFL.

2010; Ewing 1999).

The radioactive microparticles detected in this study are not definitively natural or industrial. Notably, however, the most significant number of monazite particles were detected at the SSFL fenceline, evidencing that, whether industrial or natural, the Santa Susana Field Laboratory or its exposed bedrock is a potential source of the thorium monazite particles detected in this study. Also notable, the fire ash sample 180 A from Thousand Oaks, CA that had the highest alpha and beta count rates of all 360 samples and a 9.8% thorium particle, also contained particles composed primarily of lead, an industrial metal. This finding suggests that the ash in this sample resulted from a manufactured substrate’s combustion or an industrially contaminated material. Finally, as previously noted, ash samples collected at the SSFL site’s perimeter contained thorium isotopes at up to 500% of the site-specific background creating further evidence that thorium mobilizes from the Santa Susana Field Laboratory.

California Environmental Protection Agency (CalEPA) data found a similar pattern of scattered localized areas of elevated radioactivity samples. CalEPA found elevated alpha and beta activity at a Bell Canyon location 1.4 km S of the SSFL. Further analysis by Lawrence Livermore National Laboratory identified isotopes consistent with low levels of cesium-137 at one site and alpha emitters [such as radium or thorium] in the Bell Canyon sample (DTSC 2020). These CalEPA findings mirror those of this study, with generally unremarkable data in the fire zone save for the scattered higher-activity locations where ashes were deposited. Likewise, US EPA data has found thorium levels significantly above site background activities but has not used any X-ray techniques to determine the excess thorium’s chemical or mineral state (EPA 2012c). Based on this study’s findings, any future proposed environmental analyses should include an SEM/EDS analysis of onsite dusts, remnant ashes, and surface soils to determine if similar thorium monazite particles exist onsite beyond the detection rate found for fenceline and offsite samples.

4. Conclusions

A significant majority of samples (97% of 360 samples) collected in the study zone registered radioactivity levels that matched existing area background levels. Nevertheless, some ashes and dusts collected from the Woolsey Fire zone in the fire’s immediate aftermath contained high activities of radioactive isotopes associated with the Santa Susana Field Laboratory (SSFL). The data show that Woolsey Fire ash did, in fact, spread SSFL-related radioactive microparticles, and the impacts were confined to areas closest to SSFL and at least three other scattered locations in the greater Simi Valley area. Alpha and beta counting, high-

resolution alpha and gamma spectroscopy, and X-ray microanalysis using SEM/EDS confirmed the presence of radioactive microparticles in the Woolsey Fire-related ashes and dusts.

Most of the fire-impacted samples found near the SSFL site's perimeter were on lands accessible to the public. There were, however, scattered localized areas of increased radioactivity due to the presence of radioactive microparticles in ash and recently-settled dusts collected just after the Woolsey fire. These radioactive outliers were found in Thousand Oaks, CA, and Simi Valley, CA, about 15 and 5 km distant from SSFL, respectively. The Thousand Oaks samples had alpha count rates up to 19 times background, and X-ray spectroscopy (SEM) identified alpha-emitting thorium as the source of this excess radioactivity. Excessive alpha radiation in small particles is of particular interest because of the relatively high risk of inhalation-related long-term biological damage from internal alpha emitters compared to external radiation.

The nuclides identified as the sources of excess radioactivity in impacted samples were predominately isotopes of radium, uranium, and thorium. These have naturally-occurring sources, but these isotopes are also contaminants of concern at SSFL and were detected at generally increasing activities as the distance from SSFL decreased. In addition, the number of radioactive microparticles per gram of particulate matter also increased strongly with decreasing distance from SSFL. These data demonstrate that fire and/or other processes have spread SSFL contamination beyond the facility boundary.

Credit author statement

Marco Kaltofen, conceptualization, methodology, formal analysis, writing – original draft; M. Gundersen, Resources, data curation, editing, Project Administration, funding acquisition; A. Gundersen, Investigation, editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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A REUTERS SPECIAL REPORT

How Boeing created a nature preserve that may also preserve pollution

Boeing and dozens of other companies have granted "conservation easements" on some of the most contaminated land in the U.S. Companies can save millions on cleanups with these deals, arguing that no one will ever live there. Neighbors of one site are up in arms.

By JIM DOWDELL and ANDREA MANIATA | Filed July 20, 2022, 11 a.m. EDT

The scientists and engineers of the Santa Susana Field Laboratory saw themselves as pioneers. Their work from the 1940s through the early 2000s helped put men on the moon and build missiles used to stare down the Soviet Union during the Cold War. They helped develop the first atomic reactor launched into space and operated one of the first nuclear plants to power U.S. homes.

But the innovation came at a cost.

Decades of unsafe pollution management created a health hazard that would endanger neighbors for decades to come.

Engineers mounted engines on platforms, then burned liquid rocket fuel in thousands of tests. Workers flushed the engines with solvents that flowed onto the ground, eating away asphalt and draining into unlined ponds. Chemicals eventually contaminated groundwater and a nearby creek.

To get rid of waste, workers regularly burned it in open pits. They also fired rifles at barrels full of chemicals until they exploded, sending toxic plumes into the air.

And in 1959, operators pushed one of the lab's nuclear reactors past its limits, causing a partial meltdown of the core. Scientists later estimated that the amounts of some radioactive materials released in the incident exceeded those from the notorious Three Mile Island nuclear accident, which exposed an estimated 2 million people to small doses of radiation two decades later.

Today, chemicals and radioactive materials permeate the soil, groundwater and bedrock at the 2,850-acre Santa Susana property, about 30 miles northwest of downtown Los Angeles. Some pollution has traveled beyond the site, creating health concerns for more than a quarter of a million people who live within five miles.



A 2007 federal health study – conducted in response to neighbors’ concerns – documented high rates of adult thyroid cancer, a disease tied to radiation exposure, within two miles of the site.

No government health studies have been done since then, but activists have documented at least 81 children and 74 adults with cancer living within 20 miles of Santa Susana. Activists showed Reuters extensive evidence to support the tally, including medical documents, news stories, photos and links to fundraisers, as well as the obituaries or memorials for 12 children.

After a 2018 wildfire on the property, scientists conducted a peer-reviewed study in 2021 that found radioactive ash at homes and on public land as far as nine miles away. Government and independent testing found contamination from Santa Susana at a neighboring

children’s camp, nearby parks and residential neighborhoods. Stormwater carries chemicals off the site, exceeding government limits.

Boeing Co, the National Aeronautics and Space Administration and the U.S. Department of Energy share responsibility for the site – and they are on the hook to clean it up. Boeing assumed liability for a large portion of the property in 1996, when it acquired the previous co-owner, Rocketdyne. In 2007, Boeing signed an agreement with California to make 1,900 acres clean enough that people could live on the land and eat vegetables from their gardens.

But most of that cleanup never happened. Now, Boeing is pursuing an unorthodox strategy that could enable it to bypass cleaning up much of the land. The company is using a legal agreement meant to preserve nature to

SECURING SANTA SUSANA’S OPEN SPACE

Stephen Thor Johnson

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“We are experiencing the most rapid changes in our global environment since humans evolved as a species,” said Stephen Thor Johnson, president of North American Land Trust.

“My colleagues and I are inspired and motivated to take meaningful steps to keep our environment healthy and resilient, with projects that can be models and inspiration for others to follow.”

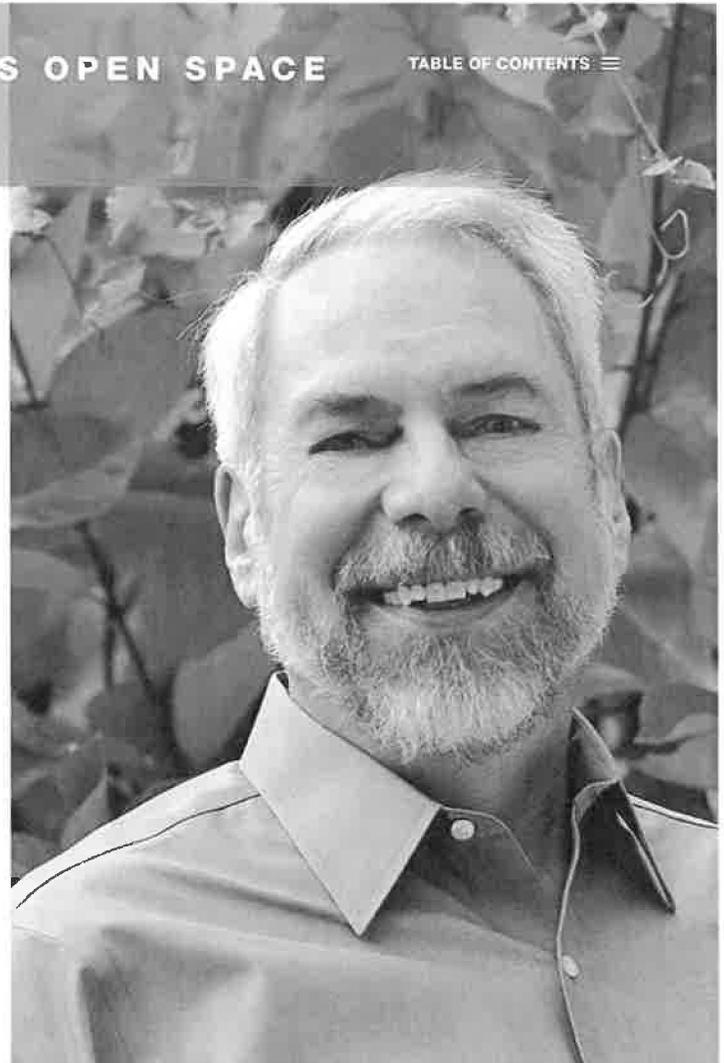
Through an agreement between Boeing and the North American Land Trust*, a national nonprofit land conservation organization, about 2,400 acres (971 hectares) within the Southern California Santa Susana Field Laboratory will be forever protected from residential and agricultural development, regardless of future ownership. The property is home to a number of sensitive species and serves as a wildlife corridor ensuring the

viability of animal species that depend on the ability to move throughout large territories. The property also includes important cultural resources, including Native American archaeological sites, which are protected by the conservation easement.

In addition to Boeing’s ongoing progress with cleanup and site restoration, the transformation of Santa Susana is well underway, with native plants and animals reclaiming most of the previously developed areas of the field laboratory. Santa Susana is home to more than 16 plants and animals that are either endangered, rare or a special species of concern. The site includes unique plants such as the Braunton’s milkvetch and the Santa Susana Tarplant, which serve as critical habitat for pollinators and other animal species.

“The opportunity to collaborate with Boeing to conserve such a significant tract of wildlife habitat and cultural and historic resources is a once-in-a-lifetime opportunity. To do so within an hour’s drive of 20 million people is simply extraordinary. The value of this open space will be magnified over the coming decades and be remembered as a truly visionary act like the creation of Central Park or the conservation of the Presidio.”

*See Endnotes



GLOWING REPORT: Boeing’s 2018 environmental report featured Stephen Thor Johnson, then president of the North American Land Trust, who lauded the company’s plans to preserve open space at Santa Susana.

argue that it should be allowed to leave much of the pollution untouched.

The aerospace giant donated the property's development rights to a land trust under an arrangement known as a "conservation easement." Such easements, which restrict building, are intended to preserve open space, protecting scenic vistas, wildlife habitat and cultural heritage.

Boeing has held up the donation as an example of its commitment to environmental stewardship. In its 2018 annual environmental report, it quoted Stephen Thor Johnson, then president of its partner in the easement deal, the North American Land Trust (NALT). "The value of this open space," Johnson said, "will be magnified over the coming decades and be remembered as a truly visionary act like the creation of Central Park or the conservation of the Presidio."

Left unsaid was how Boeing stands to benefit. Within a month of donating the easement to NALT, Boeing told the state of California it no longer intended to make the property clean enough to live on. Because the easement prohibits building on the land, the company said, Boeing instead intended to make the property safe for light recreation, such as hiking. That lesser standard would leave the vast majority of chemical pollution in the ground and shave at least tens of millions and perhaps hundreds of millions of dollars off the company's cleanup costs, according to a Reuters analysis of the proposed cleanup standards and soil sampling data. Four independent cleanup specialists vetted the analysis.

California rejected Boeing's argument that the conservation easement warranted a lesser cleanup, but to avoid a lawsuit and further delays, the state reopened negotiations with the company anyway. Boeing has won a preliminary victory in getting the state to consider new cleanup scenarios, including some that take the easement into account. All of the new options would leave more pollution behind than the cleanup the state approved years ago, according to a Reuters review of the company's latest agreement with the California Department of Toxic Substances Control (DTSC).

Boeing's strategy angers Jen Connell, who lost her husband, Mike, in April to glioblastoma, an aggressive brain cancer. He lived most of his 50 years within five miles of Santa Susana's rocket-testing platforms and blamed radioactive ash from there for his disease. Radiation is



GUARDED: A gatehouse greets visitors to the former Santa Susana Field Laboratory property in June in California's Simi Hills. REUTERS/Mike Blake

known to increase the risk of glioblastoma. "What about preserving human life?" said the mother of two. "They got a smoke screen going on to make them look like they have a halo."

Boeing, in a statement to Reuters, said it is "misleading" to say that it is using the conservation easement to limit cleanup at Santa Susana. Boeing noted it has agreed to clean up one type of contaminant – radioactive material – to levels present before the field lab existed. Though its agreement with California expresses Boeing's preference to clean up other contaminants to the safe-for-recreation standard, the company also noted it has agreed to accept whatever cleanup the state chooses, including a stricter option that would make the site safe for homes and gardening. State officials told Reuters they intend to require this.

Still, state officials acknowledged that all the options outlined in the new Boeing agreement would clean up less soil than called for in the old one. In a written response to Reuters, they said the changes reflected the state's use of "best available science." Regulators will hold Boeing to the same health protections required previously, they wrote, and the easement will not influence their choice of a cleanup option.

'Foolish'

The idea of using a conservation easement to lobby for a lesser cleanup of polluted land rankles James Florio, the former U.S. representative who authored the Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Congress passed the act,

commonly known as the Superfund law, to require companies to clean up their toxic messes. Easements shouldn't be used as an excuse to leave pollution behind, Florio said.

"Saying you're not going to clean it up because it's not going to do any harm, because it's not going to be used, is foolish," he said.

Yet dozens of companies across the United States have benefited from the strategy. And the country's top environmental watchdog, the U.S. Environmental Protection Agency, is encouraging conservation easements on polluted land as a way to make contaminated sites useful again.

Reuters found conservation easements on at least 40 contaminated sites, including former landfills, mines, waste ponds and burn pits. Twenty-four of the locations are or have been in the federal Superfund program, which targets the nation's most toxic waste sites. In each case Reuters uncovered, the easement contract notes the land's history of contamination. For at least 25

Conservation easements on contaminated sites

● Current or former Superfund site ● Other federal and state cleanups



Because of decentralized record-keeping systems, no one knows how many conservation easements are on contaminated land. Reuters identified 40 mostly by scouring county land records and regulatory documents.

sites, Reuters found documents that acknowledge the safety of the cleanup relies in part on the conservation easement's promise to prevent development or other activities on the land. In at least six cases, state or federal regulators cited the easement's land restrictions as a reason to let polluters conduct lesser cleanups that left some contamination behind.

Meant to protect people from dangerous exposure to toxic substances, the easement arrangements rely on landowners, land trusts and developers to honor prohibitions on unsafe activity for as long as the danger remains. But Reuters found that these agreements and others like them are inconsistently enforced, lapses that can result in dire health consequences, legal and environmental scholars said.

Environmental monitoring reports show pollution is migrating from some of these contaminated sites and threatening neighboring communities. At others, contaminants endanger plants and animals. People have built homes, unwittingly or not, on or near properties that had restrictions similar to conservation easements, exposing them to contaminated water, toxic fumes and cancer causing chemicals.

The Matchmaker

Some environmental regulators and cleanup consultants argue that easements can play an important role on polluted properties. Along with deed restrictions, zoning controls and other notices attached to land records, easements aim to ensure that people don't build on contaminated land.

Nor is it always possible to fully decontaminate polluted land. The cost can be out of reach. It also can be technically impossible or impractical.

"I wish there were endless resources to clean everything up," said Jim Kuipers, a consulting engineer who has worked on mine cleanups for decades. "The EPA's charge is to protect human health and the environment. It's not to restore to background or entirely pure conditions."

Regulators have long supported easements as a warning flag for future generations. Reuters found some dating back as far as 1991.

But that was never their intended purpose, scholars say. "Plunking a conservation easement on a property in lieu of cleaning it up is a perversion of the use of a conservation easement," said Nancy McLaughlin, a law professor at the University of Utah whose work focuses on the legal agreements.

Yet in recent years, the U.S. Environmental Protection Agency, the regulatory body responsible for monitoring

and approving cleanups of Superfund sites, has been encouraging companies to use easements to save time and reduce costs. The agency notes additional benefits: Preserving land can boost a company's image as a friend of the environment, and some can claim tax deductions for donating their polluted land.

Easements can "provide win-win-win opportunities for everyone and in many cases, also vulnerable species," the EPA told Reuters in a statement. The deals also can help companies "repair their relationship with the community."

The agency held a webinar in January 2020 called "The Brilliant and Profitable Role of Conservation Easements in Superfund Site Redevelopment."

"Never underestimate the value of a great story," Bill Denman, then EPA acting national program manager



The Brilliant & Profitable Role of Conservation Easements in Superfund Redevelopment

EPA Superfund Redevelopment
January 28, 2020

PROMOTION: The EPA has encouraged the use of conservation easements on contaminated sites. The idea was the focus of this webinar the agency held in 2020.

for Superfund redevelopment, told participants. "The environment wins, the community wins, the developer wins."

Denman has played matchmaker, looking to connect companies with land trusts willing to take easements on contaminated land. One ally is Kat West, a former EPA lawyer turned consultant who has called herself the "EPA whisperer."

West was a featured speaker at the January 2020 webinar. She contacted EPA regulators that month via email, saying she had spoken with NALT – the land trust that holds the easement on Boeing's Santa Susana property – about doing more work on contaminated sites.

NALT was looking for new partners, she said.

"Steve Carter is the President and said we can send people directly to him," West wrote.

West arranged a call with Carter and the EPA's Denman. Soon, Denman provided Carter a new opportunity. In a February 2020 email, Denman introduced the NALT leader to a cleanup specialist from the multinational chemical company BASF to discuss a conservation easement on contaminated BASF land. The EPA told Reuters the conversation was meant to explore placing a conservation easement on the land to protect a bird habitat that had been created during a cleanup nine years earlier.



"More profitable projects, public benefits & a happy community - What's not to love?" That's what speakers at @Brownfields2019 "The Brilliant & Profitable Role of Land Conservation Easements" asked before talking about how developers, local gov't & land trusts can work together.



2:14 PM · Dec 13, 2019 · Twitter Web App

SPREADING THE WORD: The EPA's Bill Denman (back row, right) and EPA contractor Kat West (back row, center) spoke about placing conservation easements on contaminated sites at an event in Los Angeles. The EPA's Office of Land and Emergency Management highlighted the event in this 2019 Twitter post.

The EPA said the conservation idea never came to fruition. A BASF spokesperson said he was unaware of any ongoing discussions with NALT. West declined to comment.

Asked about the agency's promotion of conservation easements, the EPA described the deals as tools to ensure the future safety of a site, not influencers of its cleanup decisions. The EPA said it encourages adding easements after a cleanup method is chosen, not before.

An opaque system

Conservation easements gained prominence after the U.S. Congress in 1980 created permanent tax breaks for them, to preserve “natural resources and cultural heritage.”

It is impossible to know how many companies have placed conservation easements on contaminated land. Also unknowable is whether companies have sought tax breaks for such easements in the name of land conservation. That’s because neither corporations nor nonprofits are required to disclose detailed information about the easements. The EPA and other regulators say they don’t keep count or any central record of them. Tax deductions and land appraisals are private, and the United States keeps no comprehensive records of property conservation.

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Reuters identified most of the 40 easements on contaminated land by searching for mentions in environmental regulatory documents and by reviewing land records in hundreds of U.S. counties, where the easements are recorded along with property deeds. Beyond Boeing, major multinationals that have granted easements on polluted land directly or via subsidiaries include oil companies Chevron, BP, ExxonMobil and Citgo Petroleum, chemicals giant DuPont, aerospace contractor Lockheed Martin and drug maker AstraZeneca.

Boeing and Chevron were among a handful of companies that said they did not seek tax deductions for

“Plunking a conservation easement on a property in lieu of cleaning it up is a perversion of the use of a conservation easement.”

Nancy McLaughlin, a law professor at the University of Utah whose work focuses on conservation easements

their conservation easements. Citgo Petroleum confirmed it took a tax deduction but declined to disclose the amount. The others either declined to comment, didn’t respond to inquiries or said they didn’t know if they took a deduction. Reuters found 13 companies with easement contracts that refer to the section of the Internal Revenue Service code that allows for conservation-easement tax deductions, leaving the door open to claim them.

Even without claiming tax breaks, companies can realize significant financial savings by leveraging the easements in cleanup negotiations with regulators.

Companies save money because in choosing a cleanup plan, regulators consider how people might use the property in the future and what health risks the contaminants pose. The most expensive cleanups restore property to a pristine condition or make it safe enough for people to live there, drink the groundwater and eat food grown in home gardens. Less cleanup is required if the land is to be used for hiking or other recreation. Even less is necessary if a conservation easement allows little to no use of the property.

The savings can easily total tens of millions of dollars, said engineer Kuipers, who has consulted on dozens of cleanups and testified in court cases as an expert on cost estimates. For the largest and most contaminated sites, like Boeing’s, he said, companies could save hundreds of millions of dollars.

EPA records show Chevron saved an estimated \$45 million when the EPA approved a less costly cleanup for a Questa, New Mexico, site where Chevron once mined molybdenum, a metal used mainly in the construction and energy sectors. The agency cited a 2009 conservation easement as a reason to allow the company to make part of the site clean enough for industrial use rather

than requiring it to make the land safe for housing.

The choice left 25 times more cancer-causing polychlorinated biphenyls (PCBs) in the ground than the most stringent cleanup would have allowed, EPA records show. The records also show that molybdenum, which had been found at levels 75 times higher than is safe for housing, was not required to be cleaned up at all in that section. Chevron provides bottled water to employees of a local fishery because the metal – harmful to people



SAVINGS: A conservation easement placed on contaminated land helped Chevron save up to \$45 million in cleanup costs at its former molybdenum mine in Questa, New Mexico, shown in this undated EPA photo.

and wildlife in high doses – has been found in tap water there, according to a 2018 state and federal report about the site. A fishery employee confirmed that the company is still providing water today.

In an emailed response to questions, Chevron said the conservation easement supports the cleanup goals for the property. It said that the land is too steep for home construction and that the company is doing everything the EPA requires in its cleanup.

Boeing declined to answer questions about how much it stands to save if California allows it to scale back the cleanup at Santa Susana. State regulators said they have not yet estimated the costs of the various scenarios.

“Based on similar cleanups, we expect the costs of cleaning up the Boeing areas of responsibility to be in the hundreds of millions of dollars,” the regulators said.

A Reuters analysis of the state’s various cleanup standards shows Boeing’s cleanup could allow some chemicals to remain at levels tens, hundreds, and even thousands of times higher than previously promised.

Officials from the DTSC objected to the news agency’s focus on the amount of pollution the cleanup would leave behind. What matters, they said, are the health standards driving the cleanup requirements. Those standards focus on minimizing the risk of cancer or other health issues.

State officials said they still intend to require Boeing to make the land safe enough to live on, even though the law requires them to consider other scenarios, some of which require less cleanup.

“DTSC has fought fervently for a clear path toward this high standard and will continue to do so until the cleanup is complete,” they said in an emailed response.

Yet at Boeing’s behest, the state has changed the way it calculates safety standards at Santa Susana.

A Boeing contractor urged DTSC officials to reexamine the formula that determines which parts of Santa Susana need to be cleaned up, state emails show. DTSC officials said they agreed because their previous calculations did not reflect the “best science.” Under the state’s revised formula, even the strictest cleanup DTSC is considering – one that allows homes on the property – would leave far more pollution behind.

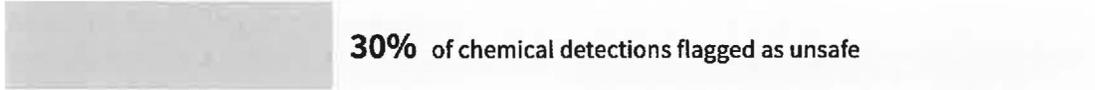
Corporations and their partners who support the use of conservation easements say that even if some contaminants remain, the open land still provides viable wildlife habitat and green space for people to enjoy. If the land were fully cleaned up, some argue, those benefits would be lost because companies would sell the land to developers to recoup some of their cleanup costs.

If remaining contamination is properly managed, cleanup specialists said, sites can be used safely as parks, soccer fields, parking lots and more. Easements and other land-use restrictions can help conserve land worth

How the cleanup requirements could change

Boeing agreed in 2007 to clean up enough pollution to make it safe for people to live and garden on the former Santa Susana Field lab property. Following a settlement with Boeing in May, the state is now considering different cleanup levels, all of which would leave behind more contamination, according to a Reuters analysis. Boeing's preferred approach would make the land safe for recreation. State officials say they still favor a stricter cleanup that would make the land safe for homeowners and gardening; however they are calculating safety thresholds differently, so even that option would clean up less pollution overall than Boeing agreed to earlier.

PREVIOUS AGREEMENT



2022 HOME AND GARDEN STANDARD (PREFERRED BY CALIFORNIA)



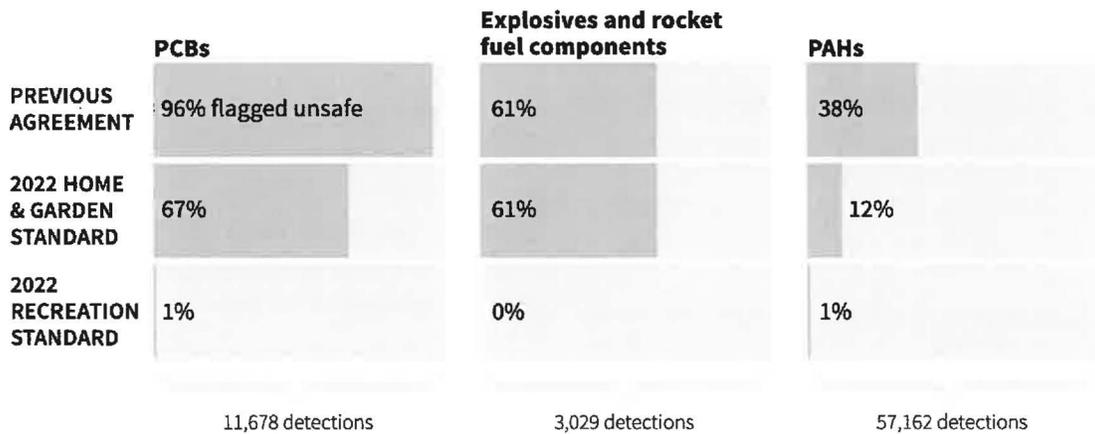
2022 RECREATION STANDARD (PREFERRED BY BOEING)



160,914 CHEMICAL DETECTIONS

The impact on three types of contaminants

Boeing detected 78 different contaminants on the site, including some that pose health risks and some that have migrated to the surrounding area.



Polychlorinated biphenyls are a group of manmade carcinogens banned for over 40 years. In addition to cancer, they have been linked to reproductive and immune problems in people and wildlife.

This group includes TNT, a believed carcinogen, and the rocket-fuel component perchlorate, which has been known to disrupt thyroid function. Perchlorate was heavily used at SSFL and has been found in groundwater nearby.

Polycyclic aromatic hydrocarbons (PAHs) are a byproduct of burning coal, oil and gas. Several chemicals in this group are carcinogens and can cause blood and liver disorders at high exposure.

Sources: Reuters analysis, California Department of Toxic Substances Control, Environmental Protection Agency, Centers for Disease Control

preserving and protect people from the hazards that remain.

Some environmental scientists say the benefits to wildlife and the environment are often overstated.

Take Santa Susana. Boeing has said that the land preservation plan has “secured Santa Susana’s bright future as open space habitat.” The site is home to endangered plants and more than 150 types of animals.

Some of the cleanup options the state is considering would leave wildlife vulnerable to cancers and reproductive issues for decades, if not centuries, to come, said Frank von Hippel, a professor of environmental health sciences at the University of Arizona who reviewed the primary Santa Susana cleanup scenarios. Studies have



SENTINEL: A Boeing tower marks the entrance to the Santa Susana Field Laboratory in the Simi Hills in Ventura County, California, June 22, 2022. REUTERS/Mike Blake

linked many of the site’s contaminants to animal tumors, cancers, and reproductive and immune dysfunction.

“If the property is not safe for people, then it certainly is not safe for much of the wildlife,” von Hippel said.

State regulators said they would use Boeing’s ecological risk assessments in evaluating the impacts on wildlife.

“The assertion that the cleanup will ‘leave wildlife vulnerable’ is incorrect,” the regulators said in their response.

The use of conservation easements as protection for people isn’t foolproof, either. The limits recorded in conservation easements, deed restrictions and other controls linked to property records can get lost with the passage

of time. And history shows that can have devastating health consequences.

It was this very kind of public health disaster that spurred Congress to create the Superfund program in 1980 to require cleanup of the nation’s most polluted lands. Congress was responding to a national outcry over children and adults sickened by pollution in the Love Canal neighborhood of Niagara Falls, New York.

The owner of a former chemical plant had sold to the Niagara Falls Board of Education – for a cost of \$1 – land that the company had used as a dumping ground for more than 21,000 tons of toxic waste. Attached to the 1953 sale documents – and publicly filed at the Niagara County clerk’s office – was a warning that the land contained dangerous chemicals and that the buyers assumed all liability, including risk of death. Though different from a conservation easement, the notice had the same intent: to warn people about the property’s limitations.

Just a year later, the Board of Education, needing classrooms for a growing community, built an elementary school on the property. For more than 20 years, children splashed in contaminated puddles and played over leaking waste drums buried just beneath the surface. Several children required medical treatment for chemical burns on their faces.

After chemicals seeped into neighboring homes, the state declared a public health emergency in 1978. Pregnant women and children under age 2 were told to evacuate. The school was closed, at least 80 chemicals were identified at the site, and residents of the Love Canal neighborhood were instructed to stay out of their basements. More than 700 homes would eventually be razed.

Reuters found other examples of failed protections.

They included an abandoned battery recycling plant in Hamburg, Pennsylvania, where the EPA found chickens and cows grazing on contaminated land and drinking lead-contaminated water in 2012 in violation of a conservation easement. Lead contamination can transfer from cows and chickens to people who consume their dairy products. Reuters was unable to determine whether that occurred here.

In Newark, New Jersey, Ronson Metals Corp closed a

“Put quite simply, our goal is to leave places better than we found them.”

Boeing, in a 2017 white paper on corporate conservation

decades-old factory that had made cigarette lighters. The company, with state permission, left hazardous chemicals – including trichloroethylene, which can cause neurological damage and has been linked to cancer – in the soil, covering the site with clay and crushed stone. It filed a deed restriction in 2002, limiting the land’s use to non-residential purposes such as parking. Despite this, developers built 19 homes and five businesses on the land in the 2000s. After the state learned of the situation in 2012, it installed pumps to vent toxic fumes from residents’ basements.

Conservation easements, in theory, carry more protection than the simple notice filed in the case of Love Canal. They require some entity – such as a government agency or a land trust – to accept responsibility for enforcement.

The Land Trust Alliance, the primary association of land trusts, publishes best practices for land trusts overseeing conservation easements. They call for visiting the land at least once every five years. In intervening years, annual checks can be done from the air. In the event a land trust disbands, it should take “reasonable steps” to transfer conservation easements to other stewards.

NALT, the land trust that accepted Boeing’s controversial easement, left the voluntary alliance because it disagreed with a 2019 policy change requiring member land trusts to review donors’ tax appraisals, said Carter, NALT’s president. NALT believed that policy conflicted with IRS guidance, he said.

NALT’s holdings of more than 500 easements include others that have stirred controversy, including one on property owned by former President Donald Trump. That property is the subject of a tax fraud investigation by the New York attorney general. Trump denies wrongdoing and calls the probe a politically motivated witch hunt.

Since 2006, at least nine IRS disputes over NALT easements have ended up in U.S. Tax Court. The cases

include some on golf courses with conditions that the IRS says run counter to conservation, such as strong chemicals used to maintain the greens and a border collie trained to chase away wildlife. The IRS also opened an audit of an investment group’s 2018 tax return that included a \$220 million deduction facilitated by NALT. The deduction relied on a practice lawmakers have labeled an “abusive tax shelter” that uses overinflated land valuations. Asked about the status of the case, the IRS said it could not comment on “pending litigation.” NALT declined to comment.

Carter said the trust does not shy away from “messy” projects that fit its conservation mission.

NALT and Boeing declined to disclose the full terms of their deal. Carter said Boeing paid NALT a “pretty hefty” sum to monitor the Santa Susana site in perpetuity. Neither he nor Boeing would reveal the amount.

Asked what the monitoring would entail, Carter said NALT intends to visit the property at least once a year and will use drones and satellite imagery to help enforce the easement. Carter emphasized that NALT is not responsible for monitoring any remaining pollution and assumed no liability for the contamination.

Since granting the easement to NALT, Boeing has been promoting the deal on its website and in company reports as an example of its commitment to environmental stewardship.

In 2021, at a ceremony sponsored by Boeing, the Wildlife Habitat Council gave the company an award for its efforts to preserve the Santa Susana site. The nonprofit council, created by industry to promote corporate conservation, also listed Boeing as the sponsor of a 2017 white paper on corporate conservation, in which the company’s director of environment, health and safety wrote: “In our pursuit of global environmental leadership, we champion the value of going above and beyond compliance. Our robust remediation and restoration program exemplifies this approach. Put quite simply, our goal is to leave places better than we found them.”

Margaret O’Gorman, president of the Wildlife Habitat Council, declined to comment on the dispute over the Santa Susana cleanup, but called the site “an incredible asset for nature as one of the last open spaces in the Simi Valley.” A spokesman for the council said its awards are



SURVIVOR: Grace Bumstead, 12, shown in June with her brother Luke and parents, Melissa and Chad, in the back yard of their home in West Hills, California, was diagnosed with cancer at age 4. REU-

based on scores determined by third-party reviewers.

Melissa Bumstead has been speaking out against such claims since learning about the Santa Susana pollution seven years ago.

The mother of two says she still regrets moving her family in 2012 to West Hills, less than five miles southeast of the Boeing site. Two years after they settled there, her daughter, Grace, was diagnosed with a rare form of leukemia at age 4.



LOOKING UP: Her cancer in remission, Grace Bumstead rests on a trampoline at her home in West Hills, California, June 22, 2022. REUTERS/Mike Blake

Grace has spent much of her childhood in hospitals. With a weakened immune system, playgrounds, dance classes and even eating fresh strawberries proved too dangerous for her to enjoy. Two girls she befriended in treatment have since died.

After a relapse and bone marrow transplant in 2017, Grace, now 12, is in remission but must take growth

hormone shots daily until she's 16 to counter side effects of treatments she's endured.

"I struggle with this now even though I know it's not my fault," Bumstead said. Grace's cancer is considered "one in a million," but there has been at least one other child diagnosed with the same rare cancer less than five miles from Santa Susana since Grace got sick, Bumstead said.

In 2005, Boeing paid \$30 million to settle neighbors' claims that contamination from Santa Susana caused cancers and other illnesses, according to a plaintiff in the case. Boeing declined to comment on the settlement.

The 1959 nuclear reactor accident at the site may have caused hundreds, if not thousands, of cancer cases in neighboring communities, an advisory panel of scientists and other stakeholders concluded in a 2006 government-commissioned report.

A separate 2007 government-funded study found the area had an unusually high rate of thyroid cancers, and noted evidence that thyroid-disrupting contaminants from the lab had leaked into off-site groundwater. The scientists said there were too few cases to draw any conclusions about childhood cancers.



SPEAKING OUT: Activists at a 2018 protest in front of California Governor Gavin Newsom's campaign office present a map of childhood cancers near the Santa Susana Field Lab. Parents Against Santa Susana Field Lab/Handout via REUTERS

No government-sponsored research has been done since 2007, but activists say they have documented at least 81 children with cancer within 20 miles of the Boeing site. The cases include leukemia, rhabdomyosarcoma, Ewing sarcoma and aggressive and fatal brain cancers.



A MOTHER'S IRE: Melissa Bumstead speaks at a 2018 protest. She began fighting for a cleanup of the Santa Susana Field Lab after her daughter Grace's cancer relapsed in 2017. Parents Against Santa Susana Field Lab/Handout via REUTERS

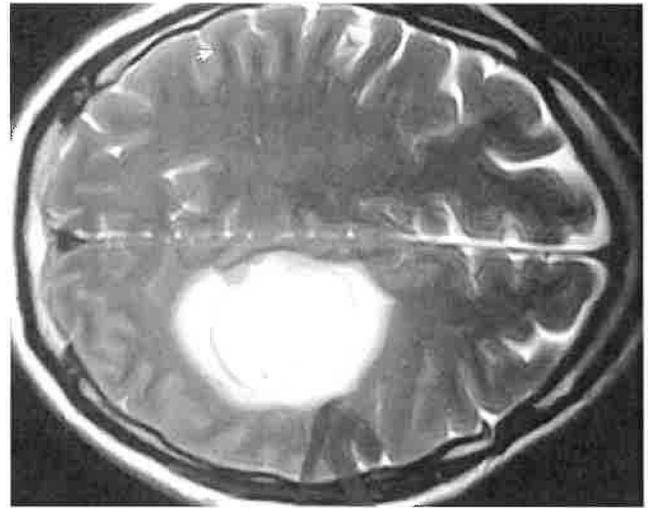
In response to questions, Boeing sent Reuters links to studies, reports, memos and a professor's slideshow that had mixed conclusions. Some did not find unusual cancer rates, while others found elevated rates only in some types of cancers.

Bumstead, who founded Parents Against Santa Susana Field Lab in 2017, said she sees Boeing's conservation easement as the latest in a long line of greenwashing tactics to avoid cleanup. Though none of the cleanup scenarios the state is considering would require a complete cleanup of the site, her grassroots group is determined to keep pressing for that outcome.

Jen Connell joined Bumstead's efforts and began tracking brain cancers in the area after her husband, Mike, was diagnosed in September 2020 at age 48 with glioblastoma, a rare and aggressive brain cancer linked to radiation exposure. Activists have documented at least 20 cases of the cancer within 20 miles of the former field lab. Half were diagnosed after the 2018 Woolsey fire that started at Santa Susana. Reuters reviewed fundraising posts, statements from relatives, and obituaries for some of the cases.

The couple was married for 20 years with two teenage sons. Mike lived all but two years of his life less than five miles downhill from the Santa Susana Field Lab. The other two were spent living near another toxic waste site.

Mike believed the 2018 wildfire stirred up radiation that



GRIM VIEW: Mike Connell's diagnosis of glioblastoma multiforme was confirmed by a 2020 brain scan. He died on April 6, 2022, from the cancer, which he believed was caused by radiation from the Santa Susana Field Lab. Jen Connell/Handout via REUTERS

caused his cancer. In his last Facebook post, five months before his death, he reflected on living in the shadow of Santa Susana and recalled playing near the field lab as a kid.

"We used to hear the rocket test motors daily," he said. "Those Rocketdyne hills have always been a hot spot over the years and now ... the 2018 fires have spread all this existing mess across Simi Valley."

He passed away in his wife's arms on April 6th, after 19 months and three surgeries fighting cancer.



FIGHTING CANCER: Mike Connell poses with his wife, Jen, shortly before his first brain surgery. He lived within five miles of the Santa Susana Field Lab and was diagnosed with brain cancer in 2020. Jen Connell/Handout via REUTERS



March 5, 2021

RE: Santa Susana Field Laboratory

Dear Leaders and Community Members:

NRDC (Natural Resources Defense Council) is a national, non-profit organization of scientists, lawyers, and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC serves more than two million members, supporters, and environmental activists with offices across the United States and in Beijing. NRDC has been engaged with the environmental issues surrounding nuclear energy, nuclear weapons, and nuclear waste since our founding. We specifically began working with the community around the Santa Susana Field Laboratory decades ago to address the site's health, safety, and environmental risks and to ensure a full cleanup of the site.

The Santa Susana Field Laboratory was established in the late 1940s for rocket testing. In the early 1950s, nuclear reactor work commenced at the site. As originally planned, the site was meant to be a remote field lab for work too dangerous to conduct near populated areas. However, the Los Angeles and Ventura communities grew up around the site, and what was once sparsely inhabited is now a packed community of 150,000 living within five miles of the site and more than half a million people living within 10 miles.

The fact that Santa Susana Field Laboratory was not remote did not stop dangerous activities from occurring at the site. These activities left their mark through numerous chemical and radioactive releases and spills on the site that resulted in contaminated buildings, soil, surface water, and groundwater. Over the years, the Santa Susana Field Laboratory hosted a variety of heavy industrial activities including testing rocket engines and nuclear reactors, fabricating plutonium fuel, and disassembling highly irradiated nuclear fuel. For decades, despite requirements to the contrary, radioactive and toxic chemical wastes were burned in open "burnpits." The rocket-engine testing released toxic chemicals like TCE, dioxins, PCBs, and heavy metals. And four significant nuclear accidents occurred.

The worst nuclear accident to occur at Santa Susana Field Laboratory happened in 1959. An experimental nuclear reactor at the site experienced a dangerous, out of control power increase. Even so, operators continued to run the reactor for a week and a half. Only after rising radioactivity readings and numerous other signs of a reactor in trouble did the operators finally shut the reactor down and discover that 13 of 43 fuel elements had experienced melting. Partially because the reactor did not have a containment structure like modern reactors to prevent radiological releases into the environment, scientists estimate that this one incidence may have released more radioactive iodine than Three Mile Island. Yet while Three Mile Island is a household name, the existence of Santa Susana Field Laboratory and the partial nuclear meltdown that occurred there is still mostly unknown. This was intentional. The federal agency responsible at the time for nuclear issues hid the extent of the incident from the public. To this day, much of the public remains unaware of the decades of unsafe operating conditions or the extent of damage done by nuclear reactors and other activities at Santa Susana Field Laboratory.

Santa Susana Field Laboratory is no longer an active site. But it is not benign. Wind and rain, and fires like the Woolsey Fire that burned 80 percent of the site in 2018, continue to carry contaminants from

the site into the neighborhoods that have grown up around it. Cleaning up the remains of decades of irresponsible chemical and radioactive handling on the site remains vital.

NRDC became involved with Santa Susana Field Laboratory at the start of the advocacy to clean up the site. In the early 2000s, the Department of Energy proposed cleanup standards that would have left 99% of contamination not cleaned up. NRDC partnered with the City of Los Angeles and Committee to Bridge the Gap to insist that the parties responsible for Santa Susana not be allowed to walk away from the site. And we won. A federal judge told the Department of Energy that it could not abandon the site and that it had to consider how the cleanup would impact the environment and public health.

Through this lawsuit, we were able to give time and traction to the community's environmental and health arguments. In 2007, Boeing, the Department of Energy, and NASA all signed legally binding Administrative Orders on Consent (AOCs) for the cleanup with California. The Department of Energy and NASA signed a second round of more stringent AOCs in 2010. The AOCs not only set the level of cleanup for toxins and radioactivity in the soil and groundwater, they also give California the final authority over the cleanup standards and methods.

The AOCs were the right deal to make; NRDC strongly supported the deal then, and still does to this day. These are historic cleanup agreements. One of the major roadblocks in cleaning up contaminated sites across the country is agreeing on the level of cleanup; there are many ways to define what is "safe enough" and it is easy for negotiations over cleanups of contaminated sites to get stuck in the science of defining what is "enough." The AOCs did away with those fights. They said Santa Susana Field Laboratory will be cleaned up to background—if contamination is detected, it gets cleaned up. It's as simple as that.

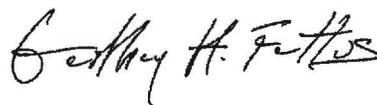
Unfortunately, since signing the AOCs, Boeing, NASA, and the Department of Energy all have tried to renege on the cleanup agreements. Each responsible party has dragged its feet for years, not only missing deadlines for completing the cleanup, but not even starting it. They have flouted the authority of the state of California by proposing to breach the cleanup agreements and leave the contamination in place. This cannot stand.

The neighbors of Santa Susana Field Laboratory will continue to be at risk until California, the Department of Energy, NASA, and Boeing meet their full obligations to clean up the site. We stand beside the City of Los Angeles, County of Ventura, local organizations, and community members to ensure fully compliance with the AOCs by each responsible party. The toxic remnants must be removed and the site cleaned up so the nearby residents can live in safety and peace.

Sincerely,



Caroline Reiser
creiser@nrdc.org



Geoffrey Fettus
gfettus@nrdc.org

Natural Resources Defense Council
1152 15th St. NW, #300
Washington, D.C. 20005



WISHTOYO
CHUMASH FOUNDATION
FIRST NATIONS ECOLOGICAL CONSERVATION ALLIANCE

It is Boeing's responsibility to the surrounding communities and the environment to properly clean up and remediate the Santa Susana Field Lab. SSFL has been and continues to pollute the surrounding watersheds and groundwater basins for decades, causing irreparable harm to sensitive plants, wildlife, and residents of the nearby areas. Boeing continues to report persistent exceedances of harmful pollutants in their storm water discharges. Highly toxic contaminants persist in the region surrounding the lab, having long lasting impacts on sensitive and endangered species that rely on the unique habitats of the Santa Susana Mountains. Contaminants associated with SSFL have caused immense harm to the natural cultural resources and made it unsafe for local native community members to partake in traditional gathering and ceremonial practices. Boeing must commit to a full cleanup of this site in order to make these traditional practices possible again. The residents of the communities impacted by the lab have a right to drink water, play and explore streams and open spaces, and live without fear of contamination or risk to their loved ones' health. The cultural resources of these biodiverse mountains deserve the right to recover from the epitome of man's ignorance and greed.

A handwritten signature in black ink that reads "Tevin Schmitt". The signature is written in a cursive, flowing style.

Tevin Schmitt
Watershed Scientist
Wishtoyo Chumash Foundation

*The physician and health advocate voice for a world free from nuclear threats
and a safe, healthy environment for all communities.*



April 2021

**Physicians for Social Responsibility
Los Angeles**

To Whom It May Concern:

It is my pleasure to provide this letter of recommendation for Parents vs SSFL.

I first met Parents vs SSFL co-founder Melissa Bumstead in 2015 when she attended a community meeting regarding the Santa Susana Field Laboratory (SSFL) cleanup. SSFL is a former nuclear and rocket-engine testing site that is heavily polluted with hazardous nuclear and chemical contamination. My organization, Physicians for Social Responsibility-Los Angeles, has worked to fully clean up the site for over 30 years.

Melissa spoke during the meeting about concerns that SSFL may be the cause of pediatric cancers in the area. Her daughter was being treated for a rare leukemia at Children's Hospital Los Angeles (CHLA) where she was surprised to meet other families of pediatric cancer patients who lived near her, given the rarity of childhood cancer. Cleanup advocates like myself were tremendously concerned in part because it wasn't the first time we'd heard such a story. In 2006 mothers of children with retinoblastomas, a rare eye cancer, also met at CHLA and identified SSFL as a possible cause. They sued site-owner Boeing and won, but as part of the settlement could no longer talk about their experiences.

Melissa and her group of mothers, who would eventually become Parents vs SSFL, refused to settle. They determined that their priority was to protect other families from SSFL contamination, and that meant working to ensure SSFL was finally and fully cleaned up. They identified numerous other pediatric cancers near SSFL and worked with a statistician who confirmed the cases are above average. They quickly mobilized to learn all that they could about SSFL's site history, contamination, and unfulfilled plans for its cleanup.

Since then, Parents vs SSFL has made a tremendous difference in the fight to clean up SSFL. They've learned how to communicate technical information about SSFL's contamination and cleanup to the community in a simple, understandable manner. Their warmth, humility and compassion has helped them win the community's admiration and trust. When dealing with agencies, elected officials, and media, Parents vs SSFL brings authenticity and a human face to the SSFL cleanup struggle.

Parents vs SSFL is also creative, innovative, and social-media savvy. Melissa launched a Change.org petition for the SSFL cleanup that has over 730,000 signatures, and has helped dramatically increase community participation in cleanup decisions. Parents vs SSFL has held many informative and motivating community events and produced clever organizing materials including social media graphics, videos, T-shirts, yard signs, buttons, and stickers. Their events and initiatives have garnered considerable media attention, locally and nationally.

Parents vs SSFL's efforts have resulted in real wins for the community, such as stopping LA County plans to build hiking trails near SSFL and plans for the City of Simi Valley to use groundwater for drinking water. They've also joined the national network Alliance for Nuclear Accountability to learn from peers throughout the country and advocate for cleaning up contaminated nuclear sites nationwide.

Parents vs SSFL's work to educate and engage community members in the SSFL cleanup is critical to ensuring the site is fully cleaned up and nearby communities are no longer at risk of exposure to its toxic contamination. They have and continue to make a critical difference in the community so that, as they say, they can reduce to the full amount possible any parent having to hear the words "your child has cancer."

Please feel free to contact me for any additional information or questions, I can be reached at dduffield@psr-la.org or 310-339-9676.

Sincerely,

A handwritten signature in black ink that reads "Denise Duffield". The signature is written in a cursive, flowing style.

Denise Duffield
Associate Director
Physicians for Social Responsibility-Los Angeles



MEMBERS OF THE BOARD
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**BOARD OF SUPERVISORS
COUNTY OF VENTURA**

GOVERNMENT CENTER, HALL OF ADMINISTRATION
800 SOUTH VICTORIA AVENUE, VENTURA, CALIFORNIA 93009

March 9, 2021

RE: Support for Urgent Action to Clean-Up SSFL and Support for Parents Against SSFL

To Whom it May Concern:

As a Ventura County Supervisor, I am all too familiar with the extraordinarily toxic legacy of the Santa Susana Field Lab (SSFL), and the actions of responsible parties to delay, diminish, and generally thwart efforts to compel its clean-up under agreed-upon terms.

Recently, the Ventura County Board of Supervisors added clean-up of the SSFL to the County's State Legislative Platform to press for more aggressive action to compel clean-up by State agencies. The Board of Supervisors also recently voted to oppose the designation of the over 2,000-acre property as a Historical District, an action that would be likely to impede clean-up under the adopted administrative orders (AO/AOC).

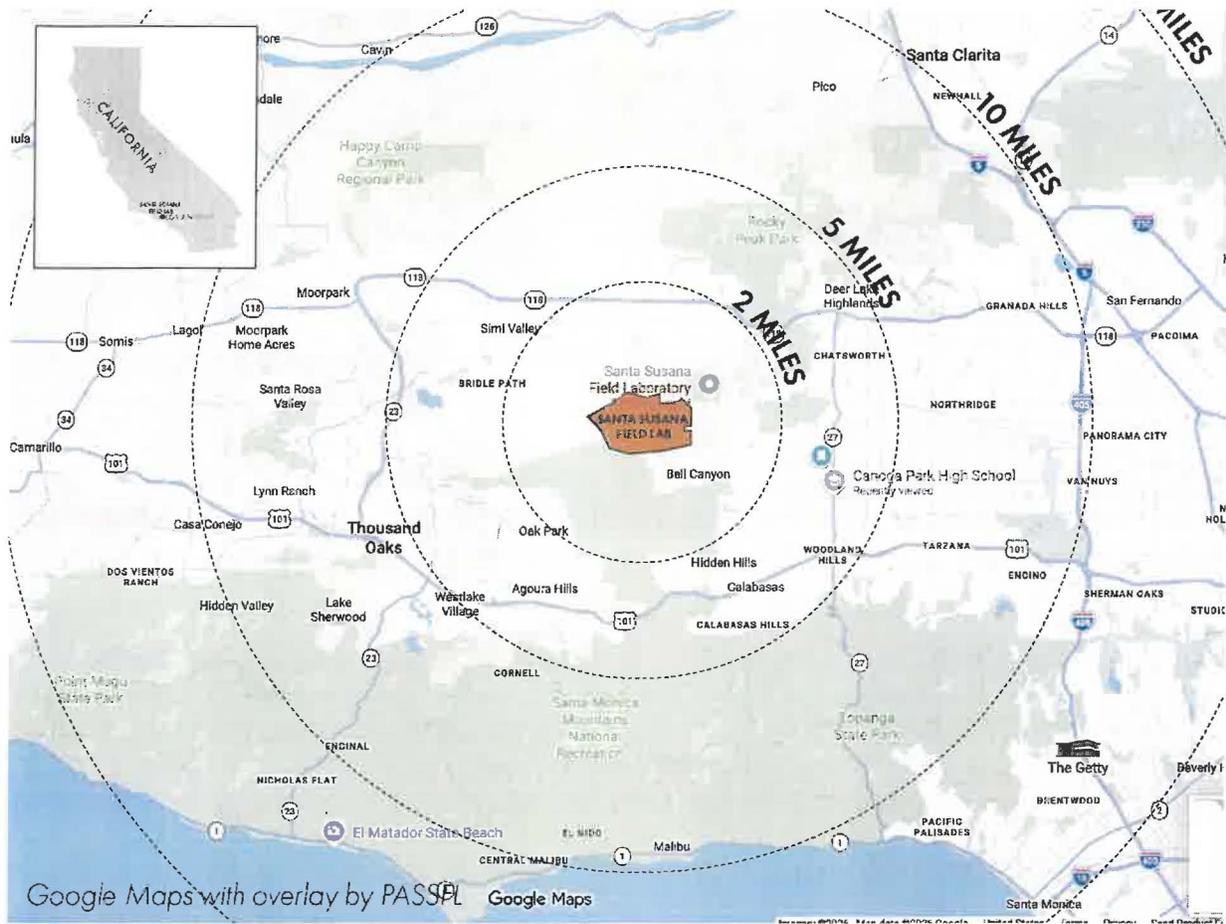
I encourage other entities to join the effort to compel prompt clean-up of the SSFL per the AO/AOC, and I support the efforts of grass-roots citizens organizations including Parents Against SSFL.

Cordially,

A handwritten signature in cursive script that reads "Linda Parks".

Linda Parks
Supervisor, Second District

SANTA SUSANA FIELD LAB LOCATION



SANTA SUSANA FIELD LAB ELEVATION



WATER CONTAMINATION DETECTED OFFSITE OF SANTA SUSANA FIELD LAB

UCLA: Potential for Offsite Exposures Associated with SSFL, 2006
Ch4 Water Final PDF page 9

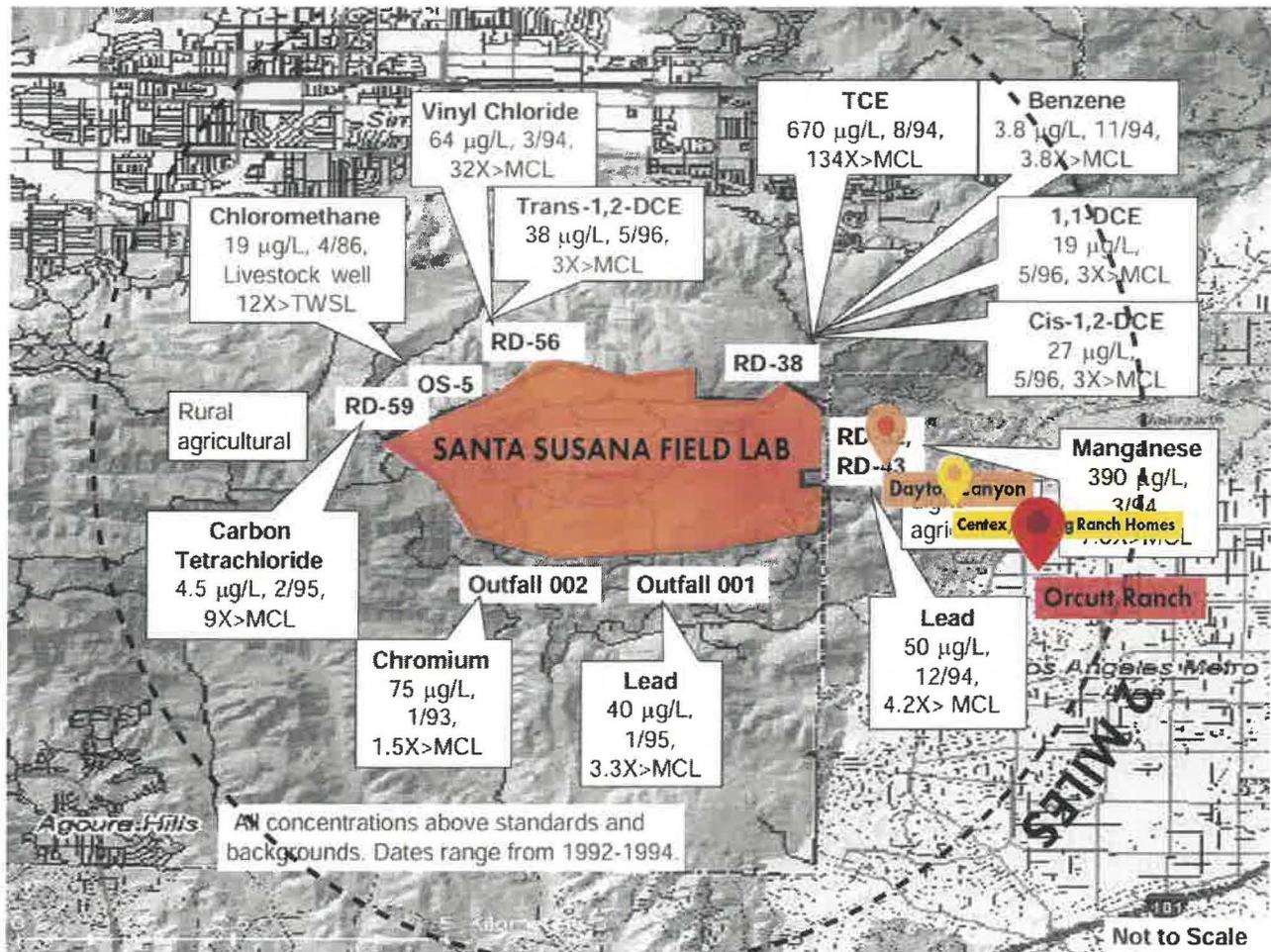


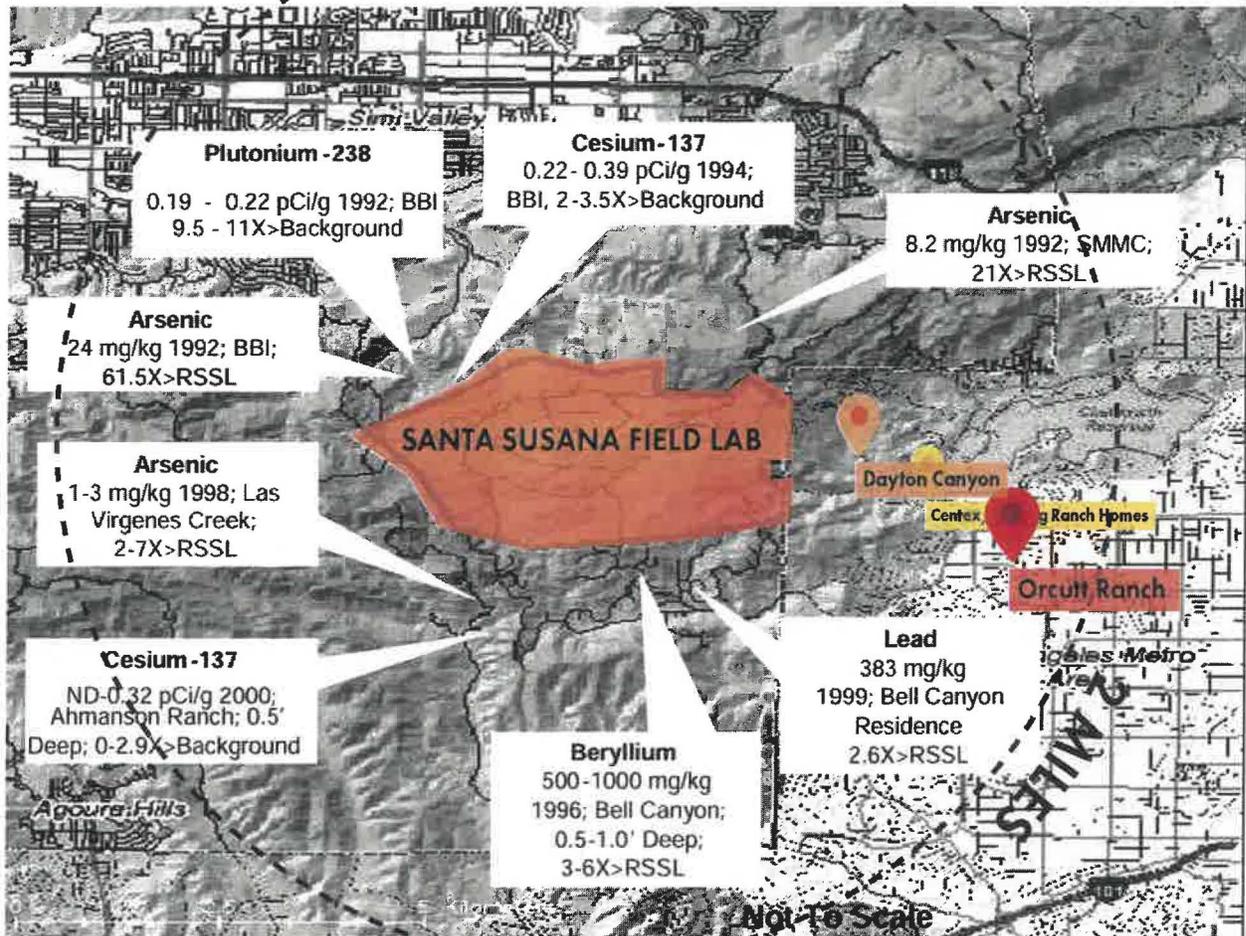
Figure 4-3. Offsite Locations of Selected Groundwater Contaminants of Concern Detected at Levels Above Health-Based Standards. All offsite water contaminants (surface water and groundwater) were compared to MCLs, or Maximum Contaminant Levels (EPA-suggested drinking water standards). The identified contaminants are listed with their offsite detection levels, their dates of sampling, and the factors by which their concentrations were found to be above the MCLs. Contaminants were detected above health-based standards in groundwater northeast, northwest, and east of the facility, as well as in NPDES outfalls on the northeast and south borders of the facility.

“...It is apparent that hazardous waste constituents have migrated from the unlined pond at the Sodium Disposal Facility... and Chatsworth Formation groundwater system... migration is likely to continue... early evaluation and evidence of groundwater contamination beneath the SSFL site suggest that there is a high likelihood that migration of contaminants, from leaky surface impoundments, has contributed to groundwater contamination.”

Potential for Offsite Exposures Associated with SSFL: Chapter 4: Water, page 64

SOIL CONTAMINATION DETECTED OFFSITE OF SANTA SUSANA FIELD LAB

UCLA: Potential for Offsite Exposures Associated with SSFL, 2006
Ch5 Soil Final PDF page 3

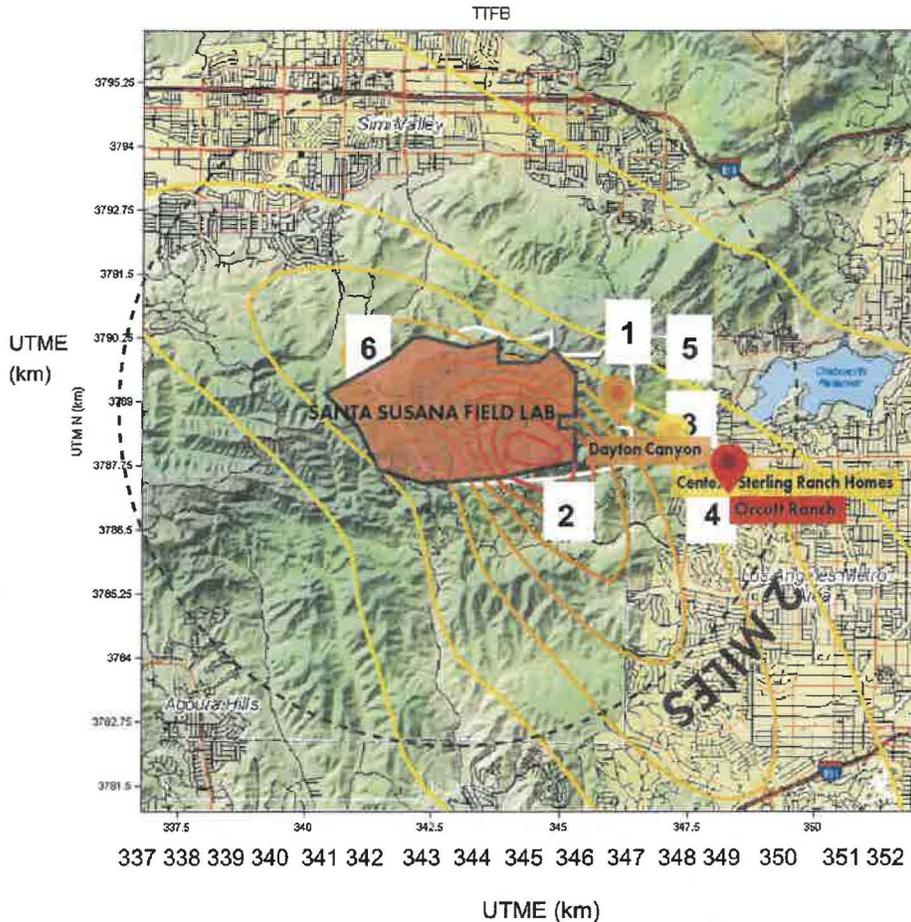


Note: Data collected from 1992 to 1994. Concentration, date detected, location of detection, depth of detection, and exceedence of a health-based standard or background concentration are presented. Depth presented where provided in monitoring reports. (Detections assumed to be at surface level for the purpose of exposure assessment unless otherwise stated in original monitoring report.)

Soil and sediment samples were collected in areas of Bell Canyon that were likely to have been impacted by surface water flow from the SSFL site (Ogden, 1998a,b). Note that beryllium was 5.3 TCE is discussed in Section 5.3. Chapter 5 - Page 78 DRAFT REPORT detected (up to 1000 mg/kg in soil) above health-based standards (150 mg/kg RSSL) at depths of 0.5 to 1.0 feet (Figure 5-1; Appendix H). Atmospheric deposition is unlikely to have caused contamination at such depths. It is more plausible that the beryllium migrated to offsite areas via runoff and sediment transport during periods of rainfall: at such times, surface water from SSFL flows primarily in (1) a northerly direction via two channels that ultimately discharge at NPDES-permitted outfalls at the northwest property boundary and (2) a southerly direction via two channels that ultimately discharge at two NPDES-permitted outfalls at the southern property boundary (ATSDR, 1999). Note also that soil and sediment sampling along NPDES drainage channels within the BBI and SMMC suggests that PCBs, TCDD (dioxins), and mercury may have migrated in drainages from the Sodium Disposal Facility to offsite areas (McLaren/Hart, 1995).

AREAS OF HIGH CONCERN FROM SSFL CONTAMINATION

Potential for Offsite Exposures Associated with Contaminants from SSFL
Louisiana State University, Health Sciences Center, School of Public Health



Potential "Hot Spot"

Area where:

- i. contaminant levels exceed health-based standards;
- ii. exposure is possible;
- iii. exposure could result in an adverse health effect at the levels detected.

Potential Hotspots

1. Northeast Quadrant
2. Bell Canyon
3. Dayton Canyon
4. West Hills
5. Woolsey Canyon
6. Northwest Quadrant

Areas to Monitor:

Dayton & Woolsey Canyons, Meier & Runckle Canyons, Bell Canyon campgrounds & playgrounds, Bell Creek, Dayton Canyon & Creek, **Orcutt Ranch**, Santa Monica Mountains Conservancy/Sage Ranch, Black Canyon, West Hills, & Brandeis-Bardin Institute campground & garden

WOOLSEY FIRE SPREADS RADIOACTIVE PARTICLES FROM SSFL

Radioactive microparticles related to the Woolsey Fire in Simi Valley, CA
Journal of Environmental Radioactivity 240 (2021) 106755
By Fairewinds Energy Education

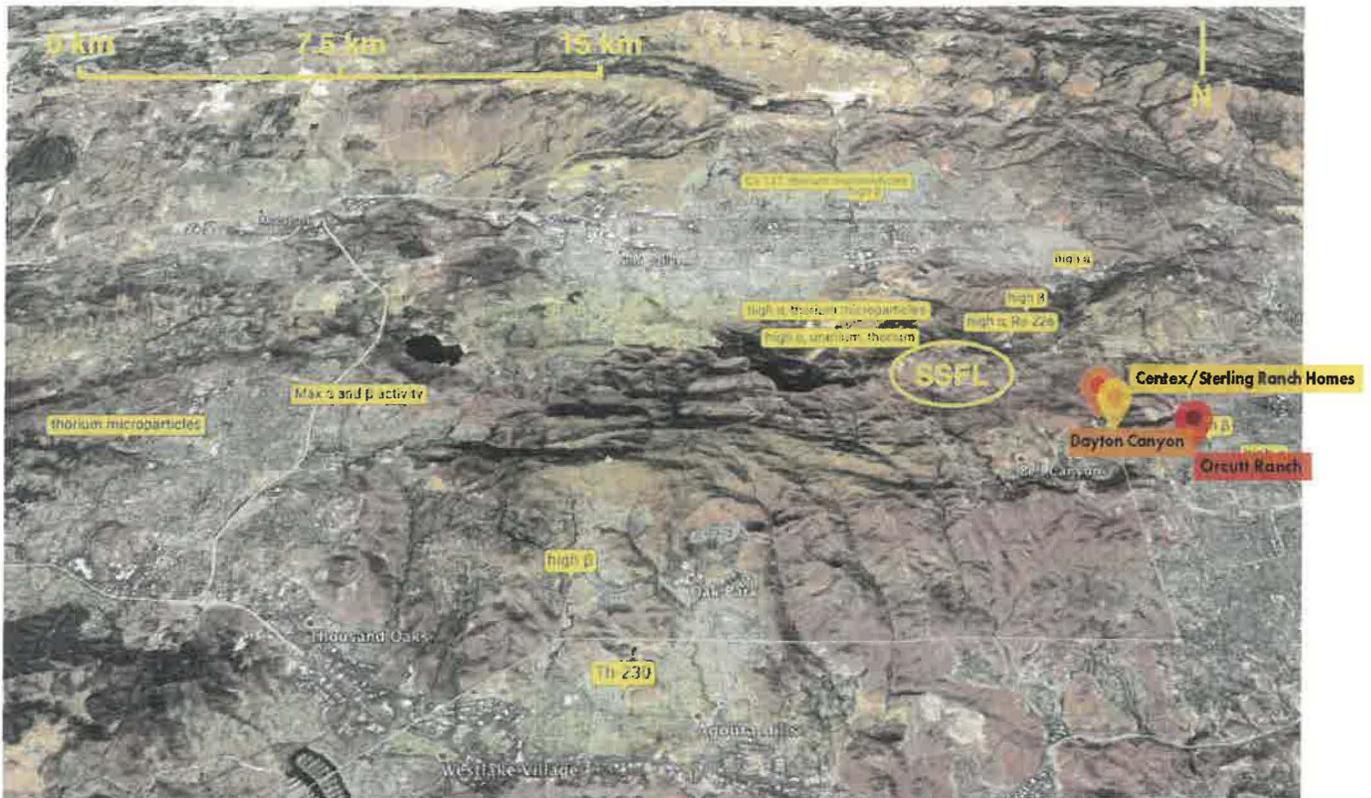


Fig. 3. Map of the notable alpha, beta, gamma, and SEM/EDS results, adapted from Google Earth (2020) (low-res version, actual is high-res).

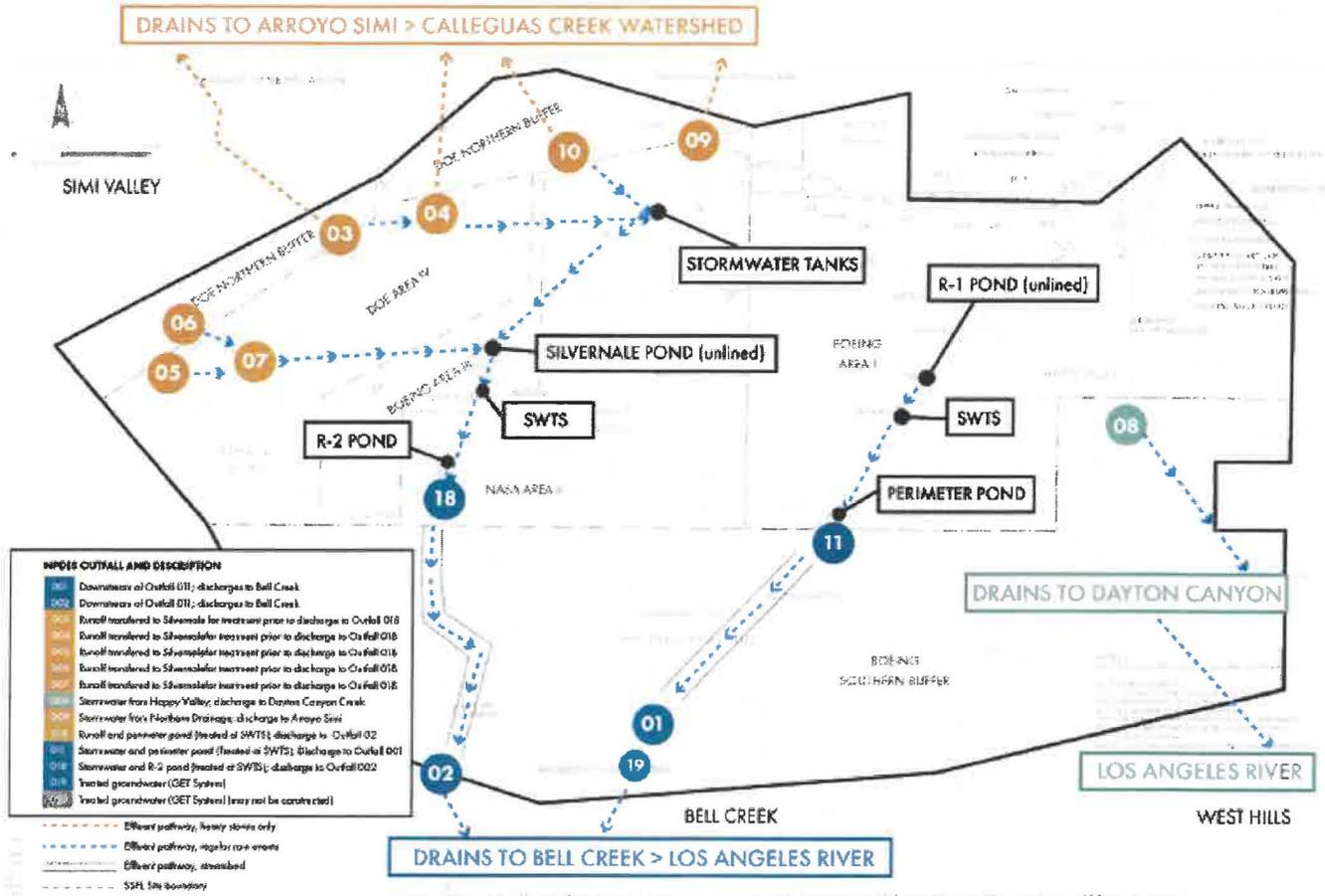
Abstract:

In November 2018, the Woolsey Fire burned north of Los Angeles, CA, USA, potentially remobilizing radioactive contaminants at the former Santa Susana Field Laboratory, a shuttered nuclear research facility contaminated by chemical and radiochemical releases. Wildfire in radiologically contaminated zones is a global concern; contaminated areas around Chernobyl, Fukushima, Los Alamos, and the Nevada Nuclear Test Site have all experienced wildfires. Three weeks after the Woolsey Fire was controlled, sampling of dusts, ashes, and surface soils ($n = 360$) began and were analyzed by alpha- and beta-radiation counting. Samples were collected up to a 16 km radius from the perimeter of the laboratory. Controls and samples with activities 1σ greater than background were also examined by alpha and/or gamma spectroscopy or Scanning Electron Microscopy with Energy Dispersive X-ray analysis. Of the 360 samples collected, 97% showed activities at or close to site-specific background levels. However, offsite samples collected in publicly-accessible areas nearest to the SSFL site perimeter had the highest alpha-emitting radionuclides radium, thorium, and uranium activities, indicating site-related radioactive material has escaped the confines of the laboratory. In two geographically-separated locations, one as far away as 15 km, radioactive microparticles containing percent-concentrations of thorium were detected in ashes and dusts that were likely related to deposition from the Woolsey fire. These offsite radioactive microparticles were colocated with alpha and beta activity maxima. Data did not support a finding of widespread deposition of radioactive particles. However, two radioactive deposition hotspots and significant offsite contamination were detected near the site perimeter.

SANTA SUSANA FIELD LAB RAIN WATER RUNOFF

SSFL Surface Water Pathways

June 5, 2024



Dangerously High Perchlorate in Dayton Creek

Centex Homes Project No. 05-8520EI February 28, 2008
AllWest Remediation

**The California Health Screening Level for perchlorate 0.01 mg/kg
Results from Dayton Canyon ranged from 320 to 62,000 mg/kg**

1.3 INITIAL STUDIES

At the request of Los Angeles City Councilman Greig Smith and in response to community concerns over possible contamination due to the Sterling property's proximity to SSFL, environmental sampling was initiated by Centex Homes on the Sterling property. The initial samples (samples 1A, 1B, 2, 3, and 4) were collected at the site on May 25, 2005. During the initial sampling event, four sediment samples and one duplicate sample were collected in jars and transported under chain of custody to MWH Laboratories, a California State Certified Laboratory, for analysis of perchlorate and volatile organics. The results of this sampling indicated levels of perchlorate, the concentrations of which ranged from 320 to 62,000 mg/kg (ppm). No volatile organics were detected in this sampling. The sample collection locations are shown in Figure 3. These results are discussed in further detail in the Phase II Site Investigation Report (Allwest Remediation, July, 2005).

1.3.1 Surface soils

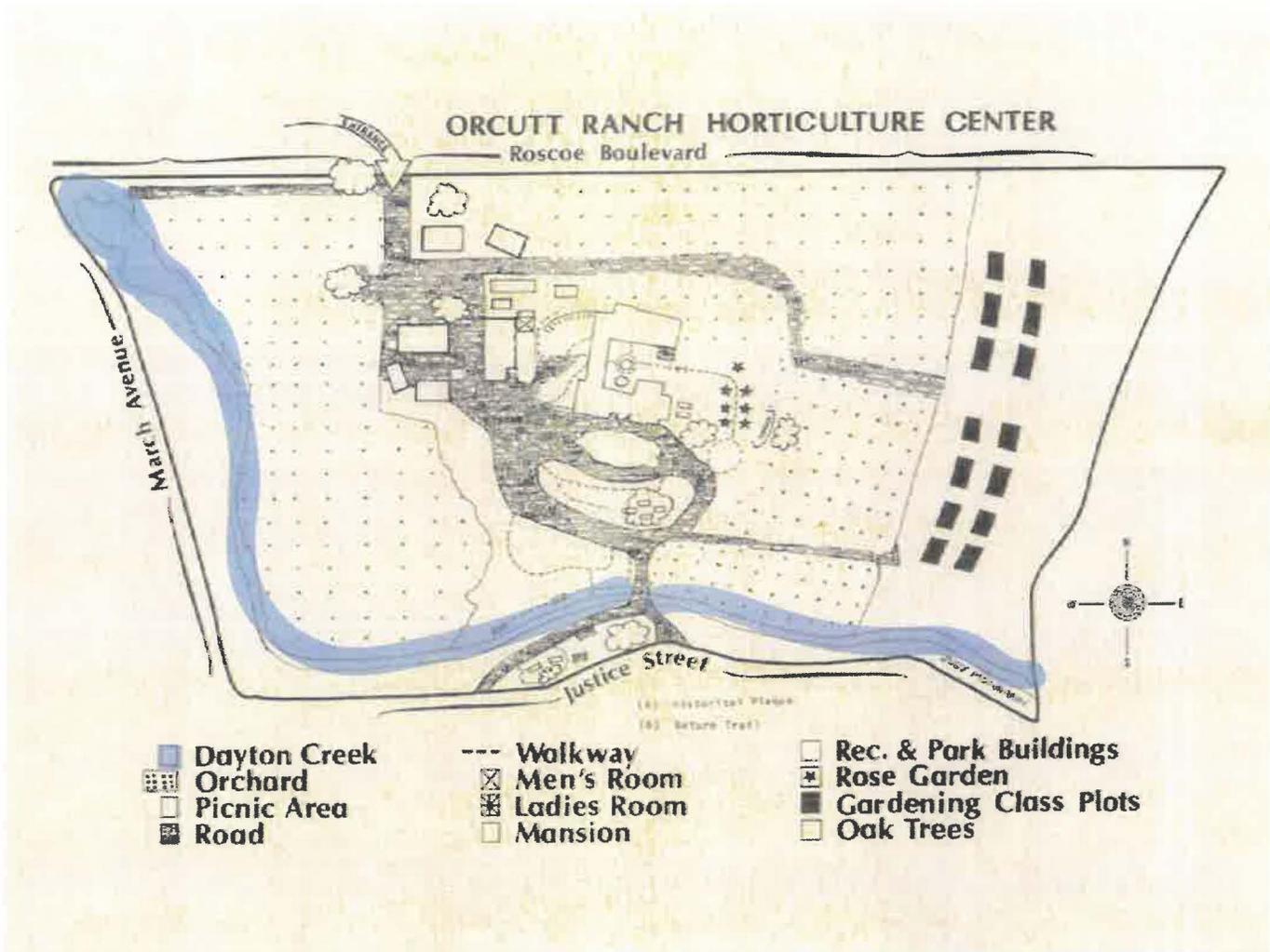
Based on the May 25, 2005 sample results, three surface soil samples (samples SS-1 through SS-3) were collected on May 27, 2005 and transported under chain of custody to MWH Laboratories for analysis of perchlorate. Two of the samples were collected in the areas indicated for future grading operations. One surface sample (sample SS-3) was collected from soils adjacent to a creek as indicated in Figure 3. All analytical results were compared to a provisional California Human Health Screening Level (CHHSL) of 0.1 mg/kg for perchlorate, which is the risk based target concentration developed for the Whitaker-Bermite site in Santa Clarita, California, which was based on uptake into produce and ingestion of home-grown produce. The results of the analysis indicated perchlorate levels below the detection limits in samples from the two future grading areas. Sample SS-3 showed levels of perchlorate up to 1,200 mg/kg (ppm) in the soil collected adjacent to the creek.

On June 14, 2005, four additional surface soil samples (samples SS-4 through SS-7) were collected approximately twenty feet south of the eastern portion of the Creek and transported under chain of custody to Associated Laboratories, a California State Certified Laboratory, for analysis of perchlorate. The analytical results of the surface soils collected on June 14, 2005, adjacent to, but outside, the creek showed perchlorate levels below detection limits.

On July 11, 2005, six additional surface soil samples (samples SS-8 through SS-13) were collected from the proposed developed area and transported under chain of custody to Associated Laboratories for analysis of perchlorate. The analytical results for the additional surface soils collected on July 11, 2005 in the proposed grading areas showed perchlorate levels below detection limits.

Dayton Creek At Orcutt Ranch

Orcutt Ranch Horticulture Center
 City of Los Angeles Brochure



Blue emphasis added by PASSFL

Orcutt Ranch

A 24-acre (10 ha) portion of the original estate, including the residence, gardens, oaks and citrus orchard, was designated as a Historic-Cultural Monument in January 1965. Those 24 acres (10 ha) were purchased by the City of Los Angeles in 1966 for \$400,000. The city-owned property includes a Spanish-style adobe residence, extensive gardens, oak trees hundreds of years old, **Dayton Creek**, nature trails, fruit orchards, rose gardens, community garden plots, picnic tables and a multitude of exotic trees, plants and shrubs.

