



California Environmental Protection Agency
Office of Environmental Health Hazard Assessment

Synthetic Turf Study

Synthetic Turf Scientific Advisory Panel Meeting

February 8, 2016

MEETING MATERIALS

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Section 1

Agenda



Agenda

Synthetic Turf Scientific Advisory Panel Meeting

Monday, February 8, 2016, 10:00 a.m. – 5:00 p.m.
1001 I Street, CalEPA Headquarters Building, Sacramento
Coastal Hearing Room

1. Welcome and Opening Remarks

Lauren Zeise, Ph.D., Acting Director, Office of Environmental Health Hazard Assessment (OEHHA)

2. Study Overview

Melanie Marty, Ph.D., Acting Deputy Director for Scientific Affairs, OEHHA

3. Task-Specific Scientific Discussions

On each topic, staff of OEHHA will provide a brief overview, followed by panel discussion

3.1. Chemicals of Potential Concern

3.2. Sample Preparation Methods

3.3. Targeted and non-Targeted Chemical Analysis

3.4. Field Sampling

4. Public Comments

For members of the public attending in-person: Comments will be limited to 3 minutes per commenter. For members of the public attending via the internet: Comments may be sent via email to SyntheticTurf@oehha.ca.gov. Email comments will be summarized by staff of OEHHA during the public comment period, as time allows.

5. Further Panel Discussion and Closing Remarks

6. Wrap Up and Next Steps

Melanie Marty, Ph.D., Acting Deputy Director for Scientific Affairs, OEHHA

Section 2

An Overview of the OEHHA Synthetic Turf Study



An Overview of the OEHHA Synthetic Turf Study

The California Office of Environmental Health Hazard Assessment (OEHHA) is conducting a study of the potential health effects associated with synthetic turf and playground mats containing recycled waste tires. OEHHA is performing the study under a contract with the Department of Resources Recycling and Recovery (CalRecycle), which regulates the use of waste tires in California. The first two years of the study is comprised of five separate tasks: 1) expert and public input and consultation, 2) hazard identification, 3) exposure scenario development, 4) sampling and analysis of new and in-field synthetic turf, and 5) personal monitoring or biomonitoring study protocol development. OEHHA will use the information obtained in conducting these tasks to conduct a health risk assessment of the potential health impacts of use of synthetic turf. Below are brief descriptions of each task and the role of the Scientific Advisory Panel on each task.

Task 1: Expert, public and interagency consultation and input

In order to ensure the study is of the highest quality, OEHHA is getting scientific advice from experts in the state and federal government agencies, and academia. As well, OEHHA is getting input from the public on the study, including concerns important to players, parents, coaches and others. OEHHA has conducted public workshops and will share draft plans, findings, and study results with the public. In November and December 2015, OEHHA began the project with three public workshops in Northern and Southern California, and a webinar to seek input from the public and interested parties.

Additionally, OEHHA formed a Scientific Advisory Panel (the Panel), which consists of seven scientific experts in exposure and biomedical sciences. The Panel will meet during the study to advise OEHHA on study plans, and interpreting and reporting of study results. All Panel meetings are open to the public. OEHHA intends to webcast all Panel meetings, but this is contingent on webcast facility availability. At each Panel meeting, there will be an opportunity for the public to provide comments and suggestions on the study. The first panel meeting is on February 8, 2016 in Sacramento and will be webcast.

Task 2: Hazard Identification

OEHHA is conducting a scientific literature search to identify the chemicals that may be released from synthetic turf and evaluate the human health hazards from exposure to these chemicals of potential concern (COPCs).

Task 3: Exposure Scenario Development

OEHHA will develop exposure scenarios using established scientific approaches and methods to consider multiple exposure activities, environments, frequencies and pathways, and ages and sensitivities of play participants.

Task 4: Characterization of chemicals that can be released from synthetic turf and playground mats and determination of human exposure

The study will identify and quantify the chemicals that may be released from synthetic turf with crumb rubber infill and playground mats made from recycled waste tires. It will estimate the exposure of users of the fields and playground mats to these chemicals.

New synthetic turf materials and playground mats will be obtained from manufacturers. These materials will be used for analytical method development and quality assurance/quality control. Additionally, these materials will be subjected to conditions simulating weathering processes to study the effect of weathering on the chemicals released from the materials.

In-field crumb rubber and artificial grass blades will be sampled from indoor and outdoor synthetic turf athletic fields. Samples of playground mats will also be collected from indoor and outdoor facilities. These samples will be analyzed as described in the following sections.

Task 4a: Procedure development to analyze chemicals of concern in crumb rubber and artificial grass blades

OEHHA will contract with suitable analytical laboratories to develop field sample collection, weathering/heating, biofluid extraction, chemical vapor collection, targeted and non-targeted chemical analyses, and quality assurance/quality control protocols.

Task 4b: New (not installed) crumb rubber—Sample collection and identification of chemicals extracted or emitted

OEHHA plans to receive samples from major crumb rubber manufacturers in California and information related to the chemicals used in the tire and crumb rubber manufacturing processes. This information will be used to help determine the chemicals of concern. The new crumb rubber materials will be used to develop and standardize the sample treatment and chemical analysis methods that will be applied on in-field samples. Some of the material will be exposed to conditions simulating weathering to examine the effects of weathering on the chemicals released from the materials.

Contracted laboratories will conduct targeted and non-targeted analyses to determine the identity and quantity of chemicals that may be released from the synthetic turf materials.

**Task 4c: Field samples of used (in-field) synthetic turf and playground mats—
Sample collection and analyses**

OEHHA plans to collect crumb rubber, artificial grass blades, air samples, and wipe samples from indoor and outdoor synthetic turf fields. Air and wipe samples will be collected from playground mats in indoor and outdoor facilities. Fields and mats of different ages and located in different climate regions throughout California will be selected for sampling. Contracted laboratories will analyze these in-field samples using protocols developed in tasks 4a and 4b.

Task 5: Protocol development for future biomonitoring and personal monitoring

OEHHA plans to develop a biomonitoring and/or personal monitoring study protocol. Chemicals of concern that are identified in task 4 will be considered for analysis in biological specimens and other monitoring measures from users of synthetic turf fields. Any decision to conduct a biomonitoring or personal monitoring study using the protocol would take place at a later date.

Task 6: Reporting

OEHHA will prepare quarterly reports summarizing the work that has been performed to date and individual task summaries of the findings for CalRecycle. A biomonitoring and personal monitoring study plan will also be prepared.

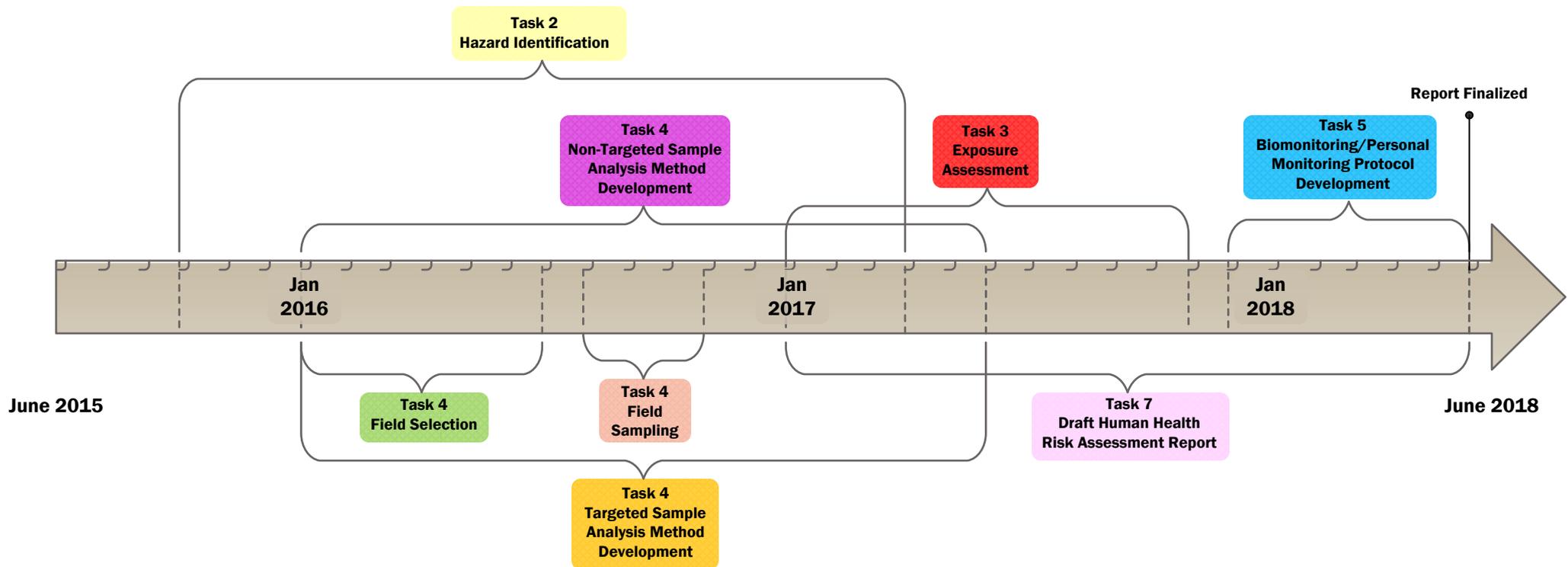
Task 7: Health Assessment from play on synthetic turf fields and playground mats

Using the results of all previous tasks, in year 3 of the study, OEHHA will conduct a health risk assessment of the potential health impacts associated with the use of synthetic turf fields and playground mats and prepare a report for CalRecycle.

Section 3
Study Timelines

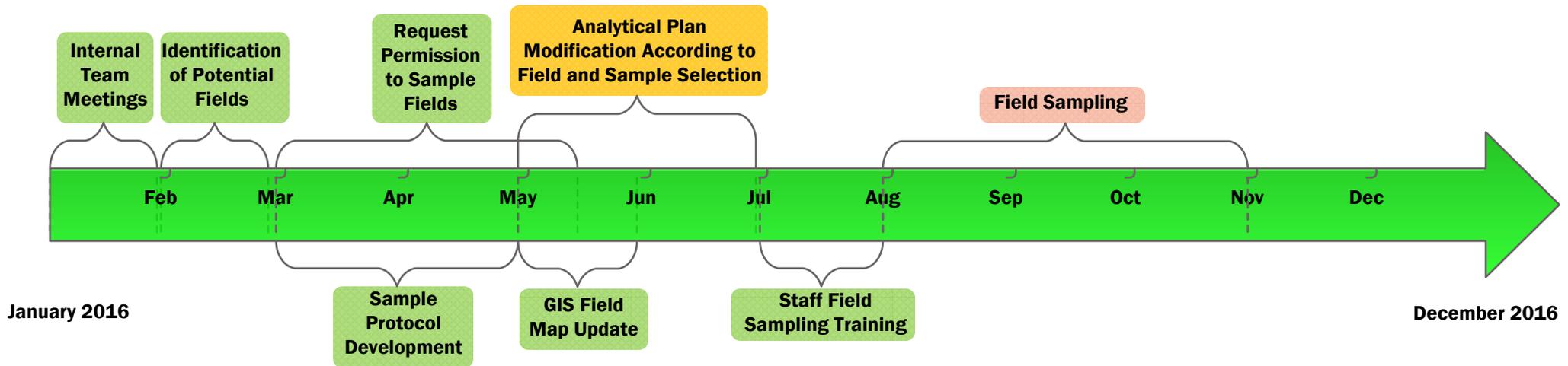


Overall OEHHA Synthetic Turf Study Plan

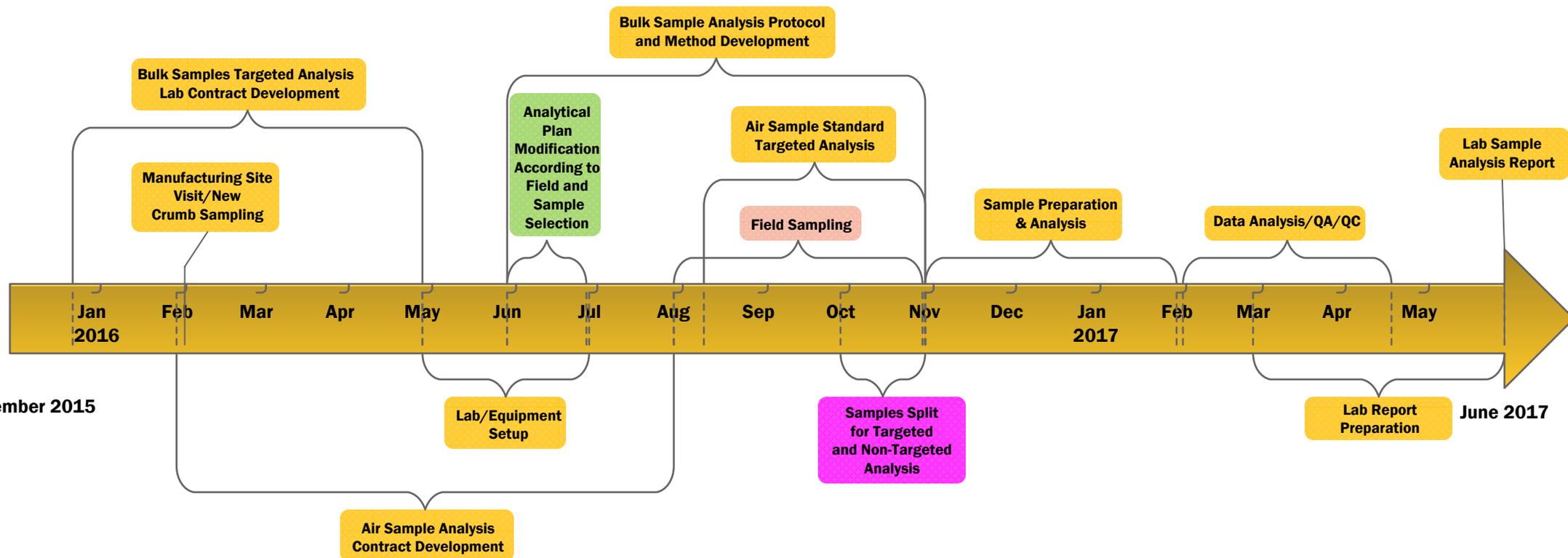




Task 4 Synthetic Turf Field Selection Plan

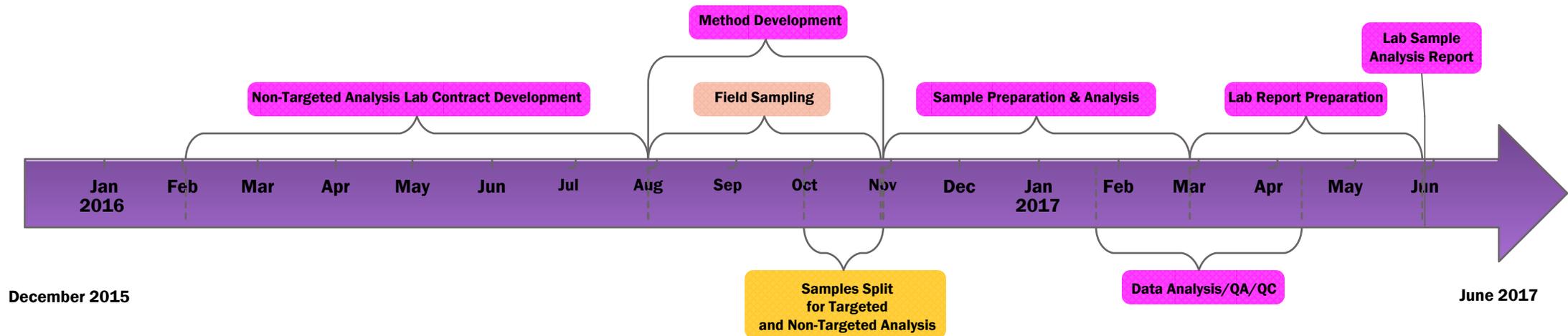


Task 4 Targeted Analysis Sample Plan





Task 4 Non-Targeted Analysis Sample Plan



Section 4

Literature Review and Data Gap Analysis



Literature Review and Data Gap Analysis

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
US EPA						
US EPA, 2009. A scoping level field monitoring study of synthetic turf fields and playgrounds	Two synthetic turf fields and one playground	1) 2-3 air samples collected at each field and upwind locations, 1m above ground in close proximity to play 2) wipe, crumb rubber blade, mat samples	1) VOCs and PM ₁₀ analyses: • US EPA Method TO-15 for VOCs • US EPA Method 6020A for metals • EPA 9200.1 for lead extraction 2) Acid digestion for total extractable metals and bioaccessibility of lead (EPA 9200.1 for lead extraction)	1) Air sample data: • VOC concentrations were generally low and similar to those measured at upwind background locations. • PM ₁₀ concentrations were similar to upwind background levels. • Metal concentrations varied between fields; some were very similar to background levels and others were above. • Tire crumb fibers not observed • Air sampling and analysis methods found to be reproducible, but metal analyses found to have variability between samples. 2) Other sample data: • Surface wipe: levels of lead similar to blanks • Blade and crumb rubber: varied levels of total lead, chromium, cadmium, zinc, and arsenic	OEHHHA-Identified Data Gaps: 1) Limited sample size for all the media 2) Lack of SVOCs, VOCs, and PAHs analysis for crumb rubber and surface wipes 3) Lack of SVOCs and PAHs analyses for air samples 4) Incomplete bioavailability measurements for metals.	1) Crumb rubber samples will be collected from multiple manufacturers and fields of various ages, in different locations and climate zones (Tasks 4b and 4c). 2) Samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, and metals (Task 4). 3) Samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, and metals (Task 4). 4) Crumb rubber samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
CALIFORNIA						
OEHHA, 2007. Evaluation of health effects of recycled waste tires in playground and track products		1) Three samples of shredded tires from three recyclers (two CA, one OH) 2) Wipe samples of three playground and sport track surfaces. Nearby cement surface wipe as background control 3) SBR tiles, EPDM tiles, SBR crumb	1) Shredded tires: <ul style="list-style-type: none"> gastric digestion simulation: EPA Method 6020 for metals EPA Method 8270C for sVOCs 2) Surface wipes: metals, sVOCs, PAHs 3) Tiles and Crumb: guinea pig skin sensitization test	1) OEHHA used the literature data to estimate the amount of chemicals that are available for ingestion uptake for children and assessed the hypothetical cancer and non-cancer risks based on a one-time ingestion for young children. <ul style="list-style-type: none"> zinc and trichloroethylene exceeded their screening level for noncancer effects cancer risk is below the <i>di minimus</i> level of one-in-a million cancer risk 2) Gastric extract analysis shows: <ul style="list-style-type: none"> low levels of metals and sVOCs calculated exposure doses were at or below screening levels for noncancer effects; cancer risk is below the <i>di minimus</i> risk level 3) Wipe test results are: <ul style="list-style-type: none"> playground surface wipes samples <ul style="list-style-type: none"> contained 5 chemicals (zinc, chrysene, fluoranthene, phenanthrene, and pyrene) at levels above background estimated exposure levels were below health screening values for noncancer effects cancer risk for chrysene is very slightly above the <i>di minimus</i> risk level sport track wipe samples <ul style="list-style-type: none"> found 5 PAHs (chrysene, fluoroanthene, phenanthrene, naphthalene, pyrene) at levels above background high school indirect ingestion via hand-to-mouth activities considered insignificant 4) Skin sensitization test shows these surfaces are not likely to cause skin sensitization in children, including children already sensitized to latex.	1) Focused on rubberized outdoor playground and tract field, not synthetic turf field 2) Lack of indoor field measurements 3) Incomplete gastrointestinal bioavailability measurement – only artificial gastric fluid stimulation was conducted 4) Limited number of fields 5) Hazard identification was based on literature data	1) Study will focus on synthetic turf materials (crumb rubber, artificial grass blades, backing material), and playground mats (Task 4). 2) Synthetic turf materials will be sampled from outdoor and indoor fields and playgrounds (Task 4c). 3) Crumb rubber samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4). 4) Crumb rubber samples will be collected from multiple manufacturers and fields of various ages, in different locations and climate zones (Tasks 4b and 4c). 5) Hazard identification evaluation will be conducted on chemicals of concern (Task 2). Exposure to user of synthetic turf field and playground will be assessed based on sample data (Tasks 3 and 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>OEHHA, 2010. Safety study of artificial turf containing crumb rubber infill made from recycled tires: measurements of chemicals and particulates in the air, bacteria in the turf, and skin abrasions caused by contact with the surface</p>	<p>1) four artificial turf fields and nearby natural turf fields for background comparison 2) three artificial turf fields and nearby natural turf fields as control 3) Five artificial turf fields and two natural turf fields as control</p>	<p>1)air sampled for VOC analysis 2)sampled air multiple times throughout summer days 3)monitored ambient and field surface temperatures 4)air sampled for PM_{2.5} and analyzed metals on the particulate matter 5)sampled for 3 hours intervals during active field use 6)infill and blade of grass from artificial turf fields and soil and grass from natural field</p>	<p>1-3) US EPA Method TO-15 for VOCs 4-5) Analyzed PM_{2.5} by weight and metal analysis by x-ray fluorescence 6) Bacteria cultured and 3 most prominent bacterial colonies quantified and identified. • MRSA quantified</p>	<p>1) Field VOC concentrations vary during the day. 2) No effect of temperature on field VOC concentrations 3) By comparing estimated exposure concentrations and screening values for non-cancer effects, likely no adverse health effects from VOC exposure for athletes using these fields 4) Outdoor fields not a significant source of airborne PM_{2.5} or heavy metals adhered to PM_{2.5} 5) Compared to natural turf, fewer bacteria detected in artificial turf with crumb rubber infill, but higher abrasion rates observed for athletes using artificial turf 6) The overall effect of artificial turf on skin infection rates could not be determined.</p>	<p>1)Limited number of fields sampled 2)Variability in VOCs detected across fields 3)SVOCs not measured 4)Field variable such as age and field temp should be monitored to determine any influence on the release of chemicals and particulate levels. 5)Better data is needed about the amount of time athletes spend on fields for different sports and age groups, sexes. 6)Chemicals identified in chamber conditions were not identified above fields possibly due to chamber conditions. 7)Exposure for coaches, referees, and maintenance workers should be included. 8)More studies are needed to address the finding that artificial turf is associated with more skin injuries than natural turf.</p>	<p>1) Crumb rubber samples will be collected from multiple manufacturers and fields of various ages, in different locations and climate zones (Tasks 4b and 4c). 2) Air samples will be collected from fields of various ages, in different locations and climate zones (Task 4c). 3) Samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, and metals (Task 4). 4) Air samples will be collected from fields of various ages, in different locations and climate zones (Tasks 4b and 4c). 5) Exposure of and risk to users of synthetic turf field and playground will be assessed based on sample data (Tasks 3 and 7). 6) Crumb rubber samples from manufacturers will be subjected to exposure chamber measurements simulating environmental conditions and degradation processes (Tasks 4a and 4b). 7) Exposure of and risk to users of synthetic turf field and playground will be assessed based on sample data (Tasks 3 and 7). 8) Not addressing in this study</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>He et al., 2011. Identification of Benzothiazole Derivatives and Polycyclic Aromatic Hydrocarbons as Aryl Hydrocarbon Receptor Agonists Present in Tire Extracts</p>		<p>1) Shredded inner tire tread</p>	<p>Total tire extraction: • DMSO: Tire pieces soaked overnight and spun at 1500RPM for 15 minutes</p> <p>Column Fractionation: • Treads extracted with toluene • Eluted with hexane and toluene in silica gel column • Fractions dried and re-suspended in hexane</p> <p>Analyses: 1) Luciferase activity (for AhR-dependent gene expression)</p>	<p>1) Total tire extract induces luciferase in rodent and human cell lines 2) Total tire extract samples induce AhR dependent gene expression by binding to and stimulating AhR transformation and DNA binding 3) Fractions containing benzothiazole, some of its derivatives, and several PAHs were found to be capable of activating the AhR and AhR signaling pathway. 4) PAHs were previously known to be AhR agonists, but benzothiazole and its derivatives have not been reported.</p>	<p>Not applicable (N/A)</p>	<p>N/A</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
NEW YORK						
<p>New York City Department of Health and Mental Hygiene (Prepared by TRC, Windsor, CT. Report Authors: Denly E, <i>et al.</i>), 2008.</p> <p>A review of the potential health and safety risks from synthetic turf fields containing crumb rubber infill</p>				<p>This study conducted a literature review that identified 11 different risk assessments on potential health effects from ingestion, dermal or inhalation exposure to crumb rubber.</p> <p>1) All 11 studies concluded that exposure to COPCs from crumb rubber may occur, but the exposure via ingestion, dermal, or inhalation is too small to increase the risk for any health effect.</p> <p>2) Risk assessments on oral and dermal exposures were based on theoretical estimates of exposure and risk. Given the overestimated parameters applied, these risk assessments may be conservative. The risk assessments addressed the potential increased susceptibility for children to chemical, but uncertainties existed in the risk assessment.</p> <p>3)The report recommends that users of fields should be educated about the buildup of heat with crumb rubber infill in order to prevent heat-related illnesses.</p>	<p>Author-Identified Data Gaps</p> <p>1) Consistent test methods for determining chemicals in crumb rubber made from different source materials and by different processing techniques are needed.</p> <p>2) Most of the data used in the risk assessments were from indoor fields. Studies on outdoor air concentrations of COPCs on newly installed and older synthetic turf fields, especially collected in hot and calm days, are needed to evaluate worst case scenario, and to better represent playing in parks.</p> <p>3) There is a lack of background air concentrations of COPCs in NYC to compare to the air sample data.</p> <p>OEHHA-Identified Data Gaps</p> <p>4) High uncertainties are present in ingestion and dermal exposure assessments due to the lack of actual measurements.</p>	<p>1) Crumb rubber samples, will be collected from multiple manufacturers and fields of various ages, in different locations and climate zones (Tasks 4b and 4c).</p> <p>2) Synthetic turf materials will be sampled from outdoor and indoor fields and playgrounds (Task 4c).</p> <p>3) Air and particulate matter will be collected on fields and at upwind location nearby the fields. Upwind samples will serve as background controls for the field data (Task 4c).</p> <p>4) Synthetic turf materials collected from manufacturers and fields, as well as particulate matter samples will be subjected to artificial biofluid extractions to simulate ingestion, inhalation and dermal exposure doses.</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>New York State Department of Environmental Conservation (Report Author: Lim L), 2008.</p> <p>A Study to Assess Potential Environmental Impacts from the Use of Crumb Rubber as Infill Material in Synthetic Turf Fields</p>				<p>The report conducted a literature review and proposed a study to examine the three major issues identified:</p> <ol style="list-style-type: none"> 1) leaching of semi-volatile organic chemicals (SVOCs) from crumb rubber under acid rain conditions 2) leaching of metals from crumb rubber under acid rain conditions 3) off-gassing of volatile organic chemicals (VOCs) under different temperature levels and heat 	<p>N/A</p>	<p>Environmental impacts will not be addressed in this study</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>New York City Department of Health and Mental Hygiene (Prepared by TRC, Windsor, CT. Report Authors: Vetrano, K and Ritter G), 2009.</p> <p>Air quality survey of synthetic turf fields containing crumb rubber infill</p>	<p>1) Two outdoor crumb rubber fields</p> <p>2) One natural grass field (for comparison)</p>	<p>1) Four air samples per field, two upwind air background samples per field, plus field, trip, and lab blanks:</p> <ul style="list-style-type: none"> stationary samplers at three feet above ground surface background and field samples collected at the same time samples collected in late morning to afternoon over four separate days field samples collected under simulated playing conditions One-hour samples for VOCs analysis and two-hour samples other chemical analyses <p>2) One crumb rubber sample per field</p>	<p>1) Air: sVOCs (17 PAHs and benzothiazole), 69 VOCs, 10 metals, PM2.5</p> <p>2) Crumb rubber: 77 organic compounds (VOCs and some sVOCs) and 8 metals for matching to air COPCs</p>	<p>1) Eight VOCs detected in the air samples:</p> <ul style="list-style-type: none"> Five VOCs present in both the synthetic turf and natural grass field at levels below the New York State Department of Environmental Conservation (NYS DEC) guidelines for the Control of Toxic Ambient Air Contaminants Three VOCs present only at the synthetic turf (two were below the guideline levels and the third, chloroform, exceeded guideline values) <p>2) No SVOCs detected in any samples</p> <p>3) Zinc and chromium detected in air samples:</p> <ul style="list-style-type: none"> Zinc concentration exceeded the NYS DEC guideline value at the grass field Chromium detected only in samples from the synthetic turf fields at levels above the NYS DEC guideline value, but was considered as a laboratory contaminant <p>4) PM_{2.5} not detected at levels above background</p> <p>5) Due to low number and levels of compounds detected in samples, it is unlikely that air constituents would cause any adverse health effects and do not warrant a risk assessment analysis for inhalation exposure</p>	<p>OEHHA-Identified Data Gaps</p> <p>1) Limited fields sampled and limited sample size per field</p> <p>2) Incomplete metal analysis in crumb rubber, air samples, and particulate matter</p> <p>3) Lack of data for ingestion and dermal exposure assessment</p> <p>4) Lack of multi-route exposure assessment</p>	<p>1) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones (Tasks 4b and 4c).</p> <p>2) Samples will be subjected to CAM 17 metal analysis including lead and mercury (Task 4).</p> <p>3) Crumb rubber samples will be subjected to five to six artificial fluid extraction for bioavailability measurements to support a multiroute exposure (including ingestion, inhalation, and dermal contact) assessment (Task 4).</p> <p>4) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>New York State Department of Environmental Conservation and New York Department of Health (Report Authors: Lim L and Walker R), 2009</p> <p>An assessment of chemical leaching, releases to air and temperature at crumb-rubber infilled synthetic turf fields</p>	<p>1) Two fields of different ages on summer days when the temperature was above 80 degrees; collected over 2-day period</p> <p>2) Four types of crumb rubber (ambient processed car, truck, and mixture, and cryogenic processed tire mixture) from tire processing facilities</p>	<p>1) Thirty-one random crumb rubber samples from 4 types of tire-derived crumb for leaching test, solvent extraction, and off-gassing tests</p> <p>2) One surface runoff sample each at two synthetic field during rainfall events</p> <p>3) Thirty-two Groundwater samples from downgradient wells</p> <p>4) Ambient air and ambient particulate matter samples, surface wipe sampling, surface microvacuum sampling, ambient particulate matter monitoring, meteorological monitoring, (9 samples each from 2 fields)</p> <p>5) Temperature survey (compared to nearby grass field)</p>	<p>1) Synthetic Precipitation Leaching Procedure test (SPLP, EPA SW-846 method 1312): acidic water (pH 4.2) extraction for 18 hours under agitation</p> <p>2) Acid digestion using conc. nitric acid (EPA SW-846 method 6010B): determine lead content in crumb rubber sample</p> <p>3) Off-gassing of VOCs and SVOCs from crumb rubber samples at 3 different temperature levels</p> <p>4) Analyses: VOCs, sVOCs, PM, metals, Tentatively identified compounds (TIC)</p>	<p>The report concluded that crumb rubber may be used as infill without significant impact on groundwater quality, when separation distance to groundwater table were addressed, and no clear cumulative impact on ambient air. The synthetic turf fields examined were not important contributors of exposure to particulate matter.</p> <p>1) SPLP test results:</p> <ul style="list-style-type: none"> zinc, aniline, and phenol have potential to leach at levels above groundwater standards. benzothiazole released but no standard for water. leachate levels attenuated and diluted as leachate migrated through soil and entered the groundwater table chemical leaching potential is dependent on the type of crumb rubber with truck tires reporting the highest leaching potential <p>2) Acid digestion test result:</p> <ul style="list-style-type: none"> lead concentration in crumb rubber samples well below federal hazard standard for soil <p>3) Surface and ground water samples testing results:</p> <ul style="list-style-type: none"> surface water samples detected some metals at low levels ground water samples found no zinc nor organics. <p>4) Ambient air, particulate, and wipe samples testing results:</p> <ul style="list-style-type: none"> air samples from two synthetic fields had low levels of many previously studied analytes that have been found in crumb rubber (common urban environmental contaminants, e.g., benzene, 1,2,4-trimethylbenzene, ethylbenzene, carbon tetrachloride) rubber dust was not identified in the respirable range <p>5) Temperature survey results:</p> <ul style="list-style-type: none"> temperatures were increased on synthetic turf fields compared to grass fields suggesting that there is potential for heat-related illness 	<p>Author-Identified Data Gaps</p> <p>1) Not analyzed for lead</p> <p>2) Did not examine effects of solar radiation, compression or degradation</p> <p>3) The strong absorption of VOCs and SVOCs to crumb rubber prevents quantitative analysis of the chemicals.</p> <p>4) Only one surface water runoff sample analyzed.</p> <p>5) Inadequate evaluation of particulate data</p> <p>OEHA-Identified Data Gaps</p> <p>6) Limited fields sampled and limited sample size per field</p> <p>7) Incomplete metals analysis</p> <p>8) Lack of multi-route exposure assessment to support the conclusion</p>	<p>1) Samples will be subjected to CAM 17 metal analysis including lead and mercury (Task 4).</p> <p>2) Crumb rubber samples from manufacturers will be subjected to exposure chamber measurements simulating environmental conditions and degradation processes (Tasks 4a and 4b).</p> <p>3) Crumb rubber samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4).</p> <p>4) Ecological risk will not be evaluated in this study.</p> <p>5) Particulate matter samples will be collected from fields of various ages, in different locations and climate zones. Samples will be subjected to artificial biofluid extraction, followed by targeted and non-targeted chemical analyses. (Task 4c).</p> <p>6) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones (Tasks 4b and 4c).</p> <p>7) Samples will be subjected to CAM 187 metal analysis, including lead and mercury (Task 4).</p> <p>8) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
CONNECTICUT						
<p>Connecticut Department of Public Health (Ginsberg et al., 2010). Human health risk assessment of artificial turf fields based upon results from five fields in Connecticut</p> <p>AND</p> <p>Ginsberg et al., 2011. Human health risk assessment of synthetic turf fields based upon investigation of five fields in Connecticut</p>	<p>Four outdoor synthetic fields (high school football or soccer fields)</p> <p>One indoor synthetic field (collegiate facility)</p> <p>One outdoor suburban grass area</p>	<p>1) three to four volunteers played for two-hour sampling period while wearing personal air sampling devices</p> <p>2) stationary monitors were located at inches and three feet above the field</p> <p>3) upwind samples taken off the synthetic fields</p> <p>4) background air sample collected at a suburban location</p>	<p>VOCs, SVOCs, rubber-related SVOCs, PM₁₀, and lead</p>	<p>1) For both indoor and outdoor fields, personal sample concentrations of VOCs were higher than both stationary and background levels.</p> <p>2) Benzothiazole and butylated hydroxytoluene (BHT) found above background levels and higher in stationary samples than personal samples. These concentrations were highest in indoor fields.</p> <p>3) Generally low concentrations of PAH were found, but they are above background.</p> <p>4) Naphthalene concentration above the indoor field was the highest among all the PAH detections in any fields.</p> <p>5) Nitrosamines and PM₁₀ were not found at concentrations above background levels.</p> <p>6) Lead concentrations found in all samples were below the CT DEP Remediation Standard Regulation.</p> <p>7) Four exposure scenarios were evaluated.</p> <p>8) Cancer risks of crumb rubber exposure were at or below <i>de minimus</i> levels, with the greatest cumulative cancer risk (1.3×10^{-6}) occurred for children playing in indoor fields.</p> <p>9) Benzene and methylene chloride contributed the most to each scenario for cancer risk</p> <p>10) Noncancer hazard indices were below one for all scenarios.</p>	<p>Author-Identified Data Gaps:</p> <p>1) Small number of field and sampling events</p> <p>2) Not sampling in hot days</p> <p>3) Did not study ingestion of rubber-related dust</p> <p>4) Did not measure latex antigen in crumb rubber or PM₁₀</p> <p>5) Limited information about the ability of benzothiazole to induce contact sensitization</p> <p>OEHHA-Identified Data Gaps:</p> <p>6) Incomplete metal analysis in air and particulate</p> <p>7) No crumb rubber, artificial grass blade, or surface wipe measurements</p>	<p>1) Crumb rubber samples will be collected from multiple manufacturers and fields of various ages, in different locations and climate zones (Tasks 4b and 4c).</p> <p>2) The proposed sampling will occur in summer 2016 when it is hot (Task 4).</p> <p>3) Crumb rubber samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4).</p> <p>4) Not addressing in this study</p> <p>5) Hazard identification evaluation will be conducted on chemicals of concern (Task 2). Exposure and risk to user of synthetic turf field and playground will be assessed based on sample data (Tasks 3 and 7)</p> <p>6) Samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, and metals (Task 4).</p> <p>7) Crumb rubber samples will be collected from multiple manufacturers and fields of various ages, in different locations and climate zones (Tasks 4b and 4c).</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>University of Connecticut Health Center (Authors: Simcox et al.), 2010. Artificial Turf Field Investigation in Connecticut Final Report</p>	<p>1) Four outdoor synthetic turf fields 2) One indoor synthetic field 3) One outdoor suburban grass area 4) Six additional fields for crumb rubber bulk sampling only (fields were different ages)</p>	<p>1) three to four volunteers played for two-hour sampling period while wearing personal air sampling devices 2) stationary monitors were located at inches and three feet above the field 3) upwind samples taken off the synthetic fields 4) background air sample collected at a suburban location 5) Five crumb rubber samples each from a total of 11 fields</p>	<p>1-4) Analysis for VOCs, SVOCs, rubber-related SVOCs, PM₁₀</p> <ul style="list-style-type: none"> • EPA Method TO-15 for VOCs, • EPA Method TO-13A for sVOCs and PAHs, • NIOSH 2550 for targeted sVOCs • NIOSH 2522 for nitrosamines <p>5) Analyses for VOCs, SVOCs, lead</p> <ul style="list-style-type: none"> • WOHL Method WG086.2 for VOCs • Modified EPA SW-84603050/ICP for lead 	<p>1) Newer field infill has more VOCs than older fields. 2) Four turf-related VOCs identified in field air samples. 3) Benzothiazole and 4-tert-(octyl)-phenol are the most commonly found SVOCs in air samples 4) Five PAHs and six SVOCs detected at concentrations higher than background levels 5) Benzothiazole and BHT detected in air samples from outdoor fields at concentrations above background. 6) Nitrosamines were not detected in air samples. 7) Field air PM₁₀ levels were at or below background. 8) The highest concentrations of VOCs and SVOCs were found in the indoor field. 9) Lead found at levels below US EPA hazard level for soil.</p>	<p>Author-Identified Data Gaps: 1) Profile from indoor field not well characterized due to confounding factors (lack of air circulation, other point sources within the facility)</p> <p>OEHHA-Identified Data Gaps: 2) No ingestion or dermal exposure measurement and assessment</p> <p>3) Small sample size</p>	<p>1) Indoor fields and playground mats will be examined in this study (Task 4c).</p> <p>2) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).</p> <p>3) Crumb rubber, wipe, air, and particulate matter samples will be collected from multiple fields of various ages, in different locations and climate zones (Tasks 4b and 4c).</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>Simcox et al., 2011</p> <p>Synthetic Turf Field Investigation in Connecticut</p>	<ol style="list-style-type: none"> Four outdoor synthetic turf fields One indoor synthetic field One outdoor suburban grass area Six additional fields for crumb rubber bulk sampling only (fields were different ages) 	<ol style="list-style-type: none"> Two study team members wore sampling canisters to collect personal air samples stationary monitors were located at inches and three feet above the field upwind samples taken off the synthetic fields background air sample collected at a suburban location crumb rubber from 11 fields 	<p>Personal air samples collected at waist height from members who played for 120 min on the field in July; stationary samples collected from 6 in and 3 ft above the turf surface.</p> <ol style="list-style-type: none"> Air samples analyzed by: <ul style="list-style-type: none"> EPA TO-15 for VOCs NIOSH Method 2550 for sVOCs TO-13A for PAHs NIOSH 2522 for nitrosamines Crumb samples analyzed by: <ul style="list-style-type: none"> WOHL method WG086.3 for VOC modified EPA SW-846-3050/ICP for lead 	<ol style="list-style-type: none"> Crumb rubber samples had lead levels below US EPA hazard level for soil. Many VOCs found in personal air samples were not detected in upwind locations or stationary air samples on the fields. VOC concentrations in personal samples collected from natural grass field and those collected from turf fields were within the same magnitude. VOC levels in stationary samples collected on turf fields were similar to the levels in upwind background samples. 21 VOCs' concentrations were higher in personal air samples collected from turf fields than those from grass fields and stationary samples on turf fields. VOC concentrations from the stationary samples were similar to the upwind backgrounds for turf fields. Outdoor fields PAH levels in air generally similar to background levels. Several PAHs were found to be higher on air sampled from indoor fields than background air levels, with naphthalene having the highest concentration of all 14 miscellaneous SVOC in air were detected at concentrations greater than background levels. BZT and BHT were the only two targeted SVOCs detected in turf air samples at levels above background. Nitrosamine levels were non-detected. PM₁₀ levels in all field samples were lower than background levels. 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> Limited indoor field and total field sampled Incomplete metal analysis in air and crumb rubber samples. No SVOCs or PAHs analysis for crumb rubber samples No ingestion or dermal contact exposure evaluation and risk assessment 	<ol style="list-style-type: none"> Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). Samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, and metals (Task 4). Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).
<p>Mattina et al., 2007.</p> <p>Examination of Crumb Rubber Produced from Recycled Tires</p>		<p>Crumb rubber samples</p>	<ol style="list-style-type: none"> Soil Phase Micro Extraction (SPME) Analyzed for VOCs and metals Leaching test 	<ol style="list-style-type: none"> Benzothiazole, butylated hydroxyanisole, n-hexadecane, and 4-(t-octyl) phenol were found volatilized from crumb rubber samples. Concentrations of benzothiazole and butylated hydroxyanisole were the highest among the four detected in the gas phase These compounds along with several elements including zinc (highest level), selenium, lead, and cadmium leached from crumb rubber materials 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> Limited sampling with no field samples Limited chemical analysis 	<ol style="list-style-type: none"> Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). Samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>Connecticut Agricultural Experiment Station (Authors: Li et al.), 2010.</p> <p>2009 Study of Crumb Rubber Derived from Recycled Tires Final Report</p>		<ul style="list-style-type: none"> • crumb rubber samples • alternative infill samples 	<ol style="list-style-type: none"> 1) SPME on both materials <ul style="list-style-type: none"> • analyses for VOCs 2) Leaching studies on effect of weathering on out-gassing and leaching of substances from crumb rubber <ul style="list-style-type: none"> • EPA Method 1312 • analysis for metals and organic compounds 3) Weathering measurement control exposure of crumb in outdoor environment <ul style="list-style-type: none"> • analyses for organic chemicals 	<p>SPME results:</p> <ol style="list-style-type: none"> 1) Eleven volatile compounds were identified in all crumb rubber samples 2) Four of the eleven were identified in the gas phase over crumb rubber material and 6 were identified as PAHs 3) Benzothiazole present in the highest amount 4) VOCs detected in alternative infill products were xylenes and styrenes and fewer in number of chemicals than those found in crumb rubber <p>Crumb rubber leaching test results:</p> <ol style="list-style-type: none"> 5) Benzothiazole and zinc were found to be the two major compounds leached from crumb rubber <p>Crumb rubber weathering measurements:</p> <ol style="list-style-type: none"> 6) Under controlled weathering of crumb rubber material, five compounds (benzothiazole, 1-methylnaphthalene, 2-methylnaphthalen, naphthalene, butylated hydroxyanisole) reached steady levels of outgassing at 20 days. 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> 1) Limited sample size and data were only from uninstalled materials. 2) Incomplete chemical analysis 3) Data were not suitable for human health and exposure analyses 	<ol style="list-style-type: none"> 1) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). 2) Uninstalled synthetic turf materials and infield samples (crumb rubber, air, and wipe etc.) will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). 3) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).
<p>Connecticut Department of Public Health, 2010.</p> <p>Factsheet. The CT DPH Risk Assessment of Artificial Turf Fields</p>	<p>Factsheet covering several Connecticut studies summarized in this table</p>			N/A	N/A	N/A

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>Li et al., 2010. Characterization of substances released from crumb rubber material used on artificial turf fields</p>	<p>Aged field samples from two fields</p>	<p>Uninstalled commercial synthetic turf infill samples from manufacturers or CT schools:</p> <ul style="list-style-type: none"> • 13 crumb rubber • three alternative rubber materials 	<p>1) SPME fibers: analysis for VOCs, PAHs</p> <p>2) Leaching test with modification of EPA method 1312:</p> <ul style="list-style-type: none"> • extraction with distilled water or acidified water • agitation in shaker for 18 hours • analysis for VOCs, SVOCs, and metals • weathering measurements <p>3) Total content measurement:</p> <ul style="list-style-type: none"> • methanol extraction • analysis for VOCs and SVOCs 	<p>SPME Results:</p> <ol style="list-style-type: none"> 1) Identified 10 rubber-manufacturing related volatile chemicals in the vapor phase of all samples 2) Benzothiazole (BT) found in all samples, with lower levels in aged field samples 3) Significant reduction in levels of more volatile compounds in samples from aged field samples 4) Different compound profiles detected between recycled tire rubber and alternative rubber product 5) The concentration of volatile organic chemicals found in vapor (SPME) was lower than total amounts in rubber (methanol extraction) <p>Leaching Test Results:</p> <ol style="list-style-type: none"> 6) BT levels decreased in leachate over time following the natural weathering exposure 7) Zinc was found to be the highest leachable metal in all samples 8) There are different profiles of leachable metals between crumb and alternative infill samples 9) Under controlled weathering of crumb rubber material, volatile chemicals (benzothiazole, 1-methylnaphthalene, 2-methylnaphthalen, naphthalene) reached steady levels of outgassing at two weeks. <p>Total Content Measurement:</p> <ol style="list-style-type: none"> 10) BT found at the highest level in methanol extracts of rubber samples 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> 1) Limited number of samples and fields 2) Data not suitable for ingestion and dermal exposure assessment 	<ol style="list-style-type: none"> 1) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). 2) Crumb rubber samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4). Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>Connecticut Academy of Science and Engineering, 2010.</p> <p>Peer Review of an Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields</p>	<p>technical review of four preceding studies</p> <ul style="list-style-type: none"> • Connecticut Agricultural Experiment Station (Authors: Li et al.), 2010. • Ginsberg et al., 2011. Human health risk assessment of synthetic turf fields based upon investigation of five fields in Connecticut • University of Connecticut Health Center (Authors: Simcox et al.), 2010. Artificial Turf Field Investigation in Connecticut Final Report • Connecticut Department of Environmental Protection, 2010. Artificial turf study: leachate and stormwater characteristics (not summarized in this table) 			<p>Results of studies reviewed by the Peer Review Committee:</p> <ol style="list-style-type: none"> 1) PAHs, VOC, and rubber related SVOCs were off-gassed from crumb rubber, primarily benzothiazole 2) Some chemicals levels are greater than background levels. Levels of chemicals were typically higher in the indoor field compared to the outdoor field 3) Levels of some chemicals are higher in personal monitoring samples compared to stationary air samples 4) Risk assessment shows cancer risks are slightly above the <i>de minimus</i> (1.3×10^{-6}) and that children have the highest risk 5) Zinc levels exceed the concentration for acute toxicity in stormwater runoff that may potentially pose a risk to surface waters and aquatic animals. <p>Peer Review Committee conclusions</p> <ol style="list-style-type: none"> 6) There is a limited (low) human health risk, but there is an environmental risk based on high zinc levels in the leachates and stormwater samples. 7) The statement that the cancer risk is above the <i>de minimis</i> level is an overstatement of the risk due to exposure overestimation, no background level subtractions, and the use of non-standard estimates for breathing rates and risk factors (use of conservative unit cancer risk values) used in the inhalation exposure assessment. 	<p>N/A</p>	<p>N/A</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>Ginsberg et al., 2011. Benzothiazole Toxicity Assessment in Support of Synthetic Turf Field Human Health Risk Assessment</p>	<p>A toxicity assessment of benzothiazole</p>			<p>Results based on assessment of data available in the literature:</p> <ol style="list-style-type: none"> 1) Animal studies show BZT to have acute effects on the CNS and respiratory systems 2) No mutagenicity reported for BZT, but 2-mercapto-benzothiazole (2MBZT) shown to be mutagenic. 2-MBZT a chemical derivative commonly used as a surrogate for BZT. 3) No published subchronic or chronic studies for BZT, but studies on liver and kidney effects of 2MBZT are available. 4) Epidemiological studies suggest 2MBZT may be associated with bladder cancer in humans. <p>Author conclusions:</p> <ol style="list-style-type: none"> 5) BZT may be harmful at high levels 		<p>Hazard identification evaluation will be conducted on chemicals of concern (Task 2). Exposure and risk to user of synthetic turf field and playground will be assessed on these chemicals (Tasks 3 and 7).</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
NEW JERSEY						
Pavilonis et al., 2014. Bio-Accessibility and risk of exposure to metals and SVOCs in artificial turf field fill materials and fibers	Seven synthetic fields	<ul style="list-style-type: none"> • nine of new crumb rubber infill; • eight new turf fiber products • seven crumb rubber infill field samples 	1) Artificial biofluids extractions <ul style="list-style-type: none"> • three types of biofluids (lung, sweat, and digestive fluids) • metals, SVOCs and PAHs analyses 2) Metal extraction with nitric acid (acid digestion for total metal contents) of crumb rubber <ul style="list-style-type: none"> • analyzed metals with ICP-MS 3) SPME on crumb rubber ("total" extraction) <ul style="list-style-type: none"> • for SVOCs and analysis with GM-MS 	1) PAHs detected at levels below the limit of detection, except low levels of naphthalene and acenaphthylene (just above limit of detection) 2) Benzothiazole was not found in any biofluids, but 2,2-benzothiazole (a dimer of BZT) was found in digestive fluid extracts. 3) 4-tert-octylphenol was found in lung fluid and sweat extracts. 4) Total extraction released more PAHs than the individual biofluid extractions. 5) Majority of metals were at concentrations below the limit of detection and were not different among all the sample types. 6) Lead was found in digestive, sweat and total extract fluid extracts of most field samples 7) Hazard quotient for each individual exposure routes were orders of magnitude lower than the reference doses of chemicals detected. The greatest non-cancer risks were for young children.	OEHHA-Identified Data Gaps: 1) Lack of air, particulate matter, and wipe samples of the fields 2) Lack of VOCs analysis 3) These data gaps resulted in incomplete inhalation and dermal exposure assessments 4) Risk was assessed based on exposure to metals 5) No cancer risk evaluation included	1) Wipe, air, and particulate matter samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Task 4c). 2) Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). 3) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7). 4) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7). 5) Cancer and non-cancer risk assessment will be conducted based on chemicals data obtained from new crumb rubber and infield samples (Task 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>Zhang et al., 2008.</p> <p>Hazardous chemicals in synthetic turf materials and their bioaccessibility in digestive fluids</p>	<p>Three fields</p>	<ul style="list-style-type: none"> • seven samples of rubber granulates (artificial turf infill) • one sample artificial polyethylene grass fiber 	<ol style="list-style-type: none"> 1) Organic solvent extraction <ul style="list-style-type: none"> • dichloromethane Extraction (16 hours and concentrated by rotary evaporation) • PAH analysis with HPLC 2) Acid digestion <ul style="list-style-type: none"> • metal content: • microwave assisted digestion with nitric acid • metal content analyzed with ICP-MS 3) Biofluid extraction <ul style="list-style-type: none"> • three artificial biofluids (saliva, gastric fluid, intestinal fluid) • analysis for PAHs and metals 	<p>Solvent extraction results:</p> <ol style="list-style-type: none"> 1) Rubber granules had higher total PAH levels than the artificial grass fiber <p>Acid digestion results:</p> <ol style="list-style-type: none"> 2) Two rubber samples had very large levels of Zn 3) Chromium and lead were detected in all rubber samples analyzed and grass fibers and grass fiber had the highest chromium level than the rubber 4) Arsenic and cadmium were detected in several samples (unspecified which sample types) <p>Biofluid extraction results:</p> <ol style="list-style-type: none"> 5) Biofluid extraction of grass fiber had no detected PAHs 6) Lead was not detected in intestinal biofluid extracts of rubber samples, but was detected in intestinal biofluid extracts of grass fiber. Lead had a high bioaccessible fraction in grass fiber than in rubber. 7) With the exception of naphthalene, low bioaccessibility was noted for PAHs. 8) Aging of the field increases bio-accessibility of PAHs in artificial gastric fluid. <p>Conclusions:</p> <ol style="list-style-type: none"> 9) Lead found in rubber samples at levels below NYS DEC soil standards. 10) Artificial grass fiber samples have a high content of chromium. 11) Lead in grass fiber is highly bioaccessible in digestive juices. 12) Rubber granules contain PAH and zinc levels above NYS DEC soil standards. 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> 1)Limited number of samples and fields 2)Lack of air sampling 3)Lack of VOCs and SVOCs analyses 4)Lack of inhalation and dermal biofluid extractions 	<ol style="list-style-type: none"> 1) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). 2) Wipe, air, and particulate matter samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Task 4c). 3) Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). 4) Samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4). Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>University of Medicine and Dentistry of New Jersey (prepared by Liou et al.), 2011</p> <p>Crumb Infill and Turf Characterization for Trace Elements and Organic Materials</p>	<p>Seven fields</p>	<ol style="list-style-type: none"> 1) 9 uninstalled turf infill products, 2) 8 new turf products, 3) 7 crumb infill samples from 7 fields of various ages 	<p>Total extraction:</p> <ul style="list-style-type: none"> • microwave digestion with nitric acid • analysis by ICP-MS for metal, <p>SPME:</p> <ul style="list-style-type: none"> • GC-MS for VOCs and sVOCs <p>Biofluid extraction:</p> <ul style="list-style-type: none"> • synthetic sweat, lung, and digestive (saliva, gastric, intestine) biofluids • analyses for trace metals, PAHs, SVOCs 	<ol style="list-style-type: none"> 1) No metal levels in infill samples were above New Jersey DEP soil standards 2) Lead, copper, and magnesium found to be higher in total extracts and digestive biofluids than lung and sweat biofluids. 3) Vanadium and chromium were higher in sweat than other fluids and total extractions. 4) PAHs levels were below detection limits in all biofluid extracts of all samples, with the exception of acenaphthylene in one lung biofluid sample and naphthalene in one total extract sample 5) A small amount of PAH present in new infills or field samples is bioavailable or readily released from the materials 6) No PAH in biofluid extracts or SPME at levels exceeding the soil standards 7) The most number of compounds were found in sweat extracts, and the least in digestive biofluid extracts. 	<p>OEHHA-Identified Data Gaps: Limited samples per field and lack of air and wipe samples</p>	<p>Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c).</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
COLORADO						
Anderson et al., 2006. A Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist	A case study presenting a model approach to address concerns regarding the safety of recycled tire crumb as a playground surface with limited exposure information			<p>Results of literature Review:</p> <ol style="list-style-type: none"> 1) The use of crumb rubber in playgrounds posed minimal hazard to children, but studies were done <i>in vitro</i>. 2) Risk assessment, genotoxicity, and ecotoxicity assays conclude that crumb rubber would not pose a risk to children or the environment. <p>Authors' Conclusion:</p> <ol style="list-style-type: none"> 3) No information needed to assess the exposure to crumb rubber products used in playgrounds was available in the literature, but risk can be communicated based on the available information in published literature, with statements acknowledging the existence of data gaps. 	<p>OEHHA-Identified Data Gaps: Lack of sufficient data to conduct an exposure assessment</p>	<p>Samples will be collected from multiple crumb rubber manufacturers and fields. These samples will be subjected to targeted and non-targeted chemicals analyses for VOCs, SVOCs, PAHs, and metals. An exposure assessment and human health risk assessment will be developed based on the field data (Tasks 2, 3, 4, 7).</p>
CANADA						
Birkholz et al., 2003. Toxicological Evaluation for the Hazard Assessment of Tire Crumb for Use in Public Playground		tire crumb samples (unspecified origins)	<p>Total extraction</p> <ul style="list-style-type: none"> • with dichloromethane and solvent-exchanged to DMSO • genotoxicity assay, <p>Leachate of tire into water</p> <ul style="list-style-type: none"> • lethality assay • a battery of aquatic test representing the major trophic levels 	<ol style="list-style-type: none"> 1) No genotoxicity found for tire crumb extracts; 2) Leachate samples show positive toxicity towards bacteria, invertebrates, fish and algae, but toxicity reduced after leachate treated with sewage seed, nutrients, and aeration. 3) Results suggest that there is little health risk to children from tire crumb in playgrounds and any ecotoxicity observed decreases as tire crumb ages. 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> 1) Only genotoxicity potentials of leachates were evaluated 2) Lack of data for evaluating human health. 	<ol style="list-style-type: none"> 1) Hazard identification evaluation will be conducted on chemicals of concern (Task 2). Exposure and risk to user of synthetic turf field and playground will be assessed on these chemicals (Tasks 3 and 7). 2) Samples will be collected from multiple crumb rubber manufacturers and fields. These samples will be subjected to targeted and non-targeted chemicals analyses for VOCs, SVOCs, PAHs, and metals. An exposure assessment and human health risk assessment will be developed based on the field data (Tasks 2, 3, 4, 7).
Beausoleil et al., 2009. Chemicals in Outdoor Artificial Turf: A Health Risk for Users?	A risk assessment review			<p>Review of toxicological risk assessments in literature indicated low exposure to chemicals from artificial turf and that the risk to any players on the field is not a concern.</p>	N/A	N/A

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
DENMARK						
Danish Technological Institute (Nilsson et al.), 2005. Emission and evaluation of health effects of PAHs and aromatic amines from tyres		1) 20 tires 2) 2 falling protection tiles base (i.e. rubber playground mats) from granulated rubber	<p>Solvent extraction</p> <ul style="list-style-type: none"> samples extracted with dichloromethane for 1 hour in ultrasonic bath, then extraction with 50/50 dichloromethane/acetone extract concentrated with cyclohexane then extraction with 90/10 dimethylformamide/water analysis in GC-MS for PAHs <p>Thin layer chromatography (TLC) measurement</p> <ul style="list-style-type: none"> extraction with dichloromethane TLC identification for aromatic amines <p>Sweat extraction:</p> <ul style="list-style-type: none"> sample exposure to artificial sweat for 1 hour <p>Environmental treatment</p> <ul style="list-style-type: none"> exposed to un and elevated temperature 	<ol style="list-style-type: none"> Many PAHs were identified in rubber granulates, predominantly PAHs of low molecular weight. Aromatic amines present in higher concentrations than PAHs in the samples A higher migration of amines (water soluble) than PAHs into the sweat Sun and temperature increase the migration of PAHs and amines to sweat A health assessment based on these selected PAHs and amines (shown to migrate to sweat) shows no significant health risk on exposure to chemicals released from recycled tires on playgrounds 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> Limited sample and no field investigation Limited chemical analysis Limited exposure evaluation, only dermal exposure was assessed 	<ol style="list-style-type: none"> Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). Samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4). Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).
FRANCE						

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
Savary et al., 2011. Used Tire Recycling to Produce Granulates: Evaluation of Occupational Exposure to Chemical Agents	Occupational exposure measurement in four tire rubber granulate processing facilities	workers were fitted with pumps and sampling heads in breathing zones; static samples taken in workshops <ul style="list-style-type: none"> dust samples suspended in water, deposited on filter and examined using electron microscopy VOCs trapped with sorbent tube and identified using gas chromatography 	Dust: electron microscopy for morphology Air: analysis for VOCs	<ol style="list-style-type: none"> Particle size distribution; separated the particle into three categories: 100-150 µm, 10-15 µm, and less than 10 µm Microscopic analysis showed dust samples from shredders (used to produce rubber granulates) contain sulfur, carbon black, silicon and iron oxide at their surface Dust levels are higher than those of the ambient background air No VOCs were detected Results indicate the need for enhanced ventilation systems in these facilities 	OEHHA-Identified Data Gaps: <ol style="list-style-type: none"> Limited chemical analysis No sample data and evaluation on other exposure pathway like dermal and indirect ingestion via hand-to-mouth 	<ol style="list-style-type: none"> Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). Samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4). Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).
ITALY						
Ruffino et al., 2013. Environmental-sanitary risk analysis procedure applied to artificial turf sports fields	<ol style="list-style-type: none"> four artificial turf fields (SBR infill) of different ages one artificial turf field (TPE infill) one natural grass turf field 	<ol style="list-style-type: none"> 1200 g sample of each artificial field 1 kg soil from natural turf field gas and dust samples were collected immediately above the ground for both synthetic turf and natural grass field, and a point located in the city center <p>City center samples were collected to evaluate the influence of vehicle-emitted contaminants on the composition of gases and dust from turf fields</p>	<ol style="list-style-type: none"> Organic analysis: <ul style="list-style-type: none"> microwave-assisted extraction with dichloromethane analyzed by GC-MS for benzene, toluene, xylenes, and PAHs Metal analysis: <ul style="list-style-type: none"> microwave-assisted extraction with nitric acid, perchloric acid (sulfuric and phosphoric acid for natural soil) analyzed with ICP-OES Tyler standard sieve <ul style="list-style-type: none"> particle size distribution 	<ol style="list-style-type: none"> Rubber granulates ranged in size from 1-3 mm; soil ranged from 0.01-10 mm. Turfs made of rubber tires (SBR) have a higher PAH and xylene contents than turf made from thermoplastic elastomer (TPE). Natural soil had higher concentrations of xylene and benzene and lower PAH levels than granulates. Benzo[a]anthracene was found in all SBR samples Zinc found in higher levels than other metals in SBR infill samples. Lower levels of PAHs, benzene, toluenes, and xylenes found in water leachate obtained from older fields; Risk assessment shows the cumulative cancer risk is lower than the <i>de minimus</i> (1×10^{-6}) and the cumulative non-cancer hazard was lower than 1 	OEHHA-Identified Data Gaps: <ol style="list-style-type: none"> Limited types of sample Limited chemical analysis Lack of ingestion exposure evaluation 	<ol style="list-style-type: none"> Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>Bocca et al., 2009.</p> <p>Metals contained and leached from rubber granulates used in synthetic turf areas</p>	<p>32 playgrounds</p>	<p>250 gram samples were taken from 12 sections of each playground and 50 gram of each section sample was pooled to obtain 1 representative sample per playground</p>	<p>Microwave acid digestion:</p> <ul style="list-style-type: none"> • sample, nitric acid, hydrofluoric acid and perchloric acid digested in microwave oven for 20 min • analyzed with HR-ICP-MS and ICP-OES for metals <p>Acetic acid extraction:</p> <ul style="list-style-type: none"> • extraction with acetic acid with shaking for 24 hours • analyzed with HR-ICP-MS and ICP-OES for metals <p>Water extraction:</p> <ul style="list-style-type: none"> • two cycles of extraction with deionized water with shaking for 24 hours • analyzed with HR-ICP-MS and ICP-OES for metals 	<ol style="list-style-type: none"> 1) Granulates contained all the metals that were investigated in a wide range of varying concentrations 2) Zinc was consistently found to be present at the highest concentrations 3) Other metals present in high levels were aluminum, iron, and magnesium 4) All metals except cobalt, tin, and zinc were found at levels below the maximum allowable levels for soil. 5) Zinc and magnesium found to leach into water at the greatest levels, with zinc levels exceeding the standard in 14 samples 6) Leachability of cadmium, chromium, lead, and zinc were lower in water than in acid. 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> 1) Limited field investigation 2) Limited chemical analysis 3) Lack of suitable data for human health risk assessment 	<ol style="list-style-type: none"> 1) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). 2) Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). 3) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
Menichini et al., 2011. Artificial-turf playing fields: Contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment	13 playing fields	<ol style="list-style-type: none"> 1) Rubber granulate collection same as Bocca et al., 2009 2) air samples of ambient air were taken for about 2-3 hours (the daily duration of a training session) for 3 days 3) samples were taken outside the field to get background estimates 	<ol style="list-style-type: none"> 1) Metal analysis: <ul style="list-style-type: none"> • microwave digestion, same as Bocca et al., 2009 for 25 metals 2) PAH analysis: <ul style="list-style-type: none"> • extraction with dichloromethane then n-hexane • analyzed by HRGC-LRMS for nine PAHs 3) PCBs, PCDDs, PCDFs analysis: <ul style="list-style-type: none"> • same extraction as PAHs with additional elutions with n-hexane and dichloromethane • analyzed by HRGC-LRMS and HRGC-HRMS 	<ol style="list-style-type: none"> 1) In granulates, zinc is the only metal that was detected at levels above the Italian soil 'green area' threshold values and the NY State cleanup objective for soils, which require no use restrictions 2) There was large variability in PAHs but benzo[a]pyrene was the only PAH of major health concern that was detected at levels above the Italian standards 3) The sum of PCBs levels exceeded the Italian soil standards, while levels of PCDD and PCDF were below standards. 4) Air samples from an urban field had PAH levels similar to background levels, while samples from a field in an area of traffic had PAH levels slightly higher than background levels. 5) Risk assessment based on the benzo[a]pyrene concentration found at the high traffic field calculated an excess lifetime cancer risk of 1×10^{-6} (one in a million) for athletes with 30-year activity. 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> 1) Limited sample types 2) Limited chemical analysis 3) Exposure through multiple pathways was not evaluated 4) Risk assessment focused on only benzo[a]pyrene 	<ol style="list-style-type: none"> 1) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). 2) Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). 3) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7). 4) Hazard identification evaluation will be conducted on chemicals of concern (Task 2). Exposure and risk to user of synthetic turf field and playground will be assessed on these chemicals (Tasks 3 and 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
KOREA						
Lee et al., 2012. Work Environment and Exposure to Hazardous Substances in Korean Tire Manufacturing	Occupational exposure measurements at two different plants of a tire manufacturing company	<ul style="list-style-type: none"> Personal air sampling in breathing zone analyzed in GC-MS bulk rubber solvent analyzed for composition in GC-MS total particulates measured every 6 months with microbalance 	Air sample analyses: PAHs, styrene, 1,3-butadiene, sulfur dioxide, carbon disulfide, hydrocarbons, rubber fume, PM Solvent analysis:	<ol style="list-style-type: none"> Nine PAHs detected in breathing zone air at levels below the limits of quantitation. PAHs detected in personal air samples varied with different work processes at the facility. Air sampled from locations for curing process had the most PAHs. Levels of particulate matter corresponded with levels of rubber fume in the plants. Rubber fume levels in three air samples had concentrations above the UK maximum exposure limit. Results reveal a need to improve ventilation system in tire manufacturing plants, especially at the curing process areas. 	<p>OEHHA-Identified Data Gaps:</p> <p>Lack of evaluations on other exposure pathways</p>	Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
<p>Kim et al., 2012. Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability</p>		<p>test pieces of recycled ethylene propylene diene monomer (EPDM), an artificial turf filling, of sizes below 250 µm and above 250 µm (unspecified origins)</p>	<p>1) Total content analysis: <ul style="list-style-type: none"> decomposition with nitric acid and peroxide in microwave digestion system followed by decomposition on hot plate 2) Acid extraction: <ul style="list-style-type: none"> hydrochloric aqueous solution shook for one min and extracted for one hour 3) Artificial digestive extraction: <ul style="list-style-type: none"> used to assess bioavailability extraction for one hour in artificial gastric juice, pH adjustment, extraction for another one hour two-hour extraction in artificial duodenal juice and bile Decomposition via hot plate and extraction 4) Analysis: lead</p>	<p>1) Total content extraction leached out more lead than the acid and artificial digestion extractions. 2) A higher bioavailability for particles less than 250 µm using acid digestion than in digestion extraction. 3) Lead bioavailability for rubber particles below 250 µm for acid extraction was twice as high as for particles above 250 µm. 4) The hazard index from lead exposure was greatest in lower elementary grades children and lowest in high school children. Hazard index values were between 0.01 and 0.1 for the average scenarios. 5) For larger rubber particles, there is a 2x difference in the hazard index between the lead exposure levels estimated by digestion extraction and acid digestion methods. 6) For the worst exposure scenarios, hazard indices exceeded 1 for elementary school children.</p>	<p>OEHHA-Identified Data Gaps: 1) Lack of field investigation and limited sample type examined 2) Limited chemical analysis 3) Limited exposure assessment, only evaluated for ingestion exposure</p>	<p>1) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones. Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). 2) Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). 3) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).</p>

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
NORWAY						
Norwegian Institute of Public Health and the Radium Hospital, 2006. Artificial turf pitches--an assessment of the health risks for football players	Four indoor sports halls	Air samples previously collected for the facilities	<ol style="list-style-type: none"> Analyses: VOCs, particles, phthalates, alkyl phenols, benzene, PCBs Exposures occur through inhalation, skin contact, and swallowing; characterization based on adult, juniors, and children Exposure duration and frequency based on the information from managers of the sports halls selected; information was used to select the worst case scenarios 	<ol style="list-style-type: none"> No increased health risk associated with airborne dust, PAHs, PCBs, phthalates, and alkyl phenols For VOCs, no health risk associated with acute exposure, however there isn't much toxicity data available for the detected VOCs and it was not possible to perform any health assessment No health risk associated with oral exposure to phthalates and alkyl phenols, based on theoretical exposure levels. No health risk associated with dermal exposure to PCBs, PAHs, phthalates, and alkyl phenols, based on theoretical exposure levels. The low levels of allergens present in the rubber would not likely lead to development of a contact allergy. No increased cancer risks caused by exposure to benzene or PAHs in the halls 	OEHHA-Identified Data Gaps: <ol style="list-style-type: none"> Limited field investigation and sample data Limited chemical analysis Lack of adequate data to support the multi-route exposure assessment 	<ol style="list-style-type: none"> Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).
Dye et al., 2006. Measurement of air pollution in indoor artificial turf fields	three indoor artificial turf fields <ul style="list-style-type: none"> one new one a year old one made from TPE 	Airborne dust collection	VOCs and PAHs	<ol style="list-style-type: none"> Quantities of airborne dust found at levels that would be expected for indoor environments and close to recommended norm. Airborne dusts contained large quantities of rubber from turf granulates. There are large portions of unidentified organic materials. Total VOC levels were higher than normal or anticipated levels in indoor air. They are expected to be elevated over time even with proper ventilation. Total VOC levels detected from field with TPE were lower than those with crumb rubber infill. 	OEHHA-Identified Data Gaps: <ol style="list-style-type: none"> Lack of background control data, e.g., from outside of stadiums Some unknown peaks were not identified but only reported as peaks Many identified chemicals have no health screening levels, so health risk from exposure to these chemicals cannot be estimated. Need air particulate data from outdoor fields. Did not measure metal content of PM 	<ol style="list-style-type: none"> Air samples will be collected nearby upwind locations to provide background information (Task 4c). Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). Hazard identification evaluation will be conducted on chemicals of concern (Task 2). Exposure and risk to user of synthetic turf field and playground will be assessed on these chemicals (Tasks 3 and 7). Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
PORTUGAL						
Gomes et al., 2010 Toxicological Assessment of Coated versus Uncoated Rubber Granulates Obtained from Used Tires for Use in Sport Facilities		2 rubber granulate coatings: <ul style="list-style-type: none"> PVC coated rubber granulates, cross-linked alquidic polymer coated rubber granulates uncoated raw rubber granulates 	<ol style="list-style-type: none"> Granulates: <ul style="list-style-type: none"> Extraction with acetone followed by petroleum ether Extract passed through silica gel column Analyzed in GC-MS Leachates: <ul style="list-style-type: none"> Extracted with dichloromethane Concentrated in silica gel column followed by cyclohexane Analyzed in GC-MS Analyses: PAHs, heavy metals 	<ol style="list-style-type: none"> Rubber granulates produced through cryogenic processes release fewer particulates into the air than mechanically produced granulate. Coated granulates had a higher content of PAHs than raw granulates, but leached less PAHs into water than raw granulates. Levels of heavy metals leached were small, except one of the two coatings tested had a leaching level of tin above the regulated limit Coating of rubber granulates result in lower ecotoxicity compared to raw rubber granulates. 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> Lack of field investigation and limited sample size Limited chemical analysis 	<ol style="list-style-type: none"> Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4).
SPAIN						
Llompert et al., 2013. Hazardous organic chemicals in rubber recycled tire playgrounds and pavers	Nine urban playgrounds	<ol style="list-style-type: none"> 17 samples of floor tile compositions and carpet covers from nine playgrounds seven commercial samples (two puzzle pavers, five recycled rubber tire tiles of different colors) 	<ol style="list-style-type: none"> Ultrasound-assisted extraction with ethyl acetate for 15 min followed by GC-MS Pressurized solvent extraction with ethyl acetate for 15 min followed by GC-MS SPME of 500mg samples followed by GC-MS Organic Analyses: 16 PAHs, vulcanization additives (e.g., benzothiazole), antioxidants, plasticizers 	<ol style="list-style-type: none"> Large numbers of VOCs and sVOCs were found in playground samples PAHs found in the vapor phase of all samples. Commercial samples had higher levels than playground samples. Pyrene, naphthalene, phenanthrene, fluoranthene, and chrysene were the most abundant PAHs detected in playground samples. Benzo[a]pyrene was found in five playground samples at low levels. Phenanthrene and fluoranthene were the most abundant PAHs in commercial samples. Also, benzo[a]pyrene was present in high concentrations in these samples. Benzothiazole (BTZ) was found in all playground samples and two commercial samples at low levels, while the other commercial samples had high levels of BTZ. 2-Mercaptobenzothiazole was found in playground samples but not in commercial samples. 4-Tert-butlyphenol was found in half of playground samples at low levels, but high levels in all commercial samples. BHT was found in all samples. Phthalates were found in all samples and were higher in commercial samples. SPME studies found that PAHs and vulcanization additives detected in samples are volatile and potential for inhalation exposure. 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> Limited sample and field types Limited chemical analysis, no metal analysis Bioavailability of chemicals in recycled tire rubber was not assessed. 	<ol style="list-style-type: none"> Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4). Samples will be subjected to five to six artificial fluid extraction for bioavailability measurements (Task 4). Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7).

Report/Study	Field	Samples	Sample Preparation and Analysis	Results	Data Gaps	Task to Address Data Gaps
SWEDEN						
KemI (Swedish Chemicals Inspectorate), 2006. Synthetic turf from a chemical perspective--a status report				<p>Results from the literature reviewed:</p> <ol style="list-style-type: none"> 1) Levels of PAHs and zinc shown to be above the Norwegian Pollution Control Authority (SFT) guidelines in run-off water. 2) Zinc shown to be predominant in the leachate from synthetic grass fibers and may pose a risk to aquatic organisms. 3) Particulate levels in dust at synthetic fields were found below national guidelines, but contained significant amounts of granulate. 4) Health assessment shows no increased risks from synthetic turf with crumb rubber infill <p>Authors' conclusion:</p> <ol style="list-style-type: none"> 5) although recycled tires contain substances that could be hazardous, concentrations of those substances when emitted are low and pose a low risk to aquatic environments, and probably do not pose harm to players on synthetic turf fields. 	<p>Author-Identified Data Gaps:</p> <ol style="list-style-type: none"> 1) Need more knowledge of the hazardous chemical release from the rubber 2) Need more information on human exposure 3) Water quality should be studied more 	<ol style="list-style-type: none"> 1) Hazard identification evaluation will be conducted on chemicals of concern (Task 2). Exposure and risk to user of synthetic turf field and playground will be assessed on these chemicals (Tasks 3 and 7). 2) Multiple exposure pathways (e.g., inhalation, incidental ingestion, indirect ingestion via hand-to-mouth activities, dermal contact) will be examined. Risk from exposures via these pathways will be assessed (Tasks 3, 4, and 7). 3) Water quality will not be addressed in this study.
TAIWAN						
Chang et al., 1999. Emission characteristics of VOCs from athletic tracks	Athletic tracks of various age: <ul style="list-style-type: none"> • 5 polyurethane type I • 9 polyurethane type II • 5 synthetic rubber tracks 	<ol style="list-style-type: none"> 1) one gas sample per field collected by dynamic flux chamber method for VOC emission 2) For three newest fields: <ul style="list-style-type: none"> • three air samples taken at 1.5m above track in middle of lanes, • three samples taken at 1.5 m above ground sites at least 50m from track or any possible VOC source for VOC concentration at breathing height (background) 	23 VOCs, SVOCs	<ol style="list-style-type: none"> 1) 23 VOCs identified in a preliminary study 2) 19 VOCS quantified. Others were at levels below limit of quantitation. Hexanal was the most abundant compound emitted from tracks 3) Lower levels of VOCs were emitted from older synthetic tracks. 4) Tracks made of polyurethane type II and synthetic rubber have greater gas permeability and levels of VOC emitted decreased quickly with time. 5) VOC concentration at breathing height on the tracks were at similar levels to background 	<p>OEHHA-Identified Data Gaps:</p> <ol style="list-style-type: none"> 1) Limited field (track only) and sample (air only) types 2) Limited chemical analysis 	<ol style="list-style-type: none"> 1) Crumb rubber, wipe, and air samples will be collected from multiple fields of various ages, in different locations and climate zones Indoor fields and playground mats will be examined in this study (Tasks 4b and 4c). 2) Field samples will be subjected to targeted and non-targeted chemical analyses, including VOCs, SVOCs, PAHs, and metals (Task 4).

Section 5

Charge Questions to the Panel



Charge Questions to the Panel

Chemicals of Potential Concern

OEHHA conducted a literature search on studies of synthetic turf, crumb rubber, or tires. **Appendix C1** contains a list of chemicals that have been identified in the studies. **Appendix C2** contains a list of commercially available biocides marketed for use on synthetic turf. **Appendix D** contains a Material Safety Data Sheet (MSDS) and the specifications for two turf products.

1. What are the chemicals of potential concern for the purposes of this study?
2. Should biocides be included as the chemicals of potential concern? Which specific biocides should be considered?

Sample Preparation Methods

OEHHA proposes to apply artificial biofluid extraction to simulate the physiological conditions and processes associate with crumb rubber exposures (i.e. ingestion, inhalation, and dermal contact).

Pavilonis *et al.* (2014) studied the bioaccessibility of metals and semi-volatile organics in artificial turf field materials (**Appendix E1**: “*Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers*”). Table 1 in the article shows examples of artificial biofluid composition used to simulate oral (saliva, gastric, and intestinal fluid), inhalation (lung fluid), and dermal (sweat) exposures.

1. What chemical extractions should be employed in the study to mimic human exposures?
2. What are the compositions of biofluids suitable for the extraction? Some examples are provided in Appendix E2.
3. What should the extraction conditions be (e.g., method of shaking, length and temperature of extraction)?
4. What are the physiological conditions of athletes being exposed (e.g., athletes who have recently eaten versus those who have not, heat stress) that the extraction phase of the study should consider?

Targeted and Non-Targeted Chemical Analyses

1. OEHHA proposes to conduct targeted chemical analyses that identify and quantify volatile organic compounds (VOCs), semi-volatile organic compounds (sVOCs) including polycyclic aromatic hydrocarbons (PAHs), CAM 17 metals (the 17 metals specified in the California Administrative Manual for hazardous waste qualification), and biocides. Standard analytical procedures have been established by US EPA for these chemical groups. These procedures are included in Appendix H. Are there other classes of chemicals that should be covered in the targeted chemical analyses?
2. Should we use summa canister or absorption cartridge to collect chemical vapor (e.g., VOCs) in air?
3. What is the best methodology for measuring particles in the air in the fields?
4. We would like to conduct some (limited) non-targeted analyses. What suggestions do you have regarding how to best conduct non-targeted analyses? What kinds of the methodology are the best?

Field Sampling

Appendix F shows a simple diagram of a soccer field and an example of sampling locations. **Appendix G** illustrates an example of climate zone areas and locations of synthetic turf fields in California.

1. We plan to select fields in various climate zones, and across the state to help understand variability in exposures. What are the most important criteria (e.g., climate zone, Northern versus Southern California, coastal versus high elevation, or population density) in selecting fields to sample?
2. What is the best way to ensure samples collected are representative of the entire field and the dataset collected from the fields sampled is representative of California?
3. Given that we have time and resource limitations, would it be better to take fewer samples at more fields or more samples at fewer fields?
4. **Appendix F** is an example of soccer field sampling locations. We would like to take samples from places in fields that are highly impacted by play instead of less impacted parts of the field. What locations (e.g., in the middle of a field, a few feet in front of the goal) on a turf field should we sample? Should samples be individual or composite? If composite, what is the most appropriate way to composite the collected samples?

Section 5. Charge Questions to the Panel

5. What are the media that should be sampled (e.g., crumb rubber, artificial grass blades, air surface wipes of balls, and turf)? In collecting air samples, we plan to collect both VOCs and particulate matter. What size fraction of particulate matter is most appropriate (e.g., PM_{2.5}, ultrafines (if possible), total suspended particulate)?
6. What would be proper controls and blanks for the crumb rubber and artificial grass samples?

Section 6a
Workshop Posters



SYNTHETIC TURF STUDY: OVERVIEW OF THE STUDY ELEMENTS

Synthetic Turf

Synthetic or Artificial Turf is increasingly used in athletic fields.

Synthetic turf is composed of two parts:

- **Crumb rubber infill**
 - ◊ is made of chopped-up waste tires
 - ◊ supports synthetic grass blades
 - ◊ cushions falls
- **Synthetic grass blades**
 - ◊ soften the play surface
 - ◊ look like natural grass

Tire rubber is a complex material made of natural rubber and synthetic materials.

The types and levels of chemicals released from tire rubber depend on the source of material, weather, age of field, and other factors.

Study Purpose and Scope

What: OEHHA will conduct a health study on synthetic turf

Why: To further our understanding of:

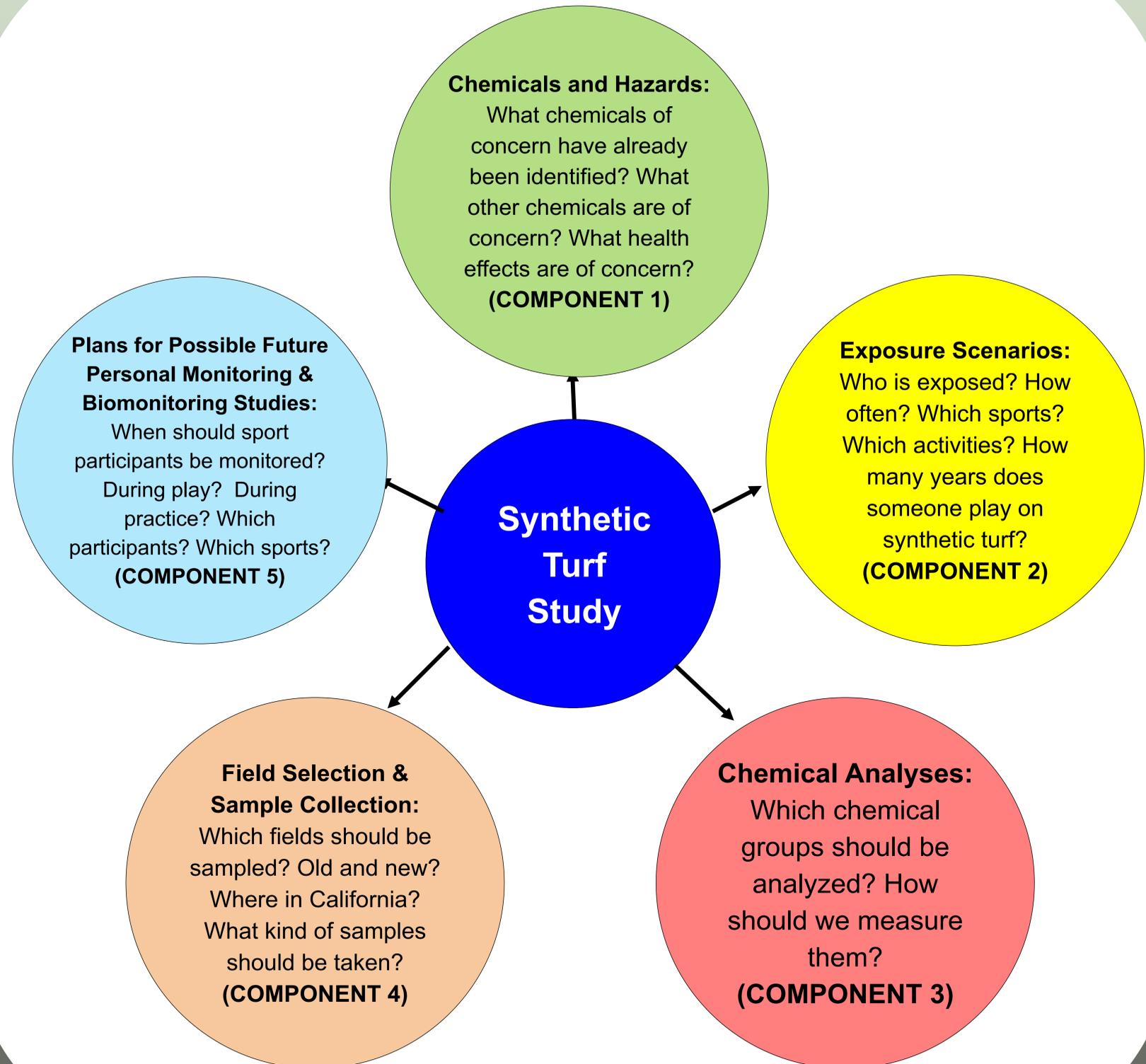
- chemicals that can be released from synthetic turf
- human exposures to these chemicals
- potential adverse health effects of these chemicals

When: 2015-2018

Contact Information

California Environmental Protection Agency
Office of Environmental Health Hazard Assessment
Email: SyntheticTurf@oehha.ca.gov
[http:// www.oehha.ca.gov](http://www.oehha.ca.gov)

Study Approach



CHEMICALS AND HAZARDS:



WHAT CHEMICALS OF CONCERN HAVE ALREADY BEEN IDENTIFIED?

WHAT OTHER CHEMICALS ARE OF CONCERN? WHAT HEALTH EFFECTS ARE OF CONCERN?

Adverse Health Effects

- Effects can be caused by short-term or long-term exposure to chemicals
- Different chemicals or chemical classes may cause different types of adverse health effects
- Some chemicals can cause more than one type of adverse health effect
- Age, sex, race, and family background, etc., can change a person's response to chemicals

Questions

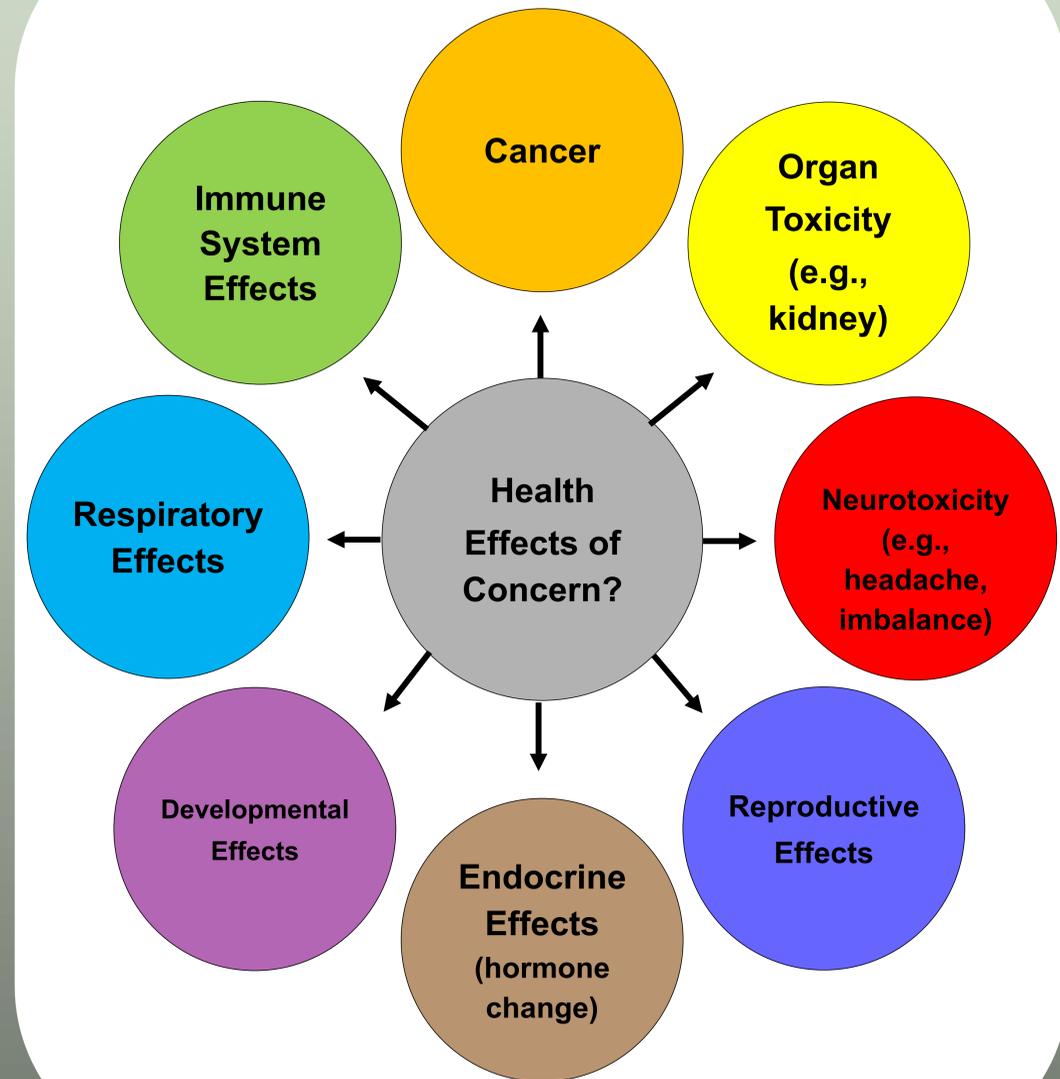
- What health effects are you concerned about?
- Do you notice any health issues that you think might be associated with playing on synthetic turf or playground mats?
- Do you know of any studies we have missed?

Potential Health Effects from Exposure

Chemical	Known Effects	Detected in Turf/Mat Samples	Study
Benzene	Cancer: leukemia; neurotoxicity	Air, surface wipe, crumb rubber and artificial grass blade samples from indoor and outdoor synthetic turf fields and playground mats; athletic tracks; shredded tires	US EPA 2009, Simcox 2010, Simcox et al 2011, Ginsberg et al. 2011, Ginsberg et al. 2010, NIPHRH 2006, Chang et al. 1999, Lim 2008, OEHHA 2010, OEHHA 2007
Toluene	Developmental effect & neurotoxicity	Air, surface wipe, crumb rubber and artificial grass blade samples from indoor and outdoor synthetic turf fields and playground mats; shredded tires; athletic tracks	US EPA 2009, Simcox 2010, Simcox et al 2011, Ginsberg et al. 2011, Ginsberg et al. 2010, NIPHRH 2006, Chang et al. 1999, Lim 2008, OEHHA 2010, OEHHA 2007
Mercury	Developmental effect & neurotoxicity	Rubber granulate; artificial turf fields and crumb rubber; air samples above synthetic turf fields	Keml 2006, Menichini et al. 2011, Bocca et al. 2009, Lim 2008, Lim 2009, OEHHA 2007
Manganese	Reproductive & respiratory effect, neurotoxicity	Air, surface wipe, crumb rubber and artificial grass blade samples from synthetic turf fields and playground mats	US EPA 2009, Menichini et al. 2011, Ruffino et al. 2013, Bocca et al. 2009, Lim 2009
Hexane	Neurotoxicity & respiratory effects	Air, surface wipe, crumb rubber and artificial grass blade samples from indoor and outdoor synthetic turf fields and playground mats; athletic tracks	US EPA 2009, Simcox 2010, Simcox et al 2011, Ginsberg et al. 2011, Ginsberg et al. 2010, Chang et al. 1999, OEHHA 2010
Zinc	Skin, eyes, nose, & throat irritations	Air, surface wipe, crumb rubber and artificial grass blade samples from synthetic turf fields and playground mats; crumb rubber leachate; shredded tires	Zhang et al. 2008, US EPA 2009, Mattina et al. 2007, Keml 2006, Menichini et al. 2011, Ruffino et al. 2013, Bocca et al. 2009, Lim 2008, Lim 2009, OEHHA 2007

Select chemicals and their known health effects

Potential Health Effects of Concern



Contact Information

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 Email: SyntheticTurf@oehha.ca.gov
<http://www.oehha.ca.gov>



EXPOSURE SCENARIOS:

WHO IS EXPOSED? HOW OFTEN? WHICH SPORTS? WHICH ACTIVITIES? HOW MANY YEARS DOES SOMEONE PLAY ON SYNTHETIC TURF?

Data Collection and Exposure Modeling

- Input from the public - parents, coaches, etc.
- Advice from scientific experts
- Review of literature

Possible Sensitive and Highly Exposed Groups

- Young children
- Youth sport participants

Regional Climate and Activity Patterns

Regional climates influence activity patterns.

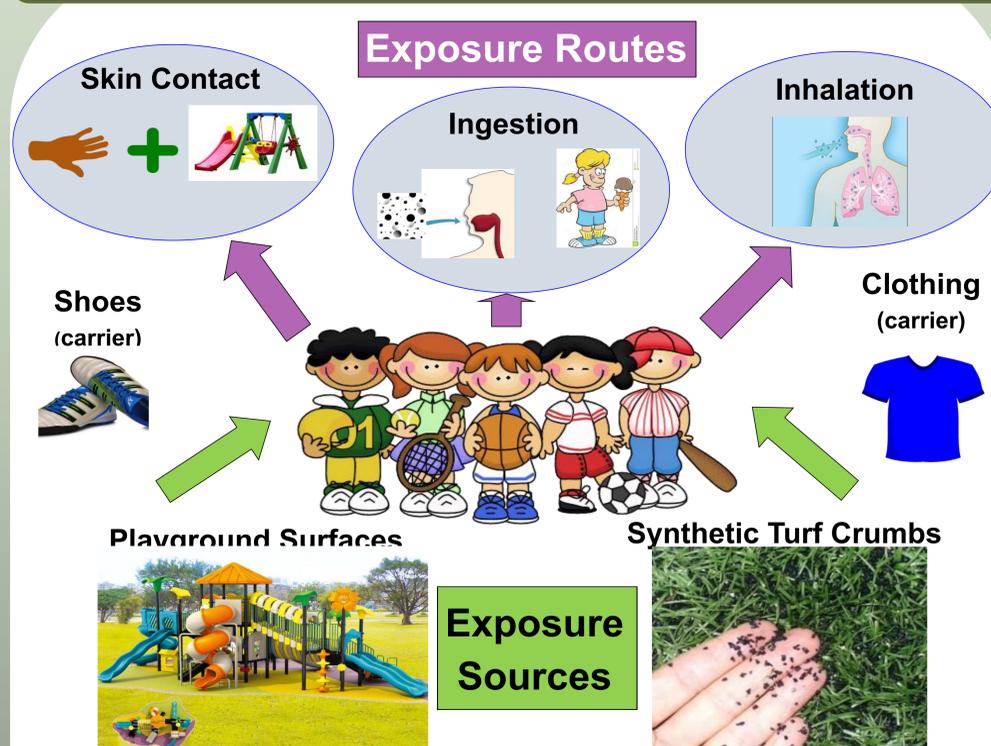
Warmer and less rainy areas:

- longer outdoor seasons
- higher temperatures enhance the release of certain chemicals

Contact Information

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Web site: <http://www.oehha.ca.gov>

Exposure Routes and Factors



Exposure Factors



Key Points to Consider

Young Children/Youth Sport Participants

- Exposed early in life
- Hand-to-mouth activity
- Combined exposure (multiple locations & routes)
- Seasonal or year-round
- Frequency and location
- Exposure patterns associated with type of sports
- Starting age and length of participation
- Exposure at home from "carried" turf crumbs

Coaches, Referees & Parents

- Seasonal or year-round
- Frequency and location
- Starting age and length of participation

Questions

- Do you have concerns for specific groups or activities?
- Do you have information on sport participants' ages, activity patterns, and other related information you want to share with us?
- How much crumb rubber does an athlete "carry" home after a game or practice?
- What sports should be studied?
- Have we captured all the kinds of exposures?
- Do you know of any good studies of exposure characterization?

FIELD SELECTION AND SAMPLE COLLECTION:

WHICH FIELDS SHOULD BE SAMPLED? OLD AND NEW? WHERE IN CALIFORNIA?

WHAT KINDS OF SAMPLES SHOULD BE TAKEN?



Sampling

Sample Types:

- New crumb rubber, artificial grass blades, and playground mats
- In-field crumb rubber and artificial grass blades
- Air—gas and particulates
- Surface wipe — particles and chemicals adhered to gloves and balls after a game



Field Selection:

- Age of field
- Climate region, altitude

Air Sampling

- Chemical vapors and particulates
- Collect samples upwind (background) & on-field

Sampling Height:

- Breathing zone for kids —3 feet above ground
- Near ground surface



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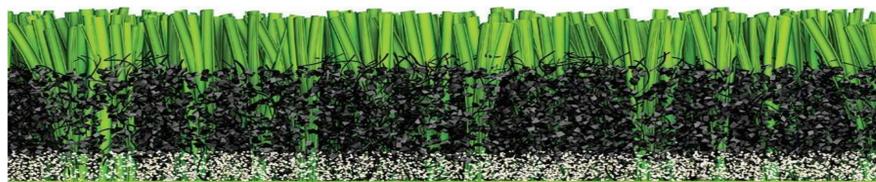
New Synthetic Turf

Analyze new, uninstalled crumb rubber, artificial grass blades, and playground mats from several major manufacturers to:

- provide background information on chemicals that can be released from synthetic turf products
- develop and standardize methods for in-field sample analysis

Analyze materials, treated under processes mimicking aging of the turf, to:

- understand chemical break-down in field aging
- guide specific plans for field sample collection
- modify analytical methods to identify and quantify break-down chemicals



Synthetic Turf Fields: Indoor and Outdoor

Samples Collected:

- Crumb rubber
- Artificial grass blades
- Air—on-field and upwind
- Surface wipe—fields & balls



Fields Selected:

- Several regions of CA (outdoor only)
- Fields of different ages



Playground Mats: Indoor and Outdoor

Samples Collected:

- Air—upwind of mats (outdoor only) and on mats
- Surface wipe

Mats Selected:

- Several regions of CA (outdoor only)
- Mats of different ages



Questions

- Do you know of any fields or playground mats that could be considered for field sampling?
- Are there certain regions of the state and times of the year when field sampling would be especially important?
- Of the different kinds of samples described in this poster, are there certain kinds that you feel are particularly important?
- Is it better to sample many fields with fewer samples, or fewer fields with more samples?

CHEMICAL ANALYSES:

WHICH CHEMICAL GROUPS SHOULD BE ANALYZED?

HOW SHOULD WE MEASURE THEM?



Chemical Analyses

Identification and quantification of chemicals released from crumb rubber and artificial grass blades

Steps: (1) Extraction and (2) Analysis

Extraction

Artificial Biofluids:

1. Saliva
2. Stomach fluid
3. Intestinal fluid
4. Sweat
5. Lung fluid

Chemical Groups

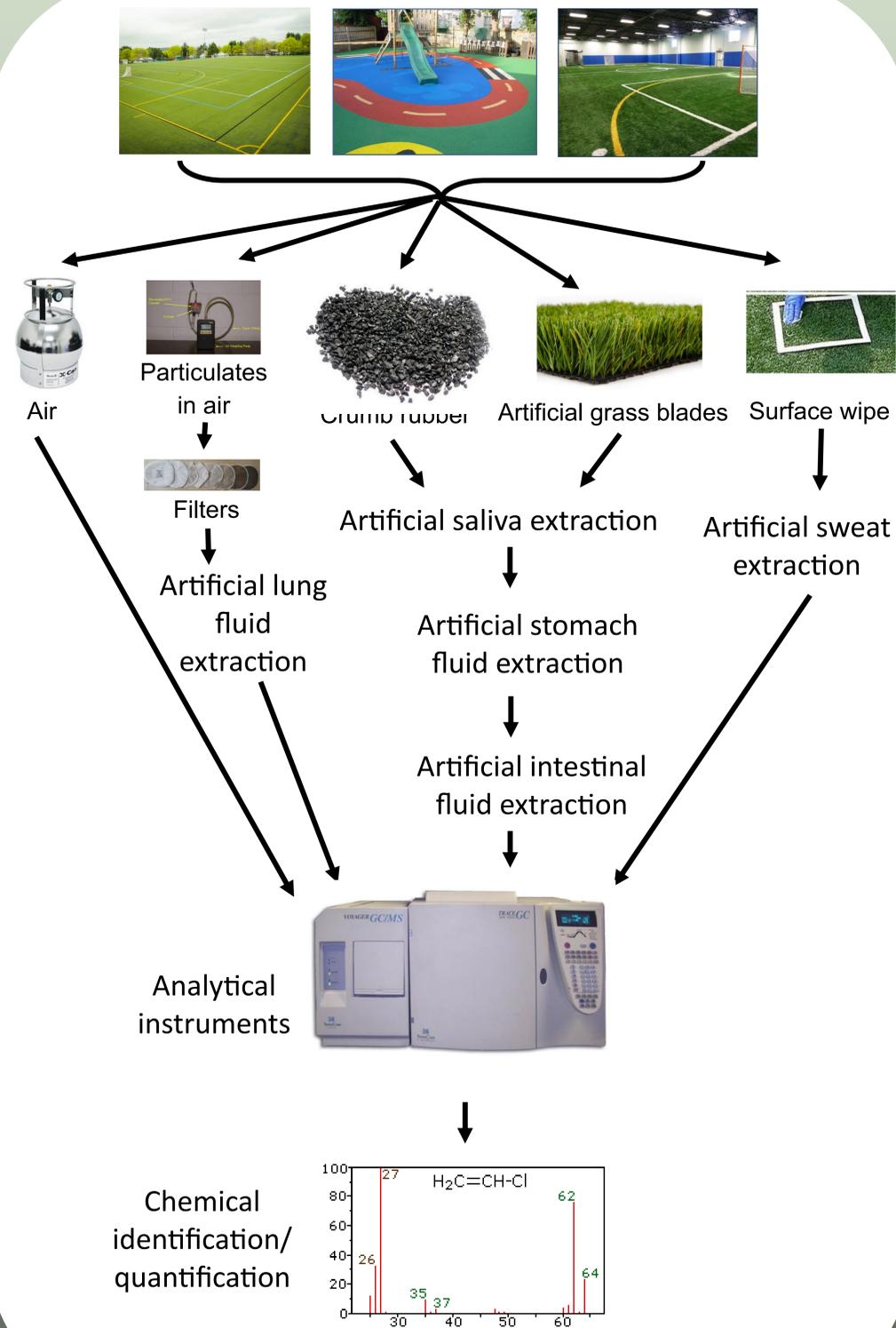
Organics:

- Volatile organic compounds—chemicals that are easily released into the air
- Semi-volatile organic compounds—chemicals that are released into the air to some degree
- Polycyclic aromatic hydrocarbons—most are not volatile; complex chemicals found in tars and petroleum

Metals:

- Zinc
- Lead
- Chromium

Exposure Routes Modeled



Sample Treatments & Analyses

Type of Samples and Treatments	Possible Analyses
New (synthetic turf and playground mats) <ul style="list-style-type: none"> • Crumb rubber, artificial grass blades, playground mats • Exposure chamber (e.g., study effects of weathering) • Biofluid extraction 	<ul style="list-style-type: none"> • Standard chemical analyses • Unknown identification
In-field (indoor and outdoor synthetic turf fields, and playground mats) <ul style="list-style-type: none"> • Crumb rubber, grass blades, playground mats, air, and particulates • Biofluid extraction 	<ul style="list-style-type: none"> • Standard chemical analyses • Unknown identification

Questions

Are there other methods we should consider?
Are there other measurements we should consider?

Contact Information

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[http:// www.oehha.ca.gov](http://www.oehha.ca.gov)

PLANS FOR POSSIBLE FUTURE PERSONAL MONITORING AND BIOMONITORING STUDIES:

WHEN SHOULD SPORT PARTICIPANTS BE MONITORED? DURING PLAY? DURING PRACTICE?

WHICH PARTICIPANTS? WHICH SPORTS?



Plan to Study Human Subjects

Results from the new study will provide data and information on planning:

- the chemicals and health effects to be monitored
- the types of bio-sample to be collected and analyzed

Developing a plan to study human subjects and a legally required review by Institutional Review Board could take at least 2 to 3 years.

Biomonitoring

Biomonitoring measures the amount of chemicals in a person's body.

Biomonitoring may tell us:

- if people have been exposed to certain chemicals
- if their exposure level and/or pattern changes over time
- if exposure is different between different groups
 - men and women
 - children and adults
 - sport participants and spectators



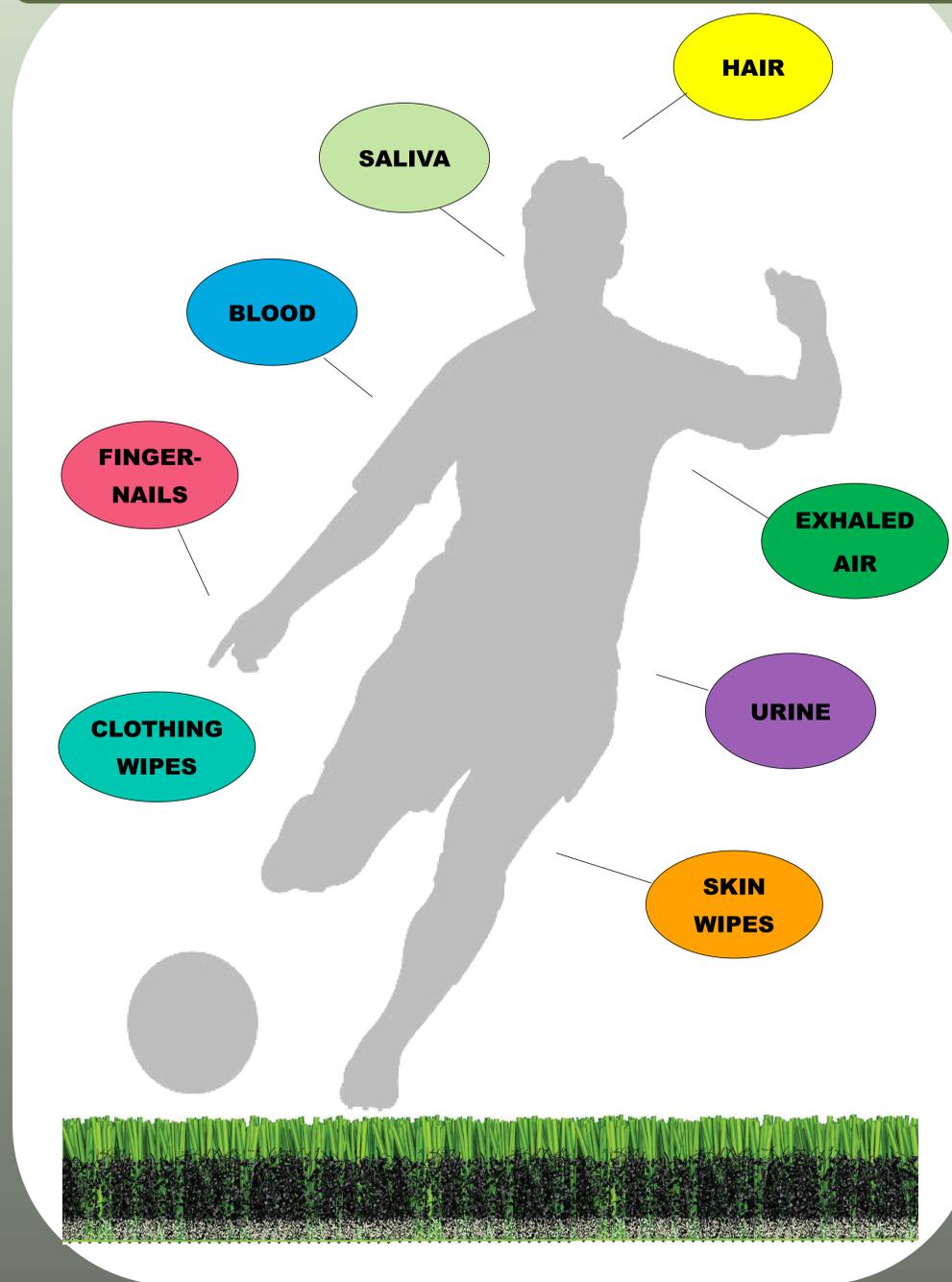
Personal Monitoring

Personal monitoring measures the type and amount of chemicals a person is exposed to while on or near synthetic turf.

Personal monitoring samples can be collected in many ways:

- Personal air monitors worn during sports/games to measure chemicals in the air
- Special clothing and gloves worn during sports/games to measure chemicals that are transferred onto skin from synthetic turf

Types of Samples



Sensitive Groups

- Young sport participants
- Family members of sport participants

Potentially Exposed Individuals

- **Sport Participants:** close contact with synthetic turf and ingestion of crumb rubber
- **Coaches and Referees:** many years of exposure



Samples Collected

Participants provide **biomonitoring samples** after playing on or around synthetic turf.

- Some samples, such as exhaled air and skin surface wipes, may provide information about the type and amount of chemicals a person is exposed to.
- Other samples, such as blood or urine, may provide information about the type and amount of chemicals that have entered a person's body.
- These and other samples may provide information about the risk of developing diseases such as cancer

Questions

- Do you prefer biomonitoring or personal monitoring?
- Who should be sampled?
- When should they be monitored, during game or practice?
- What should be the exposure duration studied? A game, over many weeks, or over a season?

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Section 6b

Highlights of Comments

Received at Public Workshops and Webinar



Highlights of Comments Received at Public Workshops and Webinar

In November and December 2015, OEHHHA held three public workshops in Northern and Southern California, and a webinar to seek input from the general public and interested parties on the overall project and components of the project.

Representativeness and Uncertainty of the Study

1. The representativeness of and the statistical power of the study are important. This includes how many fields should be sampled, how many samples per field, and the locations of the field that should be sampled.
2. The variability of crumb rubber, both in terms of physical structure and chemical composition, may complicate the interpretation of study results. Depending on the origin of the crumb rubber, the composition of crumb rubber can vary across fields and within a field. For example, car tires from different manufacturers and different types of car tires (even from the same manufacturer) may have different compositions.

Chemicals and Substances of Potential Concern

3. Chemical extraction by some researchers has shown more than 100 chemicals in the crumb rubber. Are people exposed to all of those?
4. Lead in synthetic turf, especially in the coloring agent that is used to color the blades and mats, should be measured.
5. Possible exposure to ultrafines released from crumb rubber need to be evaluated.
6. Exposure to chemicals released from the backing materials of synthetic turf should be studied.
7. Does recycled tire crumb differ from natural or virgin rubber and are the chemicals being studied found naturally in natural or virgin rubber?

Factors Affecting Exposure to Chemicals and Substances Released from Crumb Rubber

8. Deposition of crumb rubber dust in the lungs contributes to inhalation exposure to synthetic turf. Size of these particles present on synthetic turf fields should be examined.

9. Increased physical abrasions have been observed in athletes playing on synthetic turf fields. The physical abrasions can enhance chemical uptake into the bloodstream.
10. Application of sunscreen on the skin of athletes may enhance transfer of chemicals from synthetic turf onto their skin. This possibility should be considered.
11. Higher surface temperatures are commonly noted on synthetic turf fields compared to natural grass fields. The elevated temperatures may alter the amount and types of chemicals that can be released from synthetic turf. Athletes conducting sports activities during elevated temperatures may suffer from heat-related health effects that could be attributed to synthetic turf fields.
12. Ocular exposure of chemicals in synthetic turf should be investigated. Small particles of crumb rubber can enter and stay on the eyes of athletes (especially soccer goalies) for extended periods of time during sports activities. Artificial tears should be included in the artificial biofluid extraction study.

Human Health Risk Assessment

13. The health risks from exposure to chemicals in synthetic turf fields should be compared to some background exposure risks. Natural turf is most often mentioned but other materials such as coconut fiber, cork, rice husk, Nike grind, thermoplastic elastomer (TPE), EPDM (ethylene propylene diene monomer (EPDM)), and rounded silica sand have also been suggested.
14. The synergistic health effects from exposure to multiple chemicals from synthetic turf should be examined.

Investigation of Human Exposure

15. Exposures under occupational settings, such as workers in tire recycling plants and installers of synthetic turf, should also be considered.
16. The study should also look at young children playing on the sidelines with the crumb rubber and exposures that may occur from this activity.
17. Club soccer players may play up to 6 days per week. The study should consider that some children (and young adults) play many hours on these fields.
18. Sampling should be done when people are playing on the fields.
19. Sampling should be done when the fields are hot to catch the most off-gassing.

Appendix A

OEHHA and CalRecycle Interagency Contract



STATE OF CALIFORNIA
STANDARD AGREEMENT
 STD 213 (Rev 06/03)

AGREEMENT NUMBER

DRR14150

REGISTRATION NUMBER

1. This Agreement is entered into between the State Agency and the Contractor named below:

STATE AGENCY'S NAME

Department of Resources Recycling and Recovery (CalRecycle)

CONTRACTOR'S NAME

Office of Environmental Health Hazard Assessment (OEHHA)

2. The term of this Agreement is: June 30, 2015 through June 15, 2018
 Or upon DGS approval, whichever is later

3. The maximum amount of this Agreement is: \$2,858,000.00
 (Two million eight hundred fifty eight thousand dollars and zero cents)

4. The parties agree to comply with the terms and conditions of the following exhibits which are by this reference made a part of the Agreement.

Exhibit A – Scope of Work	9 page(s)
Exhibit B – Budget Detail and Payment Provisions	3 page(s)
Exhibit C* – General Terms and Conditions	GIA 610
Exhibit D – Special Terms and Conditions	2 page(s)
Attachment 1 – Recycled Content Certification	2 page(s)

Items shown with an Asterisk (*), are hereby incorporated by reference and made part of this agreement as if attached hereto.
 These documents can be viewed at www.ols.dgs.ca.gov/Standard+Language

IN WITNESS WHEREOF, this Agreement has been executed by the parties hereto.

CONTRACTOR

CONTRACTOR'S NAME (if other than an individual, state whether a corporation, partnership, etc.)

Office of Environmental Health Hazard Assessment

BY (Authorized Signature)

[Signature]

DATE SIGNED (Do not type)

6-10-15

PRINTED NAME AND TITLE OF PERSON SIGNING

Susan Villa, Deputy Director

ADDRESS

1001 I Street, MS12-B
 Sacramento, CA 95814

STATE OF CALIFORNIA

AGENCY NAME

Department of Resources Recycling and Recovery

BY (Authorized Signature)

[Signature]

DATE SIGNED (Do not type)

PRINTED NAME AND TITLE OF PERSON SIGNING

Tom Estes, Deputy Director

ADDRESS

1001 I Street
 Sacramento, CA 95814

California Department of General
 Services Use Only

Exempt per:

EXHIBIT A**SCOPE OF WORK**

1. The Contractor agrees to provide the Department of Resources Recycling and Recovery (CalRecycle), with risk assessment services as described herein.
2. The Project Coordinators during the term of this Agreement will be:

CalRecycle Contract Manager

Name: Robert Carlson
Phone: (916) 323-3411
Email: robert.carlson@calrecycle.ca.gov

Direct all agreement inquiries to:

CalRecycle

Contracts Unit

Attention: Shelly Lewis
Address: 1001 I Street
Sacramento, CA 95814
Phone: (916) 341-6649
Email: shelly.lewis@calrecycle.ca.gov

Office of Environmental Health Hazard Assessment

Name: David Ting
Phone: (510) 622-3226
Email: david.ting@oehha.ca.gov

Office of Environmental Health Hazard Assessment

Name: Patty Foey
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Sacramento, CA 95814
Phone: (916) 324-6440
Email: patty.foey@oehha.ca.gov

3. Statement of Work

I. INTRODUCTION/OBJECTIVES

Under contract with CalRecycle, the Office of Environmental Health Hazard Assessment (OEHHA) previously published two studies on the potential health impacts of using synthetic turf field and playground mats (OEHHA, 2007 and 2010). These two studies were screening in nature and limited in scope. In this agreement, OEHHA will conduct a series of scientific studies designed to further our understanding of the chemicals that can be released from crumb rubber under various environmental conditions, human exposures to these chemicals, and the associated chemical hazards and risks to human health.

II. WORK TO BE PERFORMED

OEHHA will conduct the tasks enumerated below. At the onset of Tasks 2, 3, 4, and 5, and iteratively, as necessary, OEHHA will perform a review of the pertinent literature to ensure that the most current information is being used to inform each piece of the project.

- 1) *Expert and stakeholder input and consultation:* Convene an advisory panel of experts to provide advice on study design and implementation, and hold one or more public meetings to engage the public and stakeholders in the study process. Consult with other departments in state government and the U.S. Environmental Protection Agency (EPA) on the design and conduct of the study.
- 2) *Hazard identification:* Identify the hazards to human health as a result of exposure to chemicals that may be released from crumb rubber in synthetic turf.
- 3) *Exposure scenario development:* Characterize the exposure pathways, routes, and activities leading to various levels of human exposure experienced on synthetic turf.

- 4) *Sampling and analysis of new and in-field synthetic turf*: Develop protocols, and collect samples of and perform laboratory tests on:
- new crumb rubber and artificial grass blades from synthetic turf that has not been installed,
 - in-the-field samples of crumb rubber and artificial grass blades, from fields of various ages and from different geographic locations in California, and
 - air above indoor and outdoor synthetic turf fields and playground mats.

Extraction methods will simulate conditions of human oral, dermal and inhalation contact with materials.

- 5) *Biomonitoring study protocol development*: OEHHA will develop protocols for obtaining samples of biological fluids from and exposure monitoring of children and adults who play on synthetic turf.
- 6) *Reporting*: Throughout the project, OEHHA will prepare written quarterly reports to the CalRecycle Contract Manager. The quarterly reports will describe the status and progress of the work performed. OEHHA will also prepare and submit written summaries of the findings of Tasks 2 through 4 below, and a brief summary of recommended next steps. Other deliverables are noted in the task descriptions below.
- 7) *Health assessment from play on synthetic turf and playground mats*: OEHHA will conduct an assessment of potential health impacts associated with use of synthetic turf and playground mats. OEHHA will prepare a draft report that will be made available for review and comment by an expert panel and the public, and a final report for submission to CalRecycle.

III. TASK DESCRIPTIONS

In order to provide a comprehensive understanding of the potential health impacts associated with using recycled tire rubber in synthetic turf and playground mats, OEHHA proposes six separate, major tasks. The seven tasks are described below.

Task 1: Expert, public and interagency consultation and input

- A. ***Expert input***: OEHHA will seek the advice and guidance of a panel of experts, preferably recruited from universities in California, on the design and implementation of the project. Panel members would have expertise in various specialties of the exposure and health sciences. Panel members will receive a lump sum payment per meeting to partially compensate them for meeting preparation and participation. Panel members will also be reimbursed for travel, according to state guidelines. Researchers who have previously published relevant studies will also be consulted at early stages of protocol development. It is anticipated that three meetings of the panel will be held over the course of the study. All meetings of the expert panel will be open to the public and the public will be given the opportunity to provide input at these meetings. The meetings will be webcast.
- B. ***Interagency consultation***: OEHHA will consult with the Department of Public Health (DPH) and the Department of Toxic Substances Control (DTSC) on environmental monitoring and biomonitoring protocol development, with DTSC and the Air Resources Board (ARB) on air and material sample collection, and with CalRecycle on synthetic turf composition, industry input strategy, overall study design and public participation. OEHHA will also communicate with and gather information from other states studying this issue (e.g., Washington, Connecticut) and the U.S. EPA.

- C. **Public participation:** OEHHA will seek input from the general public on study plans in an open, public meeting that will also be webcast. A world café style workshop may be used to obtain early public input.

Deliverables: Public meetings and summaries of action items and advisory panel and public recommendations from meetings.

Task 2. Hazard Identification

OEHHA will conduct a scientific literature review to identify the hazards to human health as a result of exposure to chemicals that may be released from synthetic turf, such as chemicals: 1) listed in the March 25, 2015 version of SB 47; 2) identified by researchers and published in the scientific literature, and; 3) identified as present in tires and potentially emitted or otherwise released from tire crumbs. The expert panel and the public will be given opportunities to provide input on the selection of chemicals (Task 1).

Deliverable: Written summary of findings.

Task 3. Exposure Scenario Development

OEHHA will analyze and develop exposure scenarios using well-established scientific approaches and methods identified, in part, by a literature review. In doing so, OEHHA will conduct an analysis that considers the varying exposure activities, environments (different climatic regions of California), frequency and duration of play, ages of populations playing on artificial turf, and exposure pathways. Type of use, as well as sensitive or heavily exposed sub-groups, such as small children, youth sport players, and soccer goalies, will also be considered. The analysis will also consider indoor and outdoor exposures, likely and high-end exposures, and various exposure routes (e.g., inhalation of chemical vapor released from recycled tire rubber, ingestion of crumb rubber, dermal uptake from crumb rubber, artificial grass blades and soccer balls). The expert panel and public will provide input on exposure scenarios, exposure routes, and activity patterns (Task 1).

Deliverable: Written summary of findings.

Task 4. Characterization of chemicals that can be released from synthetic turf and playground mats and determination of human exposure potentials

Based on the results of a literature review and input from the advisory panel and stakeholders, OEHHA will design a study to determine the identity and quantity of chemicals that can be released from synthetic turf made from recycled tire and other material and artificial grass blades, both under laboratory conditions and as experienced in the field. OEHHA will collect samples and contract with a laboratory or laboratories to conduct chemical analyses of:

- A. New, uninstalled crumb rubber and artificial grass blades.
1. Aqueous extracts simulating various exposure pathways. Information will be used to evaluate inhalation, ingestion, and dermal exposures.
 2. Vapor emitted from crumb rubber that has been heated to simulate chemical releases during summer conditions. Information will be used to evaluate inhalation exposures.
- B. In-use crumb rubber and artificial grass blades from indoor and outdoor fields of various ages throughout California.
1. Aqueous extracts simulating various exposure pathways. Information will be used to evaluate ingestion and dermal exposures.

2. Vapor samples that have been taken at various heights. Information will be used to evaluate inhalation exposures.
 3. Particulate in air samples that have been taken at various heights. Information will be used to evaluate inhalation exposures.
- C. Wipe samples from fields and balls used on those fields.
- Aqueous extracts simulating various exposure pathways. Information will be used to evaluate ingestion and dermal exposures.

This task is comprised of sub-tasks.

Task 4a. Procedure development to analyze chemicals of concern in crumb rubber and artificial grass blades

OEHHA will develop contracts with suitable analytical (preferably governmental and/or university) laboratories to develop sampling, sample pre-treatment, and analytical procedures to simulate oral, dermal and inhalation exposure pathways from play on synthetic turf fields and playground mats. The expert panel and public will provide input on procedures (Task 1).

A. Procedures that will be developed include protocols for:

- i. Field and new sample collection
- ii. Weathering/heating of new (not installed) samples in the laboratory
- iii. Chemical aqueous extractions from sample, combining the different simulated oral extracts from saliva, gastric juice, intestinal juice, aqueous sample division/aliquoting
- iv. Generation of chemical vapor from new (not installed) material
- v. Chemical analyses for targeted identification of chemicals
- vi. Chemical analyses for non-targeted identification of chemicals
- vii. Quality assurance and control

B. *Sample collection:* Protocol development will involve multiple aspects, including deciding which old and new fields to sample in different geographical locations, where on the field to take the sample, techniques used to remove the crumb rubber and blade samples from the field, taking of blank samples, containing and transporting samples, labeling of samples, maintaining chain of custody. For use in estimating inhalation exposure, chemical vapors and particulates will be monitored above varying aged indoor and outdoor fields and in various locations throughout California. Appropriate sampling collection methods and procedures will be developed to enable the analysis of particulates and other air contaminants released from synthetic turf, as discussed further below.

C. *Aqueous extractions of chemicals/sample preparation (new material and field samples):* Protocols for simulating chemical release and exposure by these pathways will be developed. Chemicals will be extracted from new (not installed) and in-field synthetic turf of different ages with one or more of the following artificial biofluids:

- lung (on respirable tire crumbs),
- sweat,

- saliva,
- gastric juice, and
- intestinal juice.

Extraction with artificial biofluids is used, rather than total extraction, to better estimate dose following oral, dermal, or inhalation exposures of individuals playing on synthetic turf fields. Protocols will be developed to optimize the extraction conditions, including but not limited to the amount of sample used and duration of extraction.

A protocol to recombine the oral exposure related elements of the extraction (saliva, gastric juice, intestinal juice) will be developed. Aqueous extracts simulating lung and sweat would not be combined. The protocol to use in dividing up the various aqueous samples for the various analytical panels would then be specified. It would include clean-up and concentration procedures to prepare the samples for specific chemical analyses.

- D. *Generation of chemical vapor from new (not installed) material:* For use in estimating inhalation exposure, chemical vapors released from new crumb rubber will be collected and analyzed. Efforts will be made to optimize the testing conditions, including but not limited to the amount of sample used, sample pre-treatment (e.g., grinding) as well as testing temperature and duration. Vapor trapping or collection methods will be developed to prepare the samples for chemical analyses.
- E. *Chemical analyses for targeted identification of chemicals:* Chemical groups likely to be analyzed by sample type are provided in the table below.

<i>Aqueous extracts:</i>	<i>Air samples emitted from new material in laboratory:</i>	<i>Field air samples:</i>
• VOCs	• VOCs	• VOCs
• sVOCs	• sVOCs	• sVOCs
• PAHs	• PAHs in vapor form	• PAHs in vapor form
• Metals		• PM ₁₀ and PM _{2.5} (e.g., PAHs, carbon black, and metals)

Additional chemicals or chemical groups may be added to the lists above based on literature review and/or input from the advisory panel or stakeholders (Task 1).

- F. *Chemical analyses for non-targeted identification of chemicals:* Protocols for non-targeted analyses will be developed via a contract, preferably with an academic or government laboratory.

Task 4b. New (not installed) crumb rubber: Sample collection and identification of chemicals extracted or emitted

CalRecycle will arrange for samples of new crumb rubber and playground mats from several major producers to be provided to OEHHA. Information related to chemicals used in the tire and the turf manufacturing process will also be provided to OEHHA. This information, as well as chemicals identified in Task 2, will be used to determine the chemicals of concern. Protocols developed

under Task 4a for sample handling and preparation will be followed. Targeted analyses for chemicals of concern will be conducted, by a commercial accredited laboratory with which OEHHA will contract.

In addition to the chemicals of concern identified from the literature, OEHHA will contract with a laboratory to identify other chemicals that can be extracted or emitted from crumb rubber samples, both new and from in-use fields. The purpose of these analyses is to identify chemicals that may be of concern but have not been previously noted as such in publications on chemical exposures from synthetic turf. Advanced analytical technologies such as “non-targeted” time of flight mass spectrometry, gas chromatography-mass spectrometry (GC-MS), or gas chromatography-mass spectrometry-mass spectrometry (GC-MS-MS) may be used for this task. To control the cost of performing this type of analysis, the number of samples analyzed using a “non-targeted” method will be limited. The work will be done via an interagency agreement with a University of California laboratory.

The purpose of this task is to determine the range of chemicals that can be released from recycled tire material from different manufacturers and made from different processes and over time.

Task 4c. Field samples of installed synthetic turf and playground mats: Collection and analyses of crumb rubber, artificial grass blade, air, and wipe samples

A. *Outdoor athletic fields:* Air, wipe (field and ball), crumb rubber, and artificial blade samples will be collected from outdoor fields of different ages in different locations in California. For good characterization of outdoor fields, OEHHA assumes sample collection from multiple outdoor fields of different ages (e.g., <12 months, 1-5 years old, and over 5 years old) or usage levels in different climatic regions of California (e.g., Northern (cold winter), Central Valley, San Francisco Bay, Los Angeles region, San Diego region, Imperial County) would be needed. Sample collection at each field would likely entail:

- Multiple crumb rubber samples (for aqueous extraction), plus blanks, if appropriate
- Artificial grass blade samples plus field blank, plus blanks, if appropriate
- Multiple wipe samples (field and ball, combined) (for aqueous extraction) plus field blank
- Multiple air samples (vapor) + reference (background) samples for comparison
- Multiple air samples (particulates) + reference (background) samples for comparison

For air monitoring, stations will be set up at up-wind and down-wind locations of the field in order to differentiate ambient (background) concentrations of measured chemicals from those released from synthetic turf. Some samples could be taken at the height of breathing zone (approximately 4 ft) and others at a low height (e.g., 1 ft from the ground level). This will provide information about the level of chemicals inhaled by players. The exact protocol will be decided in Task 4a.

B. *Indoor athletic fields.* This task will also collect samples from multiple indoor athletic fields, for example, two each of the three different ages (e.g., <12 months, 1-5 years old, and over 5 years old). Because indoor fields are expected to be less affected by the climate, results of indoor fields in one region will be used to represent the whole state.

C. *Synthetic playground mats.* Air and wipe samples will be collected from multiple outdoor and indoor playground mats of different ages (e.g., <12 months, 1-5 years old, and over 5 years old)

in different climatic regions of California. The number of mats sampled will be limited to control cost.

For air monitoring, stations will be set up at up-wind and down-wind locations of the mats in order to differentiate ambient (background) concentrations of measured chemicals from those released from the mats. All air samples will be taken at a low height, for example, 1 ft. from the surface of the mats. This will provide information about the level of chemicals inhaled by small children using the mats. The exact protocol will be decided in Task 4a.

Deliverable: Written summary of findings of Tasks 4a through c.

Task 5. Biomonitoring and personal monitoring protocol development

Considering the results of the tasks above, a scientific literature review, and input from the advisory panel and public (Task 1), OEHHA will develop a protocol to collect and analyze biological specimens or other personal monitoring measures of exposure from players on synthetic turf. OEHHA will select chemicals of concern that are released from synthetic turf and determine whether players using these fields are exposed to greater than expected concentrations of these chemicals compared to relevant controls or established standards, if applicable. Consideration will also be given to monitoring for specific markers of risk for diseases such as cancer (e.g., DNA adducts with tire chemicals and chromosomal damage in circulating lymphocytes), personal air monitoring (to estimate inhalation exposures) and skin and/or clothing testing (to estimate dermal exposures) while playing on synthetic turf fields.

A main objective will be to develop a study plan for Institutional Review Board (IRB) approval. The first task will be to develop a preliminary study plan, including: participant recruitment strategy, participant materials (e.g., recruitment materials, informed consent forms, exposure assessment questionnaire, individual results return template), chemicals and/or markers to be evaluated, sample collection and processing protocols, timeline, and budget. The plan will be prepared for approval by the California Committee for the Protection of Human Subjects, who would review the study protocol and all materials to ensure that participants' rights would be safeguarded.

Task 6. Reporting

Task 6a: Quarterly Reports

OEHHA will provide quarterly reports summarizing the work performed to date on Tasks 1 through 5, along with an estimate of the percentage of that task that has been completed to date.

Task 6b: Task Summaries

As noted under the individual task descriptions, OEHHA will provide summaries of the findings of Tasks 2 through 4, and a biomonitoring study plan for IRB review under Task 5.

Deliverable: Quarterly reports, written summary of findings of Tasks 2 through 4.

Task 7. Health Assessment from Play on Synthetic Turf and Playground Mats

Considering the results of year 1 and 2 activities regarding the toxicity of chemicals of concern, concentrations of those chemicals that individuals using synthetic turf and playground mats may be exposed to, the estimated duration and frequency of those exposures, and other relevant

information, OEHHA will conduct an assessment of potential health impacts associated with use of synthetic turf and playground mats. OEHHA will prepare a draft and final report for submission to CalRecycle.

- A. **Expert input:** OEHHA will seek the advice and guidance of the panel of experts described in Task 1 to review the draft and revised draft. Under Task 7, the panel will likely be expanded to include 3 to 4 additional members with expertise in key aspects of risk assessment. All meetings of the expert panel will be open to the public and the public will be given the opportunity to provide input at these meetings
- B. **Public participation:** OEHHA will seek input from the general public on the draft report in a world café style workshop.

Taking into account input from the panel and public on the draft report, OEHHA will prepare a final report.

Deliverables: Written Draft and Final Health Assessment Reports

IV. CONTRACT TASK/TIME FRAME

NOTE: Deliverables are briefly listed in the table below. See description of each task for full description of what shall be included in each deliverable.

The term of the contract will be approximately 36 months with all project deliverables completed by April 2018. Task start and end dates shown below are estimates and may be adjusted after consultation between OEHHA and CalRecycle Contract Managers.

Task Number	Task Description	Start Date	End Date
Task 1	Expert, public and interagency consultation and input	June 2015	May 2017
Task 2	Hazard Identification	October 2015	March 2016
Task 3	Exposure Scenario Development	April 2016	September 2017
Task 4	Characterization of chemicals that can be released from synthetic turf and playground mats and determination of human exposure potentials	July 2015	June 2017
Task 4a	Procedure development to analyze chemicals of concern in crumb rubber and artificial grass blades	--	--
Task 4b	New (not installed) crumb rubber: Sample collection and identification of chemicals extracted or emitted	--	--
Task 4c	Field samples of installed synthetic turf and playground mats: Collection and analyses of crumb rubber, artificial grass blade, air, and wipe samples	--	--
Task 5	Biomonitoring and personal monitoring protocol development	June 2016	June 2017

Task 6a	Quarterly Reports	June 2015	April 2018
Task 6b	Task Summaries	June 2015	April 2018
Task 7	Health Assessment from Play on Synthetic Turf and Playground Mats	July 2017	April 2018

EXHIBIT B

BUDGET DETAIL AND PAYMENT PROVISIONS

1. INVOICING AND PAYMENT:

- A. For services satisfactorily rendered and upon receipt and approval of the invoices, the State agrees to compensate the Contractor for actual expenditures incurred in accordance with the rates specified herein.
- B. Itemized invoices shall be submitted in triplicate, with two sets of supporting documentation (e.g., receipts, timesheets, etc), not more frequently than monthly in arrears to:

Accounts Payable
Department of Resources Recycling and Recovery
Fiscal Services Branch
U.S. Postal Correspondence:
P.O. Box 4025, MS-19A
Sacramento, CA 95812-4025
Federal Express Correspondence:
1001 I Street, MS-19A
Sacramento, CA 95814

- C. Each invoice submitted to CalRecycle must include the following information:
- Invoice Number
 - Contract Number
 - Description of Rendered Activities/Services
 - Submitting Contractor's Address
 - Invoice Period

2. BUDGET CONTINGENCY CLAUSE:

- A. It is mutually agreed that if the Budget Act of the current year and/or any subsequent years covered under this Agreement does not appropriate sufficient funds for the program, this Agreement shall be of no further force and effect. In this event, the State shall have no liability to pay any funds whatsoever to the Contractor or to furnish any other considerations under this Agreement and the Contractor shall not be obligated to perform any provisions of this Agreement.
- B. If funding for any fiscal year is reduced or deleted by the Budget Act for purposes of this program, the State shall have the option to either: cancel this Agreement with no liability occurring to the State, or offer an Agreement Amendment to the Contractor to reflect the reduced amount.

3. BUDGET:

Personnel Costs	Position Count (Personnel Years)	Estimated Salary Range (Monthly)		Total by Position
Personnel by Position				
Public Health Medical Officer III	0.25		\$13,333	\$40,000
Monthly Salary Range: \$9,812-\$13,463		With benefits (46.54%)	\$19,539	\$58,616
Senior Toxicologist	3.05		\$7,760	\$284,000
Monthly Salary Range: \$6,868-\$8,553		With benefits (46.54%)	\$11,371	\$416,173
Staff Toxicologist	2.25		\$7,296	\$197,000
Monthly Salary Range: \$6,404-\$7,979		With benefits (46.54%)	\$10,692	\$288,684
Associate Toxicologist	2.10		\$5,714	\$144,000
Monthly Salary Range: \$4,833-\$6,596		With benefits (46.54%)	\$8,374	\$211,019
Research Scientist III	2.95		\$6,525	\$231,000
Monthly Salary Range: \$5,796-\$7,255		With benefits (46.54%)	\$9,562	\$338,507
Benefits include OASDI (6.2%), Health/Vision/Dental (14.61%), Retirement (BA 2014) (24.28%), Medicare (1.45%)		Total Wages		\$896,000
		Total Wages with Benefits		\$1,313,000
		Total Personnel Costs		\$1,313,000
Operating Expenses				
C&P, Interdeptal.	Includes facilitation services, laboratory testing protocol development, and laboratory chemical analysis. Contractor shall use California agencies, California State Universities, and University of California campuses as subcontractors whenever possible, but up to \$600,000 may be subcontracted to private laboratories if necessary. Contractor shall follow all applicable state contracting laws and policy in awarding subcontracts. Contractor is limited to charging overhead on only the first \$25,000 of each subcontract (per SCM 3.06.B).			\$892,000
General Expense	These are ongoing expenses which fall under the category of General Expense. Expenses include but may not be limited to miscellaneous office supplies, photocopy charges/supplies, protective clothing, shipping, minor equipment, office equipment rental or maintenance; secure file storage, shelving, or record storage cabinets, etc.			\$33,000
Printing	Includes photocopy supplies, copy paper, copier maintenance, etc.			\$11,000
Communications	Includes hard lines, cellular phones, and other necessary communications.			\$11,000
Postage	Includes postage via US Mail and private courier (UPS, FedEx, etc) of sample materials and necessary correspondence.			\$4,000
Travel	Includes taxicab service, overtime meals, per diem, hotel costs, etc., in support of program investigations.			\$40,000
Training	Includes necessary training costs for project personnel.			\$11,000
Facilities Ops.	Includes rent for buildings and grounds, utilities, etc., as required to support the project.			\$102,000
IT	Includes information technology expenses necessary for project.			\$22,000
Total Operating Expenses				\$1,126,000
Indirect Costs	≈32% of Wages with Benefits		Total Indirect Costs	\$419,000
Costs for this Agreement shall be computed in accordance with State Administrative Manual Section 8752 and 8752.1.				
Total Cost				\$2,858,000

EXHIBIT D**SPECIAL TERMS AND CONDITIONS**

1. **AMENDMENT**: No amendment or variation of the terms of this Agreement shall be valid unless made in writing, signed by the parties and approved as required. No oral understanding or agreement not incorporated in this Agreement is binding on any of the parties. CalRecycle reserves the right to amend this Agreement through a formal written amendment signed by both parties, for additional time and/or funding.
2. **COPYRIGHTS AND TRADEMARKS**: Contractor shall assign to CalRecycle any and all rights, title and interests to any copyrightable material or trademarkable material created or developed in whole or in any part as a result of this Scope of Work of this Agreement, including the right to register for copyright or trademark of such materials. Such title will include exclusive copyrights and trademarks in the name of the State of California.

For contracts of \$5,000 or more, any document or written report prepared for or under the direction of CalRecycle, shall include a notation on the inside cover as follows:

"Prepared as part of CalRecycle contract number DRR14150, Total Contract Amount \$2,858,000.00, pursuant to Government Code Section 7550."

3. **DELIVERABLES**: All documents and/or reports drafted for publication by or for CalRecycle in accordance with this contract shall adhere to CalRecycle's Contractor Publications Guide at www.calrecycle.ca.gov/Publications/PubGuide/ and shall be reviewed by CalRecycle's Contract Manager in consultation with CalRecycle editor.

(The Contractor is encouraged to consult with CalRecycle's project management and editorial staff early in the development process to ensure deliverable requirements are clearly understood and to minimize the need for revisions.)

4. **ENVIRONMENTAL JUSTICE**: In the performance of this Agreement, Contractor shall conduct its programs, policies, and activities that substantially affect human health or the environment in a manner that ensures the fair treatment of people of all races, cultures, and income levels, including minority populations and low income populations of the State. (Government Code Section 65040.12(e)).
5. **RECYCLED-CONTENT CERTIFICATION AND REPORTING**: Contractors shall certify in writing, under penalty of perjury, to CalRecycle, the minimum, if not the exact, percentage of postconsumer and secondary material in the products, materials, goods, or supplies purchased with contract dollars (PCC§ 12205(a)) This certification shall be provided to CalRecycle as supporting documentation submitted with every invoice on the Recycled Content Certification Form (Exhibit D, Attachment 1), also available at: <http://www.calrecycle.ca.gov/Contracts/Forms/default.htm> CalRecycle will report these purchases in its annual State Agency Buy Recycled Campaign (SABRC) Procurement Report; therefore, to avoid double counting these purchases, the Contractor should not include these purchases on their SABRC Procurement Report that is submitted to CalRecycle [if the contractor is required to submit a report]

6. **RECYCLED-CONTENT PRODUCT PURCHASING**: In the performance of this Agreement, the Contractor shall purchase used and/or recycled-content products as set forth on the back of the Recycled-Content Certification Form (Exhibit D,

Attachment 1). For assistance in locating recycled-content products, please search the recycled-content product database available at: www.calrecycle.ca.gov/RCP. If after searching the database, contractors are unable to find the recycled-content products they are looking for, please notify CalRecycle's Contract Manager. All recycled content products purchased or charged/billed to CalRecycle that are printed upon such as promotional items, publications, written materials, and other educational brochures shall have both the total recycled content (TRC) and the post-consumer (PC) content clearly printed on them.

In addition, any written documents such as, publications, letters, brochures, and/or reports shall be printed double-sided on 100% post-consumer (PC) paper. Specific pages containing full-color photographs or other ink-intensive graphics may be printed on photographic paper. The paper should identify the post-consumer recycled content of the paper (i.e., "printed on 100% post-consumer paper"). When applicable, the Contractor shall provide the Contract Manager with an electronic copy of the document and/or report for CalRecycle's uses. When appropriate, only an electronic copy of the document and/or report shall be submitted and no hard copy shall be provided.

7. SUBCONTRACTING: All subcontracting must comply with the requirement of the State Contracting Manual, Section 3.06.
8. TERMINATION: CalRecycle shall have the right to terminate this Agreement at its sole discretion at any time upon thirty days written notice given to the Contractor. In the case of early termination, a final payment will be made to the Contractor upon approval by the Contract Manager of a financial report, invoices for costs incurred to date of termination and a written report describing all work performed by the Contractor to date of termination.
9. WASTE REDUCTION: In the performance of this Agreement, the Contractor shall take all reasonable steps to ensure that materials purchased or consumed in the course of the project are utilized both effectively and efficiently to minimize the generation of waste. The steps should include, but not necessarily be limited to, the use of reusable products, the use of recyclable and compostable products, discretion in the amount of materials used, the provision of alternatives to disposal for materials consumed, and the practice of other waste reduction measures where feasible and appropriate.

STATE OF CALIFORNIA
 Department of Resources Recycling and Recovery (CalRecycle)
 CalRecycle 74C (Rev. 06/10 for Contracts)

To be completed by Contractor	
Name of Contractor:	
Contract #:	Work Order #:

Recycled-Content Certification

Check this box if no products, materials, goods, or supplies were purchased with contract dollars and submit to the CalRecycle Contract Manager.

This form to be completed by contractor. The form must be completed and returned to CalRecycle with a row completed for each product purchased with contract dollars. Attach additional sheets if necessary. **Information must be included, even if the product does not contain recycled-content material.** Product labels, catalog/website descriptions, or bid specifications may be attached to this form as a method of providing that information. Add additional rows as needed.

Contractor's Name _____ Date _____
 Address _____ Phone _____
 Fax _____ E-mail _____ Web site _____

Product Manufacturer	Product Description / Brand	Purchase Amount (\$)	¹ Percent Postconsumer Material	² SABRC Product Category Code	Meets SABRC

Public Contract Code sections 12205 (a) (1) (2) (3) (b) (1) (2) (3).

I certify that the above information is true. I further certify that these environmental claims for recycled content regarding these products are consistent with the Federal Trade Commission's Environmental Marketing Guidelines in accordance with PCC Section 12205.

Print name _____ Signature _____ Company _____ Date _____

1. Postconsumer material comes from products that were bought by consumers, used, and then recycled. For example: a newspaper that has been purchased and read, next recycled, and then used to make another product would be postconsumer material.

If the product does not fit into any of the product categories, enter "N/A." Common N/A products include wood products, natural textiles, aggregate, concrete, electronics such as computers, TV, software on a disk or CD, or telephone.

2. Product category refers to one of the product categories listed below, into which the reportable purchase falls. For products made from multiple materials, choose the category that comprises most of the product by weight, or volume.

Note: For reused or refurbished products, there is no minimum content requirement.

For additional information visit www.calrecycle.ca.gov/BuyRecycled/

Code	Description Product Categories (11)	Minimum content requirement
1	Paper Products - Recycled	30 percent postconsumer fiber, by fiber weight
2	Printing and Writing - Recycled	30 percent postconsumer fiber, by fiber weight
3	Compost, Co-compost, and Mulch – Recycled	80 percent recovered materials. i.e., material that would otherwise be normally disposed of in a landfill
4	Glass – Recycled	10 percent postconsumer, by weight
5	Rerefined Lubricating Oil - Recycled	70 percent re-refined base oil
6a	Plastic – Recycled	10 percent postconsumer, by weight
6b	Printer or duplication cartridges	a. Have 10 percent postconsumer material, or b. Are purchased as remanufactured, or c. Are backed by a vendor-offered program that will take back the printer cartridges after their useful life and ensure that the cartridges are recycled and comply with the definition of recycled as set forth in Section 12156 of the Public Contract Code.
7	Paint – Recycled	50 percent postconsumer paint (exceptions when 50% postconsumer content is not available or is restricted by a local air quality management district, then 10% postconsumer content may be substituted)
8	Antifreeze – Recycled	70 percent postconsumer material
9	Retreated Tires - Recycled	Use existing casing that has undergone retreading or recapping process in accordance with Public Resource Code (commencing with section 42400).
10	Tire- Derived - Recycled	50 percent postconsumer tires
11	Metals – Recycled	10 percent postconsumer, by weight

Appendix B
Scientific Advisory Panel Biographies



SYNTHETIC TURF SCIENTIFIC ADVISORY PANEL

The Synthetic Turf Scientific Advisory Panel (the Panel) is a group of expert scientists invited by the Office of Environmental Health Hazard Assessment (OEHHA) to provide advice on the design and implementation of OEHHA's synthetic turf study. The study aims to characterize the exposures and health risks from playing on synthetic turf and playground mats made from recycled tire materials. Members of the Panel were selected for their expertise in the following areas of specialization: exposure science, laboratory science and analytical chemistry, environmental monitoring, biostatistics, medicine, public health, and children's health.

The Panel will meet during the study to advise OEHHA on study plans, study progress, and reporting study results. All Panel meetings are open to the public. You can view meeting notices and other related information here:

<http://www.oehha.ca.gov/risk/SyntheticTurfStudies/index.html>.

At each Panel meeting, there will be:

1. Opportunities for panel members to provide scientific advice and guidance on the study design and implementation.
2. Opportunities to hear from the public on study design and progress.

OEHHA intends to webcast all Panel meetings, but this is contingent on webcast facility availability.

Synthetic Turf Scientific Advisory Panel Members

- **Edward Avol** is a Professor of Clinical Preventive Medicine, Keck School of Medicine, University of Southern California, and has expertise in exposure assessment and acute/chronic respiratory and cardiovascular effects of airborne pollutants in populations at risk including children, athletes, and subjects with compromised lung function. He was the Deputy Director of the Children's Health Study and is a key investigator in multiple ongoing investigations of the effects of environmental exposures on human health. He is the co-Director of the Exposure Assessment and Geographical Information Sciences Facility Core in the National Institute for Environmental Health Sciences (NIEHS)-supported Southern California Environmental Health Sciences Center, co-Director of the Exposure Assessment and Modeling Core in the NIEHS/US Environmental Protection Agency-supported Children's Environmental Health Center, and is the principal investigator on several National Institutes of Health and regionally funded studies to assess the association of air pollution with children's

respiratory and cardiovascular health. Professor Avol is also actively involved in the centers' community outreach efforts, particularly with regard to the health and air quality impacts of the Los Angeles/Long Beach Port expansions. Professor Avol received his M.S. from the California Institute of Technology.

- **John Balmes** is a Professor of Medicine at the University of California, San Francisco and the Chief of the Division of Occupational and Environmental Medicine at the San Francisco General Hospital and the Director of the Human Exposure Laboratory. He is also a Professor of Environmental Health Science at the University of California, Berkeley and the Director of the Northern California Center for Occupational and Environmental Health and the Center for Environmental Public Health Tracking. His research focuses on the adverse respiratory and cardiovascular effects of air pollutants including ozone, tobacco smoke and particulate matter. He received his M.D. from the Mount Sinai School of Medicine and completed a residency in Internal Medicine at Mount Sinai Hospital and a fellowship in Pulmonary Medicine at Yale University.
- **Deborah Bennett** is an Associate Professor in the Department of Public Health Sciences at the University of California, Davis. Her research is focused on the fate, transport, and exposure of chemicals. She uses field and modeling studies to assess and predict exposure to particulate matter and organic compounds in indoor and outdoor environments. Dr. Bennett received her B.S. in Mechanical Engineering from the University of California, Los Angeles and her M.S. and Ph.D. in Mechanical Engineering from the University of California, Berkeley.
- **Sandy Eckel** is an Assistant Professor in the Division of Biostatistics, at the Keck School Medicine, University of Southern California. Her research is on statistical methods and applications in environmental epidemiology, exhaled breath biomarkers, and clinical trials for pediatric brain tumors. She completed her Ph.D. in the Department of Biostatistics at the Johns Hopkins Bloomberg School of Public Health.
- **Amy Kyle** is on the faculty in Environmental Health Sciences at the School of Public Health at the University of California, Berkeley. Her recent research focuses on cumulative impacts, chemicals policies, persistent and bioaccumulative chemicals, children's environmental health, biomonitoring, and air pollution standards. Dr. Kyle serves as a leader of the Research Translation Core of the Berkeley Superfund Research Program funded by the National Institute for Environmental Health Sciences. She previously served as an Associate Director of the Berkeley Institute for the Environment. She has served

in senior positions in environmental protection in the State of Alaska working on a wide range of environmental, health, and natural resources issues. She has served on a variety of advisory groups focused on children's health and environmental disparity, including for the US Environmental Protection Agency, World Health Organization, Centers for Disease Control and Prevention, and National Academy of Sciences. Her M.P.H. and Ph.D. in environmental health sciences and policy are from the University of California, Berkeley and B.A. in environmental sciences is from Harvard College.

- **Thomas McKone** is an international expert on exposure science and risk analysis. He retired from the position of senior staff scientist and Division Deputy for Research at Lawrence Berkeley National Laboratory and as a Professor of Environmental Health Sciences at the University of California, Berkeley, School of Public Health, but continues to work at both institutions. Dr. McKone's research interests are in the development, use, and evaluation of models and data for human-health and ecological risk assessments and in the health and environmental impacts of energy, industrial, and agricultural systems. He has authored 160 journal papers, has served on the US Environmental Protection Agency Science Advisory Board, worked with several World Health Organization committees, served on many California state advisory panels, and been a member fifteen US National Academy of Sciences committees. He is a fellow of the Society for Risk Analysis and a former president of the International Society of Exposure Science. Dr. McKone earned a Ph.D. in engineering from the University of California, Los Angeles.

- **Linda Sheldon** is an international expert in exposure assessment. She retired from the position of Associate Director for Human Health in the US Environmental Protection Agency's National Exposure Research Laboratory. Her research focuses on measuring and modeling how chemicals move through the environment and how people, particularly children, come in contact with these chemicals in their everyday lives, as well as the associated health hazards. She has served on advisory committees for international and national research centers and on workgroups for the World Health Organization in the area of exposure assessment. She earned her Ph.D. in environmental chemistry from the University of Michigan.

Appendix C1

List of Chemicals of Potential Concern



Appendix C1. List of Chemicals of Potential Concern

Based on literature search of analytical studies on synthetic turf, crumb rubber, artificial grass blades, and tires; OEHHHA identifies chemicals of potential concern for the synthetic turf study. Tables 1 to 4 summarize the chemicals detected in organic solvent extracts, aqueous extracts, biofluid extracts, or offgassing/air samples of synthetic turf materials. Carcinogenicity classifications from OEHHHA, US EPA, and IARC are also included in the tables.

Table 1. Volatile Organic Chemicals (VOCs) Detected in Extracts or Offgassing/Air Samples of Synthetic Turf Materials and Their Carcinogenicity Classifications

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
1,1,2-trichloro-1,2,2-trifluoroethane				yes		-	-
1,2,3-trimethyl benzene				yes		-	-
1,2,4-trimethyl benzene				yes		-	-
1,2-dichloropropane				yes	X	1	-
1,3,5-trimethyl benzene				yes		-	-
1,4-dichlorobenzene				yes		2B	-
1-ethyl-2-methylbenzene	solvent (unclear)			yes		-	-
1-ethyl-3-methylbenzene				yes		-	-
1-ethyl-4-methylbenzene	solvent (unclear)			yes		-	-
1-heptene				yes		-	-
2-butanone				yes		-	-
2-hexanone				yes		-	Inadequate Information To Assess Carcinogenic Potential
2-methyl furan				yes		-	-

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
2-methyl-butane				yes		-	-
2-propanol				yes		-	-
4-ethyltoluene				yes		-	-
4-methyl-2-pentatone				yes		-	-
acetone				yes		-	-
acrolein				yes		3	-
benzene	DCM			yes	X	1	Known/Likely Human Carcinogen
benzoic acid	solvent (unclear)	acid rainwater				-	Not Classifiable as to Human Carcinogenicity
bromoform				yes	X	3	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
bromomethane				yes		3	Inadequate Information To Assess Carcinogenic Potential
butanal				yes		-	-
butane				yes		-	-
carbon disulfide				yes	X	-	-
carbon tetrachloride				yes	X	2B	Likely to be Carcinogenic to Humans
chlorobenzene				yes		-	Not Classifiable as to Human Carcinogenicity
chloroform				yes	X	2B	Likely to be Carcinogenic to Humans

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
chloromethane				yes		-	-
cyclohexane				yes		-	Data are Inadequate for an Assessment of Human Carcinogenic Potential
cyclohexanone			gastric			3	-
decane				yes		-	-
dichlorodifluoromethane				yes		-	-
dichlorotetrafluoroethane				yes		-	-
ethanol				yes	X	-	-
ethyl acetate				yes		-	-
ethylbenzene				yes	X	2B	Not Classifiable as to Human Carcinogenicity
halocarbon 11				yes		-	-
heptane				yes		-	Not Classifiable as to Human Carcinogenicity
hexanal				yes		-	-
hexane				yes		-	Inadequate Information To Assess Carcinogenic Potential
isobutyl alcohol				yes		-	-
isopropylbenzene				yes		2B	Inadequate Information To Assess Carcinogenic Potential
methyl ethyl ketone				yes		-	-

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
methyl isobutyl ketone		acid rainwater		yes	X	2B	Data are Inadequate for an Assessment of Human Carcinogenic Potential
methyl chloride				yes	X	3	Not Classifiable as to Human Carcinogenicity
methylene chloride				yes		2B	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
naphthalene		acid rainwater			X	2B	Carcinogenic Potential Cannot Be Determined
nonane				yes		-	-
octane				yes		-	-
pentadecane	solvent (unclear)			yes		-	-
propene				yes		-	-
propylbenzene				yes		-	-
styrene				yes		2B	-
tetrachloroethylene				yes	X	2A	Likely to be Carcinogenic to Humans
tetrahydrofuran				yes		-	Suggestive Evidence of Carcinogenic Potential
toluene	DCM			yes	X	3	Inadequate Information To Assess Carcinogenic Potential
trichloroethylene				yes	X	1	Carcinogenic to Humans
trichlorotrifluoroethane				yes		-	-
trichlorotrifluoromethane				yes		-	-

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
undecane	solvent (unclear)			yes		-	-
vinyl acetate				yes		2B	-
xylene	DCM			yes		3	Data are Inadequate for an Assessment of Human Carcinogenic Potential

¹Organic solvents used in extraction of synthetic turf materials – ACE: acetone; ACN: acetonitrile; DCM: dichloromethane; EA: ethyl acetate; HEX: hexane; IPA: isopropyl alcohol; MC: methylene chloride; PE: petroleum ether.

²Chemicals identified as known to the state to cause cancer under California Proposition 65 (http://www.oehha.ca.gov/prop65/prop65_list/Newlist.html)

³International Agency for Research on Cancer (IARC) overall evaluation of carcinogenicity of the agent to humans: Group 1: the agent is carcinogenic to humans; Group 2A: the agent is probably carcinogenic to humans; Group 2B: the agent is possibly carcinogenic to humans; Group 3: the agent is not classifiable as to its carcinogenicity to humans; Group 4: the agent is probably not carcinogenic to humans. (http://monographs.iarc.fr/ENG/Classification/latest_classif.php)

⁴US EPA Integrated Risk Information System (IRIS) weight of evidence characterization (<http://www.epa.gov/iris>)

Table 2. Semi-Volatile Organic Chemicals (sVOCs) Detected in Extracts or Offgassing/Air Samples of Synthetic Turf Materials and Their Carcinogenicity Classifications

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
2,4-dimethylphenol		acid rainwater				-	-
22R-bishomohopane				yes		-	-
22R-trihomohopane				yes		-	-
22S-bishomohopane				yes		-	-
2-mercaptobenzothiazole	solvent (unclear)	acid rainwater				-	-
4-methylphenol		acid rainwater				-	Possible Human Carcinogen
4-tert-(octyl)-phenol	HEX	-		yes		-	-
aniline		acid rainwater	gastric		X	3	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
benzothiazole		acid rainwater	gastric	yes		-	-
benzyl alcohol		acid rainwater				-	-
bis(2-ethylhexyl) phthalate	ACE/HEX, ACE/MC	acid rainwater				2B	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
butylated hydroxyanisole	HEX,EA			yes	X	2A	-
butylated hydroxytoluene	HEX, EA			yes		3	-
carbazole		acid rainwater	digestive, lung, sweat		X	3	-
decanoic acid				yes		-	-
diethyl phthalate		acid rainwater, deionized				-	Not Classifiable as to Human Carcinogenicity

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
		rainwater					
dimethyl phthalate		deionized water				-	Not Classifiable as to Human Carcinogenicity
di-n-butyl phthlate		acid rainwater				-	Inadequate Information To Assess Carcinogenic Potential
di-n-octyl phthlate		deionized water				-	-
docosane				yes		-	-
docosanoic acid				yes		-	-
dodecane				yes		-	-
dotriacontane				yes		-	-
eicosane				yes		-	-
eicosanic acid				yes		-	-
heneicosane				yes		-	-
hentriacontane				yes		-	-
heptacosane				yes		-	-
heptadecane				yes		-	-
hexadecane				yes		-	-
isophorone		acid rainwater				-	Possible Human Carcinogen

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
linoleic acid				yes		-	-
N-nitrosodiphenylamine		acid rainwater			X	3	-
nonacosane				yes		-	-
nonadecane				yes		-	-
norpristane				yes		-	-
octacosane				yes		-	-
octadecane				yes		-	-
octadecanoic acid				yes		-	-
octanoic acid				yes		-	-
palmitoleic acid				yes		-	-
pentacosane				yes		-	-
pentadecane				yes		-	-
pentadecanoic acid				yes		-	-
phenol		acid rainwater	gastric			3	Data are Inadequate for an Assessment of Human Carcinogenic Potential
phytane				yes		-	-
pristane				yes		-	-

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
tetratriacontane				yes		-	-
tredecane				yes		-	-
tredecanoic acid				yes		-	-
triacontanoic acid				yes		-	-
tricosane				yes		-	-
tricontane				yes		-	-
tridecane				yes		-	-
tritriacontane				yes		-	-
undecane				yes		-	-

¹Organic solvents used in extraction of synthetic turf materials – ACE: acetone; ACN: acetonitrile; DCM: dichloromethane; EA: ethyl acetate; HEX: hexane; IPA: isopropyl alcohol; MC: methylene chloride; PE: petroleum ether.

²Chemicals identified as known to the state to cause cancer under California Proposition 65 (http://www.oehha.ca.gov/prop65/prop65_list/Newlist.html)

³International Agency for Research on Cancer (IARC) overall evaluation of carcinogenicity of the agent to humans: Group 1: the agent is carcinogenic to humans; Group 2A: the agent is probably carcinogenic to humans; Group 2B: the agent is possibly carcinogenic to humans; Group 3: the agent is not classifiable as to its carcinogenicity to humans; Group 4: the agent is probably not carcinogenic to humans. (http://monographs.iarc.fr/ENG/Classification/latest_classif.php)

⁴US EPA Integrated Risk Information System (IRIS) weight of evidence characterization (<http://www.epa.gov/iris>)

Table 3. Polycyclic Aromatic Hydrocarbons (PAHs) Detected in Extracts or Offgassing/Air Samples of Synthetic Turf Materials and Their Carcinogenicity Classifications

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
1-methylnaphthalene	MC			yes		-	-
2,6-dimethylnaphthalene				yes		-	-
2-methylnaphthalene	MC			yes		-	-
acenaphthene	DCM/ACN, EA			yes		3	-
acenaphthylene	EA			yes		-	Not Classifiable as to Human Carcinogenicity
aniline	HEX		gastric		X	3	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
anthracene	DCM/ACN, ACE, PE, EA	deionized water				3	Not Classifiable as to Human Carcinogenicity
benz(a)anthracene	DCM/ACN, ACE, PE, EA, DCM/HEX	deionized water		yes		2B	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
benzo(a)pyrene	DCM/ACN, ACE, PE, EA, DCM/HEX		gastric	yes	X	1	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
benzo(b)fluoranthene	DCM/ACN, IPA, DCM/HEX			yes	X	2B	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
benzo(e)pyrene	EA			yes		3	-
benzo(g,h,i)fluoranthene				yes		3	-
benzo(g,h,i)perylene	DCM/ACN, EA, DCM/HEX		gastric	yes		3	Inadequate Information To Assess Carcinogenic Potential
benzo(k)fluoranthene	DCM/ACN, EA, DCM/HEX			yes	X	2B	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
chrysene	DCM/ACN, IPA, ACE, PE, EA, DCM/HEX			yes	X	2B	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals

Chemical	Extraction Media			Offgas/Air	Proposition 65 Carcinogen ²	IARC ³	US EPA ⁴
	Organic Solvent ¹	Aqueous	Biofluid				
dibenz(a,h)anthracene	DCM/ACN, EA, DCM/HEX				X	2A	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
fluoranthene	DCM/ACN, IPA, ACE, PE, EA	deionized water		yes		3	Not Classifiable as to Human Carcinogenicity
fluorene	DCM/ACN, IPA, ACE, PE EA	deionized water		yes		3	Not Classifiable as to Human Carcinogenicity
indeno[1,2,3-cd]pyrene	DCM/ACN, EA, DCM/HEX			yes	X	2B	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
N-(1,3-dimethylbutyl)-N'-phenyl-p-phenyldiamine	DCM					-	-
N,N'-diphenyl-p-phenyldiamine	DCM					-	-
naphthalene	DCM/ACN, IPA, ACE, PE, EA	deionized water	saliva, gastric, intestinal	yes	X	2B	Carcinogenic Potential Cannot Be Determined
N-isopropyl-N'-phenyl-p-phenyldiamine	DCM					-	-
phenanthrene	DCM/ACN, IPA, ACE, PE, EA	deionized water		yes		3	Not Classifiable as to Human Carcinogenicity
pyrene	DCM/ACN, IPA, ACE, PE, EA, DCM/HEX	deionized water		yes		3	Not Classifiable as to Human Carcinogenicity

¹Organic solvents used in extraction of synthetic turf materials – ACE: acetone; ACN: acetonitrile; DCM: dichloromethane; EA: ethyl acetate; HEX: hexane; IPA: isopropyl alcohol; MC: methylene chloride; PE: petroleum ether.

²Chemicals identified as known to the state to cause cancer under California Proposition 65 (http://www.oehha.ca.gov/prop65/prop65_list/Newlist.html)

³International Agency for Research on Cancer (IARC) overall evaluation of carcinogenicity of the agent to humans: Group 1: the agent is carcinogenic to humans; Group 2A: the agent is probably carcinogenic to humans; Group 2B: the agent is possibly carcinogenic to humans; Group 3: the agent is not classifiable as to its carcinogenicity to humans; Group 4: the agent is probably not carcinogenic to humans. (http://monographs.iarc.fr/ENG/Classification/latest_classif.php)

⁴US EPA Integrated Risk Information System (IRIS) weight of evidence characterization (<http://www.epa.gov/iris>)

Table 4. Metals Detected in Extracts or Air/Particulate Matter Samples of Synthetic Turf Materials and Their Carcinogenicity Classifications

Chemical	Extraction Media			Proposition 65 Carcinogen ¹	IARC ²	US EPA ³
	Aqueous	Biofluid	Air/Particulate Matter			
aluminum	water, wet wipe				-	-
antimony	water	gastric			-	-
arsenic	acid, deionized water, acidified water (pH 4.2), wet wipe	sweat, digestive		X	1	-
barium	acid rainwater, deionized water, acidified water (pH 4.2), wet wipe	gastric			-	-
beryllium				X	1	Carcinogenic Potential Cannot be Determined (Oral route); Known/Likely Human Carcinogen (Inhalation route)
cadmium	acid, deionized water, acidified water (pH 4.2), wet wipe	digestive		X	1	Probable Human Carcinogen – Based on Limited Evidence of Carcinogenicity in Humans
calcium	acid rainwater, water, acid		yes		-	-
chromium	acid, surface water, deionized water, acidified water (pH 4.2), wet wipe	sweat, digestive, gastric, intestinal	yes	X (Cr VI)	1 (Cr VI)	(CR VI) Known/Likely Human Carcinogen (inhalation route); Carcinogenic Potential Cannot be Determined (Oral Route)
cobalt	deionized water, acid	gastric			2B	-
copper	acid rainwater, surface water, deionized water, acidified water (pH 4.2), wet wipe	sweat, digestive	yes		-	Not Classifiable as to Human Carcinogenicity
iron	acid rainwater, water, wet wipe		yes		-	-
lead	acid, acid rainwater, surface water, deionized water, acidified water (pH 4.2), wet wipe	sweat, digestive	yes	X	2B	Probable Human Carcinogen – Based on Sufficient Evidence of Carcinogenicity in Animals
lithium	water				-	-
magnesium	acid rainwater, water	sweat, digestive			-	-
manganese	acidified water (pH 4.2), wet wipe, water		yes		-	Not Classifiable as to Human Carcinogenicity

Chemical	Extraction Media			Proposition 65 Carcinogen ¹	IARC ²	US EPA ³
	Aqueous	Biofluid	Air/Particulate Matter			
mercury	deionized water, water				3	Not Classifiable as to Human Carcinogenicity
molybdenum	water	gastric			-	-
nickel	surface water, deionized water, acidified water (pH 4.2), wet wipe, water	gastric			2B	-
potassium	water, acid water		yes		-	-
rubidium	water				-	-
selenium	water, acid water	digestive	yes		-	Not Classifiable as to Human Carcinogenicity
Sodium	acid		yes		-	-
strontium	water				-	-
thallium					-	-
tin	acid water, acid				-	-
titanium	acid water, acid	sweat	yes		-	-
tungsten		lung			-	-
vanadium	water	sweat, digestive			-	-
zinc	acid, acid rainwater, deionized water, acidified water (pH 4.2), wet wipe	gastric	yes		-	Inadequate Information To Assess Carcinogenic Potential

¹Chemicals identified as known to the state to cause cancer under California Proposition 65 (http://www.oehha.ca.gov/prop65/prop65_list/Newlist.html)

²International Agency for Research on Cancer (IARC) overall evaluation of carcinogenicity of the agent to humans: Group 1: the agent is carcinogenic to humans; Group 2A: the agent is probably carcinogenic to humans; Group 2B: the agent is possibly carcinogenic to humans; Group 3: the agent is not classifiable as to its carcinogenicity to humans; Group 4: the agent is probably not carcinogenic to humans. (http://monographs.iarc.fr/ENG/Classification/latest_classif.php)

³US EPA Integrated Risk Information System (IRIS) weight of evidence characterization: (<http://www.epa.gov/iris>)

Appendix C2

Antimicrobial Products Used on Synthetic Turf



Appendix C2. Antimicrobial Products Used on Synthetic Turf

Several antimicrobial products (biocides) which are marketed to control or deter the growth of organisms on synthetic turf fields are listed in the table below. They can be used by residents or professionals. The active ingredient information of these products were obtained from the internet and are included in the table.

Company	Product Name	Action	Active Ingredients	CAS No	Concentration
Cyndan Chemicals	Algae Died B	Algaecide (Control Algae and Mold)	Alkylbenzyl dimethyl ammonium chloride	68424-85-1	142.5g/L
Rigby Taylor Ltd.	Qualgex (algaecide)	Algaecide (Control Algae)	Alcohol Ethoxylate 6	68439-45-2	1-10%
			Diocetyl dimethyl ammonium Chloride	5538-94-3	1-10%
			Propan-2-ol	67-63-0	1-10%
Agricrop	Steri-maX biocide	Biocide (control fungi, algae, and bacteria pathogens)	didecyl dimethyl ammonium chloride	7173-51-5	120 g/L
EDMAR Chemical	TurfStat PRO	Disinfectant, Sanitizer, Fungicide, Virucide & Mildewstat	Alkyl dimethyl benzyl ammonium chloride	68391-01-5	0.781% (weight)
			Alkyl dimethyl ethyl benzyl ammonium chloride	68956-79-6	0.781% (weight)

Appendix D
Synthetic Turf Product Specifications



MATERIAL SAFETY DATA SHEET

Crumb Rubber

Manufactured by
 West Coast Rubber Recycling Inc.

1501 Lana Way Hollister, CA 95023
 Phone 831.634.2800 Fax 831.634.2801

COMPOSITION

PRODUCT NAME	Crumb Rubber		
	APPROX % BY WEIGHT	CAS NO.	
TOTAL REPROCESSED RUBBER	51%		
Natural Rubber	38%	9006-04-6	
Synthetic Rubber	13%	9003-55-8	
CARBON BLACK	38%	1333-86-4	
ZINC STEARATE	4.0%	1314-13-2	
SULFUR	2.4%	7704-34-9	
ANTIOXIDANT/ANTIOZONANT	3.1%	N/A	
WAX	.8%		
ACCELERATORS	0.4%		
OTHER INGREDIENTS	<1.0%		

IDENTIFICATION/CHEMICAL & PHYSICAL CHARACTERISTICS

PRODUCT NAME	Crumb Rubber	SOLUBILITY IN WATER	Insoluble
APPEARANCE	Black Granular Power	ODOR	Slight Smell of Vulcanized Rubber
SPECIFIC GRAVITY	1.0 – 1.5	MELT POINT	N/A
VAPORE PRESSURE	N/A	VAPOR DENISTY	N/A
EVAPORATION RATE	N/A	BOILING POINT	N/A

HAZARDOUS INGREDIENTS

MATERIAL (CAS)	WT %	OSHA PEL	(AVGIHTLV)
Vulcanized Rubber Compound	Approx. 99%	N/A	N/A
FLAMMABLE LIMITS	N/A		
FLASH POINT	Ignition Temperature of dust cloud 320 degrees Centigrade (608 F)		

FIRE AND EXPLOSION HAZARD DATA

LEL .25 OZ/CU.FT> *	UEL: N/A
EXTINGUISHING MEDIA	Water, foam, dry powder, encapsulating fire Suppressant (DO NOT USE HIGH PRESSURE WATER)
SPECIAL FIRE FIGHTING PROCEDURES	Noxious gases may be formed under fire
UNUSUAL FIRE AND EXPLOSION HAZARDS	Dust may be explosive if mixed with air in Critical proportions and in the presences of an ignition

HAZARDOUS INGREDIENTS – HEALTH HAZARD DATA

STABLE	Yes
CONDITIONS TO AVOID	Conditions that will cause burning
INCOMPATABILITY	Avoid strong oxidizing agents
HAZARDOUS DECOMPOSITION OF OF BY-PRODUCTS	Thermal decomposition may produce carbon monoxide, carbon dioxide, zinc oxide fumes/dust, sulfur dioxide, liquid and gaseous hydrocarbons
ROUTES OF ENTRY	Inhalation

HAZARDOUS INGREDIENTS – HEALTH HAZARD DATA (Continued)

HEALTH HAZARD (Acute and Chronic)	Product can contain fine fiber that may cause itching. Material is generally thought to be a nuisance dust.
CARCINOGENICITY	Rubber is not listed as a carcinogen
SIGNS AND SYMPTOMS OF EXPOSURE	Itching of skin, irritation of mucous membranes, sneezing and coughing, irritation of eyes
MEDICAL CONDITIONS GENERALLY BY EXPOSURE	Could potentially aggravate allergies due to dust exposure/inhalation
EMERGENCY AND FIRST AID PROCEDURE	Normal washing of skin with soap and water; Ordinary means of personal hygiene are adequate

PRECAUTIONS FOR SAFE HANDLING AND USE

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED	Sweep or vacuum for disposal
WASTE DISPOSAL METHOD	Product is not defined as hazardous waste by U.S. EPA or state and local agencies. Dispose in accordance with federal, state and local regulations
PRECAUTIONS IN HANDLING AND STORAGE	Do not store near flame or ignitions sources. Do not store hot material in tubs or containers where spontaneous ignition could occur
OTHER PRECAUTIONS	If material burns, an oily residue will result. Residue must be disposed in accordance with federal, state and local regulations
RESPIRATORY PROTECTION (Specify Type)	Dust and mist respirator noted for up to 10mg/m ³

CONTROL MEASURES

VENTILATION	Yes
LOCAL EXHAUST	Yes, if dusty conditions
SPECIAL	None
MECHANICAL	Dust collector and exhaust fans
PROTECTIVE GLOVES	Recommended but not required
EYE PROTECTION	Safety goggles to prevent dust entry
OTHER PROTECTIVE CLOTHING AND EQUIPMENT	Enough fresh air should flow past the user to prevent exposure to airborne fibers and particles
WORK/HYGENE PRACTICES	Good personal hygiene; frequent washing with soap and water of exposed areas; remove and clean solid clothing
OTHER PRECAUTIONS	If material burns, an oily residue will result. Residue must be disposed in accordance with federal, state and local regulations
RESPIRATORY PROTECTION (Specify Type)	Dust and mist respirator noted for up to 10mg/m ³

The information contained in this MSDS is consistent with the U.S. Department of Labor OSHA Form OMB1218-0072. Consult OSHA Hazard Communication Standard 29CFR 1910.1200 for additional information. To fully understand the use of any material the user should avail themselves of reference material and expert consultation in the fields of fire prevention, ventilations and toxicology.

Prepared by Cameron Wright	Telephone (831) 634-2800	Preparation Date May 4, 2010
<p>All information, recommendations and suggestions on this Material Safety Data Sheet have been compiled from tests and data believed to be reliable. No warranty or guarantee, express or implied is made as to the accuracy or completeness of the data contained herein. It is the user's responsibility to determine the safety, toxicity and sustainability for his/her own use of the product described herein.</p>		



ASTROTURF® Diamond M System

MTi

MATERIALS

Primary Yarn Polymer	Twisted Nylon/Polyethylene
Yarn Cross Section	Diamond Monofilament
Standard Color	Red Clay, Brown
UV Stabilized	Yes
Fabric Construction	Tufted
Primary Backing	18 Pic/ 13 Pic
Coating Type	Polyurethane
Polyethylene Yarn Denier / Ends	10,600 / 6
AstroFlect™	Available

Finish Fabric	English System		Metric System		ASTM Test F-1551
	Value	Units	Value	Units	Method
<i>Nominal Specification</i>					
Pile Height [Nominal]	1 1/8	In.	29	mm	D-5823
Face Weight	35	oz/yd ²	1,187	g/m ²	D-5848
Total Fabric Weight	61.5	oz/yd ²	2,085	g/m ²	D-5848
Primary Backing Weight	6.5	oz/yd ²	220	g/m ²	D-5848
Secondary Coating Weight	20	oz/yd ²	678	g/m ²	D-5848
Tuft Bind	>10	lbs.	>2.7	kg.	D-1335
Grab Tear Strength [Average]	>200	lbs.	>68	kg.	D-5034
Lead Content	<50	ppm	<50	ppm	F-2765
Total Yarn Linear Density	10,600	Denier	11,777	D-Tex	D-1577
Elongation to Break	>50	%	>30	%	D-2256
Yarn Breaking Strength	>20	lbs.	>9.1	kg.	D-2256
Yarn Melting Point	248	F°	120	C°	D-789
Stitch Rate	3.5	In.	1.4	cm	D-5793
Machine Gauge	3/8	In.	0.95	cm	D-5793
Flammability	TEST PASSED		TEST PASSED		D-2859
Water Permeability w/ Infill	>30	In./hr	>76.2	cm/hr	F-1551
Fiber Thickness	9.5	mils	241	microns	D-3218
Fabric Width	15	Ft.	4.6	M	None

Note: Any change from the specified values is considered a special product that will require confirmation from manufacturing. All values are ± 10%
 AstroTurf® has the right to modify technical specifications on the above-mentioned product. Delivered products can slightly differ from the technical data.
 AstroTurf® guarantees the technical quality of the proposed article.

1kb15





ASTROTURF® Diamond M System

QBB

MATERIALS

Primary Yarn Polymer	Polyethylene
Yarn Cross Section	Monofilament/Slit-Film
Standard Color	Field Green
UV Stabilized	Yes
Fabric Construction	Tufted
Primary Backing	18 Pic/ 13 Pic
Coating Type	Polyurethane
Polyethylene (Monofilament) Yarn Denier / Ends	12,000 / 6
Polyethylene (Slit film) Yarn Denier / Ends	8,000 / 1
AstroFlect™	Available

Finish Fabric	English System		Metric System		ASTM Test F-1551 Method
	Value	Units	Value	Units	
<i>Nominal Specification</i>					
Pile Height [Nominal]	1 5/8	In.	41	mm	D-5823
Face Weight	35	oz/yd ²	1,187	g/m ²	D-5848
Total Fabric Weight	61.5	oz/yd ²	2,085	g/m ²	D-5848
Primary Backing Weight	6.5	oz/yd ²	220	g/m ²	D-5848
Secondary Coating Weight	20	oz/yd ²	678	g/m ²	D-5848
Tuft Bind	>10	lbs.	>2.7	kg.	D-1335
Grab Tear Strength [Average]	>200	lbs.	>68	kg.	D-5034
Lead Content	<50	ppm	<50	ppm	F-2765
Total Yarn Linear Density	10,000	Denier	11,110	D-Tex	D-1577
Elongation to Break	>50	%	>30	%	D-2256
Yarn Breaking Strength	>20	lbs.	>9.1	kg.	D-2256
Yarn Melting Point	248	F°	120	C°	D-789
Stitch Rate	2.7	In.	1.0	cm	D-5793
Machine Gauge	3/8	In.	0.95	cm	D-5793
Flammability	TEST PASSED		TEST PASSED		D-2859
Water Permeability w/ Infill	>30	In./hr	>76.2	cm/hr	F-1551
Fiber Thickness	9.5	mils	241	microns	D-3218
Fabric Width	15	Ft.	4.6	M	None

Note: Any change from the specified values is considered a special product that will require confirmation from manufacturing. All values are ± 10%
 AstroTurf® has the right to modify technical specifications on the above-mentioned product. Delivered products can slightly differ from the technical data.
 AstroTurf® guarantees the technical quality of the proposed article.

1kb15



Appendix E1

A Bioaccessibility Study by Pavilonis *et al.*, 2014



NIH Public Access

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Risk Anal. Author manuscript; available in PMC 2014 December 11.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers

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Abstract

To reduce maintenance costs, municipalities and schools are starting to replace natural grass fields with a new generation synthetic turf. Unlike Astro-Turf, which was first introduced in the 1960's, synthetic field turf provides more cushioning to athletes. Part of this cushioning comes from materials like crumb rubber infill, which is manufactured from recycled tires and may contain a variety of chemicals. The goal of this study was to evaluate potential exposures from playing on artificial turf fields and associated risks to trace metals, semivolatile organic compounds (SVOCs), and polycyclic aromatic hydrocarbons (PAHs) by examining typical artificial turf fibers (n=8), different types of infill (n=8), and samples from actual fields (n=7). Three artificial biofluids were prepared which included: lung, sweat, and digestive fluids. Artificial biofluids were hypothesized to yield a more representative estimation of dose than the levels obtained from total extraction methods. PAHs were routinely below the limit of detection across all three biofluids precluding completion of a meaningful risk assessment. No SVOCs were identified at quantifiable levels in any extracts based on a match of their mass spectrum to compounds that are regulated in soil. The metals were measurable but at concentrations for which human health risk was estimated to be low. The study demonstrated that for the products and fields we tested, exposure to infill and artificial turf was generally considered de minimus, with the possible exception of lead for some fields and materials.

1. Introduction

In an effort to reduce costs and increase field use, municipalities across the US and Europe have been replacing natural grass with artificial turf at parks and athletic fields. ⁽¹⁾ However, a number of public health concerns have been raised regarding artificial turf fields ⁽²⁻⁵⁾ including potential exposure to toxic substances contained in the turf fibers and crumb rubber infill. ⁽⁶⁻¹⁰⁾ Crumb rubber, which is manufactured from recycled tires, is used to provide cushioning and extend the life of the field. However, it can contain polycyclic aromatic hydrocarbons (PAH), volatile organic chemicals (VOCs), semi volatile organic chemicals (SVOCs), and heavy metals. The concentration of each contaminant can vary depending on the basic composition and age of the parent material used in the infill and turf. ⁽¹¹⁻¹⁴⁾

Previous studies completed in the US and Europe have provided insight into the composition and safety of primarily older turf material. Levels of PAHs and other SVOCs in the raw infill material have been reported to be above health based standards ^(9, 15) which is not

surprising given the in-fill is often composed of used shredded tires which contain many hazardous organic compounds. In one study, measurements of airborne measurements of PAHs, PCBs, PCDDs, and PCDFs at actively used artificial-turf playing fields suggested in excess of one in a million lifetime cancer risk based on BaP air concentrations.⁽¹⁶⁾ Several other studies have evaluated personal and stationary VOC, SVOC, and PM₁₀ air samples near synthetic turf fields without seeing an elevated risk. In a study that collected air samples across five synthetic turf fields (4 outdoor and 1 indoor) in Connecticut no elevated health risk was found for either cancerous or non-cancerous endpoints.⁽¹³⁾ A Norwegian study evaluating the risk from exposure to a wide range of contaminants concluded artificial turf fields do not cause any elevated health risk to children or adult athletes.⁽¹⁷⁾ Air and wipe samples were collected for PM_{2.5} and PM₁₀, VOCs, and SVOCs at artificial fields in New York State. Again, no elevated health risks were identified in air samples collected from on-field or downwind locations.⁽¹⁸⁾ In addition to organic compounds, metals have been identified as a potential contaminant of concern, particular lead which can cause severe permanent neurological health effects in children.^(9, 19-21) Lead based coloring agents used in fibers of some artificial turf can be released into the environment as the field ages. Measured concentrations have exceeded the statutory lead limit for consumer products intended for children and EPA lead-dust standard for floors.⁽¹⁹⁾

A few studies have considered the bio-accessibility of measured contaminants in selected samples of artificial turf fibers or crumb rubber in fill. Bio-accessibility takes into consideration the maximum concentration of an analyte that is soluble in laboratory prepared synthetic bio-fluids. Bio-fluids simulate the pH and composition of sweat, digestive juices, and lung fluid and are more representative of an individual's overall potential dose than total extraction alone. A study using artificial digestive fluid to extract metals and VOCs from crumb rubber found no increased risk of acute or chronic health effects to children.⁽¹⁰⁾ Zhang et al. (2008) observed high total levels of PAHs and some trace metal in the total extracts. However, it was found that the PAHs had a low bio-accessibility and only between one quarter and one half of the lead and chromium in the turf were bio-accessible.⁽⁹⁾

No published study has considered the bio-accessibility of SVOCs or metals via all three potential exposure routes: dermal, ingestion and inhalation. The goal of this study was to determine whether the bio-accessible fraction of metals and SVOCs found in artificial turf fields exceeded non-cancerous risk-based guidance values for children and adult athletes.

2. Methods

2.1 Turf fibers, crumb rubber infill, and field samples

New crumb infill (n=9) and new turf fiber products (n=8) were obtained from an architectural firm that specialized in artificial turf installation. Actual field samples were collected from seven New Jersey area communities that use crumb rubber infill products for athletic fields. This was accomplished by sweeping the infill material into a clean plastic shovel using new brushes and storing the crumb rubber collected in new Ziploc bags at room temperature until subsampled for analysis. For the selected fields, information was obtained on the manufacturer, age of the field, and general use of the field. All samples underwent the

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same bio-fluid extraction for SVOCs and metals. The “total” extractable fraction was measured by direct solid phase micro-extraction (SPME) for SVOCs and nitric acid extraction digestion for metals and used as the basis for the bio-accessibility comparisons.

2.2 Bio-fluid extractions

Using prepared synthetic solutions (Table I), bio-accessibility analyses for metals and SVOCs were performed for the following three routes of exposure: digestive system, respiratory system, and dermal. The artificial fluids used in these extracts have been documented to be functional analogs of actual biological fluids in previous studies.^(22–26) Briefly, for the digestive system 200 mg of infill or a 4cm × 4cm piece of turf was extracted with 8 ml of the artificial saliva and 100 ml of gastric fluid (pH = 1.4 ± 0.2) for 2 hours at 37°C while being shaken at 30 RPM. Half the extract was then shaken again for 2 h after adding 100 ml of intestinal fluid, adjusted to a pH of 6.5 ± 0.1 and then the two digestive extracts were recombined and shaken for 2 more hours to simulate the digestive process. For the dermal pathway, approximately 200 mg of infill or a 4cm × 4cm piece of turf was extracted with 20 ml of the sweat solution by shaking at 30 RPM in a water bath at 37°C for 1 hr. For the respiratory system, approximately 100 mg of infill or a 4cm × 4cm piece of turf was extracted with 10 ml of the synthetic lung solution by shaking at 30 RPM at 37°C for 24 hours. The metals were extracted using a nitric acid microwave digestion procedure and analyzed by Inductively Coupled Plasma/Mass Spectroscopy (ICP/MS).⁽²⁶⁾ Mixed standards were prepared in nitric acid daily for the target metals selected based on their prevalence in the turf materials determined by qualitative scans and potential adverse health effect. Quality assurance checks were run routinely.

The SVOCs were analyzed using a direct solid phase micro extraction (DI-SPME) to concentrate the semi-volatile organic analytes from 10 mL of the biofluid extract followed by GC/MS. The GC/MS ion trap was operated in the EI positive mode and scanned between 40 and 600 amu to obtain maximum information about each peak. Quantification of the PAHs was done by comparison to commercially purchased standards. For the SVOC characterization, the mass spectrum acquired from each analyte was matched to a mass spectrum from the NIST/EPA/NIH 2008 mass spectral library database of more than 64,000 compounds, with a >70% fit required for a positive identification. Approximately half the peaks were found to match an entry in the NIST library. The peaks with the top 10% area abundances were compared to the compounds listed in a series of toxicological databases (US EPA PALs, ATSDR Toxicology Profiles, ATSDR MRL 2010, CERCLA Priority Hazardous List 2007, EPA Final AEGLs, EPA Drinking Water Advisory, and Environment, Health and Safety Online Carcinogens) to identify potential compounds of concern. Of the several hundred compounds identified in the top 10% area abundances the only compound identified that was listed in any of the toxicological databases was toluene. Listings of the compounds in the various biofluids are given in the Supplementary Material. It includes a large number and variety of organic materials identified at very low concentrations but for which no hazard data are currently in toxicological databases used for regulatory purposes.

The nitric acid extraction was conducted by digesting the acid soluble fraction of approximately 0.2g of sample in a microwave pressure vessel containing 2mL of

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concentrated nitric acid under high temperature and pressure for 30 minutes. A total SVOC analysis was done by directly analyzing several grams of turf or infill by SPME coupled to GC/MS analysis.

2.3 Blanks for QA/QC

A single blank was run with each set of sample extracts. Since the salts used to prepare the artificial biofluids contained trace levels of metals, several of the blanks had detectable metal concentrations. To evaluate whether a blank correction was needed for any metal above the limit of detection the following criteria was used: if the sample value was less than twice the blank value then the sample concentration was replaced by twice the blank value, otherwise the blank value was subtracted from the sample extract concentration (see the Supplementary Material for the blank levels in the different extracts).

Blank samples of each biofluid were also analyzed for SVOCs using the same protocol as those used to extract turf samples. Compounds found to be present in the blank were not included in the list of compounds evaluated for toxicological properties. Standards spiked into blank samples were measured along with other figures of merit when the method was developed. The coefficient of variance (CV) was compound dependent as expected but ranged from 2.3 to 12%. The linearity for the compounds that were quantified were almost all 1 – 50 ppb and the method detection limits ranged from 0.3 to 1 ppb, all well below the quantitation of analyte when reported. Benzo(a) pyrene had a much higher detection limit (40 ppb) as it was not retained well on the fiber. While the expectation of homogeneity of a manufactured product may have been greater than observed, the measurement of a lower level analyte under very inhomogeneous extraction conditions was not unexpected. The CV for the method demonstrated that it was within expected analytical reproducibility.

2.4 Risk Assessment

Based upon the analytical results below, a risk assessment for potential metal exposure was conducted in accordance with standard EPA risk assessment guidance for non-cancerous health endpoints.^(27, 28) No risk assessment was conducted for the SVOCs, since no regulated SVOCs were detected in the bioextracts and in most circumstances the values were not quantifiable. Routes of exposure that were considered in this assessment included dermal, ingestion, and inhalation pathways. Values were calculated for field samples only, since they were considered the most representative estimate of exposure. Male and female exposure values were averaged. Exposure was assumed to occur 3 hours per day, 130 days a year, and across five age groups (age 6 to < 11 years; age 11 to < 16 years; age 16 to < 19 years; age 19 years to < 39 years). For the lead risk assessment we considered two age groups: 2 to < 6 years and age 6 to < 7 years. In order to be as conservative as possible, the largest measured concentrations of each analyte were used for the screening values. If all samples were below the limit of detection (LOD) the largest LOD value for that compound was used. EPA recommended age specific body weight were applied to each group to determine dermal, ingestion, and inhalation doses (age 6 to < 11 years, 31.8 kg; age 11 to < 16 years, 56.8 kg; age 16 to < 19 years 71.6 kg; age 19 years to < 39 years, 80 kg).⁽²⁸⁾

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Skin contact with the turf from sliding or running on the field was considered as the primary route of dermal exposure. Since dermal exposure can differ by the sport and the amount of equipment and clothing worn by athletes, soccer was considered as a worst case scenario for dermal exposure. Skin adherence factors used in this study were 0.04 mg/cm² (children playing) and 0.012 mg/cm² (adult soccer players).⁽²⁷⁾ The following surface area to body weight averages were used: children age 6 to < 11 years 352 cm²/kg; children age 11 to < 16 years 288 cm²/kg; children age 16 to < 19 years 257 cm²/kg; and adults age 19 years 246 cm²/kg.⁽²⁸⁾ Chemical specific skin absorption fractions used were: 0.01 for beryllium, chromium, copper, lead, magnesium, titanium, selenium, silver, and vanadium; 0.03 for arsenic; and 0.001 for cadmium.⁽²⁷⁾ Dermal reference doses were calculated by the product of the ingestion reference dose and the gastrointestinal absorption factor (arsenic 100%; cadmium 2.5%; chromium 2.5%; copper 67.5%; lead 35%; vanadium 2.6%).^(27, 29, 30)

Ingestion could be an important route of exposure to children since they have a greater propensity for hand-to-mouth contact and pica behavior compared to adults; although incidental ingestion by adults during sport related activities cannot be ignored. Ingestion rates used in this risk assessment were 50 mg/day for children and 20 mg/day for adults.⁽²⁸⁾

Based upon the study objectives and available resources, air samples were not collected in the laboratory or the field. Therefore, we relied on air measurements collected at artificial turf fields from previous studies to estimate the bio-accessible concentrations of metals for the risk assessment. Two studies were identified that published PM₁₀ (particles with an aerodynamic size <10 μm) concentrations.^(31, 14) One field in North Carolina was sampled for PM₁₀ at four different locations on two separate days. Concentrations ranged from 14.2 μg/m³ to 33.4 μg/m³ depending on the field location and day.⁽³¹⁾ Five fields in Connecticut were sampled and concentrations ranged from 4.5 μg/m³ to 16.5 μg/m³.⁽¹⁴⁾ To be conservative, we used the largest PM₁₀ concentration for the risk assessment (33.4 μg/m³). This value was then multiplied by the maximum concentration that was found in the lung bio-fluid extract for each metal which in most cases was the LOD. The 95th percentile male and female combined inhalation rate was used for each age strata: children age 6 to < 11 years 17.0 m³/day; children age 11 to < 16 years 19.3 m³/day; children age 16 to < 19 years 20.8 m³/day; and adults age 19 years 22.4 m³/day.⁽²⁸⁾ Inhalation reference doses were calculated from inhalation reference concentrations using standard EPA equations.⁽³²⁾

The EPA does not publish a reference dose for lead since toxicological effects can occur at low concentrations in children. To protect against permanent neurological effects the Centers for Disease Control and Prevention (CDC) recommends that children's (age 1 to 5 years old) blood lead levels (BLL) not exceed 5 μg/dL.⁽³³⁾ To predict BLL we used the EPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Version 1.1. The model only predicts BLL in children younger than 7 years old. We evaluated two exposure scenarios in this risk assessment: children potentially using artificial turf fields for soccer and other sports (6–7 years old); and younger children that who may also use the field for non-sporting activities (2–6 years old). To calculate BLLs, we used the maximum measured bioavailable lead concentration of 260 mg/kg, a PM₁₀ concentration of 33.4 μg/m³, exposure duration of 3 hours, and a soil ingestion rate of 50 mg/day for both age

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groups. No other sources of lead exposures were considered and default age specific ventilation rates were used.

3. Analytical Results

3.1 SVOCs

There were some differences in the LOD based on the mass of material extracted and the volume used of each artificial fluid. A larger volume was used for the digestive fluid since that is more representative of actual digestive tract conditions. In general, the detection limits for the various SVOCs and PAHs measured were between $<0.1 - <5$ mg/kg, $<0.01 - <0.5$ mg/kg and $<0.1 - <5$ mg/kg for the sweat, lung and saliva/gastric/intestinal fluid, respectively. The full listings of the SVOC compounds identified in each of the extracts of the turf samples based on our search for library matches of the mass spectra are given in supplemental materials.

For comparison with previous studies, sixteen PAHs were specifically targeted (Table II). With the exception of acenaphthylene and naphthalene, which were just above their detection limits in a small number of samples, all PAHs quantified in this study were below the LOD. Additionally, several SVOCs which had previously been observed in other turf studies and reported to be hazardous but not regulated in soil, were specifically searched for (benzothiazole, butylated hydroxyanisole, n-hexadecane, and 4-(tert-octyl) phenol).^(34, 12) Benzothiazole and 4-tert-octyl phenol, were found in the total extraction at 1.0 mg/kg and 0.2 mg/kg, respectively. The compound 4-tert-octyl phenol was present in the lung (0.2 mg/kg) and sweat (1.0 mg/kg) biofluids. Although, benzothiazole was not detected in any the biofluids, 2,2 benzothiazole, a dimer of benzothiazole, was identified at the 10 mg/kg in the digestive fluid. In addition, a similar compound Phenol, 2,5-bis(1,1-dimethylethyl)- which is used as a UV stabilizer and has environmental but not reported human toxicity was also present in the total extract at 10mg/kg.

The total extraction protocol released more organic compounds than were extracted by any individual biofluids. However, the amount of organic material extracted varied greatly across the different compounds. Of the three artificial biofluids, the artificial sweat fluid extracted more compounds, while the least number of organic compounds were present in the digestive fluid. This may be a result of the digestive fluid's acidic nature, though it did contain the organic compounds mucin, urea, and pepsin. The transfer between the different pHs, which was meant to replicate the digestive process, could also precipitate some larger organic compounds or cause them to adsorb to surfaces.

3.2 Metals

The range of metal concentrations (mg/kg) and the number of samples below the LOD are shown in Table III. The majority of the target metals in most samples were below the LOD (63%) with field samples having a larger percentage of censored observations (71%) compared to the new infill (60%), and new fiber samples (57%). Arsenic, beryllium, cadmium, selenium, and silver were below the limit of detection in all or nearly all the samples for the artificial bio-fluids and the nitric acid digestion. Lead had the smallest

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percentage of censored measurements (23%), followed by titanium (32%), and vanadium (38%).

Lead was detected in almost all field samples for digestive, sweat, and total extraction fluids with digestive fluid extract of one field sample as high as 260 mg/kg. Metal concentrations were not markedly different across the three different sample types (new infill, new fiber, field sample). However, one of the new turf fiber sample contained relatively large concentrations of chromium (820 mg/kg) and lead (4400 mg/kg) compared to the other samples tested. In general, chromium was not detected in the field samples with the majority of measurements below the LOD (71%) across all three bio-fluids and total extracts.

Concentrations found in the different bio-fluids extracts varied and were dependent on the individual metal and sample type. It was found that the nitric acid (50%) extraction yielded lower amounts of lead and cadmium than the digestive bio-fluids extract for several samples. To investigate whether these differences might be due to heterogeneity in the infill and turf material, one field sample, which had a two-fold discrepancy in lead loading between the two methods, was analyzed in triplicate. Two different extraction solutions were used- a 50% nitric acid solution and a more rigorous, destructive nitric acid method in which the infill material was completely digested. The results are given in Table IV and indicate that the variability of lead contained in the infill material is large and can span more than two orders of magnitude.

3.3 Risk Analyses

Based upon the above analytical results, risks were calculated for metals that were detected in at least 90% of the samples tested and had a reference dose. The estimated dermal (Table V), ingestion (Table VI), and inhalation (Table VII) dose for each age strata was calculated and compared to the reference dose. The quotient of estimated dose divided by the reference dose was calculated and is shown as the hazard quotient (HQ) (Table VIII). A HQ greater than 1 indicates the potential for an adverse non-cancerous health outcome. In general, for each exposure route, the estimated dose was orders of magnitude smaller than the reference dose. Across all routes of exposure the greatest risk was for children in the lowest age strata. Risk decreased as age increased, with adults having a very small risk compared to youngest age group evaluated.

Of all the exposure routes, dermal was generally found to be primary route of metal exposure. However, all dermal HQs were three orders of magnitudes less than 1. The inhalation route of exposure was found to be inconsequential for all metals due to poor solubility in lung fluid. The HQs for dermal, ingestion, and inhalation exposures were summed and presented in Table VI as the hazard index (HI). Like the HQ, a HI above 1 represents a potential for adverse health outcomes. No metals quantified in this study had a HI that approached 1 for any age group.

Figure 1 show the probability of a child having a BLL $\geq 5 \mu\text{g/dL}$ at different lung and gastrointestinal absorption rates using the maximum lead values measured in any biofluid. At a 100% absorption rate the probability of a child having a BLL $\geq 5 \mu\text{g/dL}$ was 22.5% (6–7 years old) and 34% (2–6 years old). At the EPA recommended gastrointestinal absorption

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rate (30%) and lung absorption rate (32%) there was less than a 0.5% chance of child's BLL exceeding 5 µg/dL.

4. Discussion

The major driving force for this study was concern over metal and SVOC exposures to adult athletes and children using artificial turf fields. The extraction procedures we used indicated that little of the PAHs and SVOCs present in the new infill material or field samples we collected were bio-accessible across the three biofluids used in this study. Almost every sample we tested was found to be below the LOD for PAHs and none of the levels found in the biofluids or the SPME total analysis exceeded the New Jersey Department of Environmental Protection's (NJDEP) soil cleanup criteria.⁽³⁵⁾ Therefore, the risk from long term exposure would be considered insignificant for PAHs.

Two SVOCs, 4-tert-octyl phenol and butylated hydroxytoluene (BHT), were readily found in the lung and sweat extracts. BHT has few reported adverse toxicological effect and is used as a common component of cosmetics and as a food additive.⁽³⁶⁾ BHT and 4-tert-octyl phenol are high volume production compounds and are used in the formation of rubber. They are currently not regulated or present in the toxicological databases searched.^(37, 38) Therefore, exposure to those compounds is not expected to be a hazardous above other common environmental exposures.

Concentrations of the targeted SVOCs, including PAHs, measured in the field samples in this study were lower than levels that have been previously reported for actual fields or artificial turf products.^(39, 9) Zhang et al. (2008) quantified a similar group of PAHs at eight turf fields across New York State. They reported total PAH levels as high as 38.15 mg/kg in the total extract, while the highest total PAH concentration in this study was 2.48 mg/kg.⁽⁹⁾ A second study investigating total PAH content in unused crumb rubber material found concentrations approximately an order of magnitude larger than our study.⁽³⁹⁾ These differences in reported PAH concentrations may be due to the age of the fields sampled, or differences in the new products that were used in the current study. In the New York State study, the authors found a decrease in PAH concentrations as the field age increased, with highest concentrations found within a few months of the turf being installed.⁽⁹⁾ All fields sampled in this study were installed more than two years prior to sampling.

Metals were detected in a large number of biofluids and total extracts. Nevertheless, for almost all the metals we evaluated the risk from exposure was small and below EPA criterion. Excluding lead, all Hazard Indices were three order of magnitude smaller than 1 across all age strata. Assuming exposure was an additive function, the hazard associated with metal exposure would still be inconsequential. Although cancerous health endpoints were not the focus of this study, cancer risk was calculated for metals that had cancer slope factors (arsenic, cadmium, chromium, and lead). The risk of cancer from exposure to all carcinogenic metals compounds was less than 1 chance in 1,000,000 and therefore risk was considered negligible.

One field sample did contain a high lead level (260 mg/kg) which was on the same order of magnitude as the NJ DEP cleanup value (400 mg/kg). Based on National Health and

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Nutrition Examination Survey (NHANES) only 2.5% of children (age 1–5 years old) in the US have BLLs exceeding 5 µg/dL.⁽³³⁾ Using the maximum lead values obtained from the field measurements, there was 2.5% probability that child's BLL would exceed 5 µg/dL at a lung and gastrointestinal absorption rate of 55% in children 6–7 years old and 46% in children 2–6 years old. Although these values are larger than the EPA recommended absorption rate (32% and 30% lung and gastrointestinal respectively) our study used artificial bio-fluids which more closely estimates the metal's solubility in the body compared to total extraction methods. Excluding the single high lead measurement and using the mean lead levels of the six other fields, there was a near 0% probability of a child's BLL exceeding 5 µg/dL. However, in both exposure scenarios other sources of lead were not considered. Since it is possible that children may be exposed to potentially high concentrations of lead while using artificial turf fields we recommend at a minimum all infill and fibers should be certified for low or no lead content prior to purchase and installation.

We observed a large range in lead measurements within and between fields we sampled. When the high lead field was re-sampled, all measurements were found to be an order of magnitude smaller than the initial measurement. This is likely due to large amounts of variability in the composition of the crumb rubber and not due to the analytical methods. Previous studies have also found a large degree of variability in lead measurements from artificial turf fields.^(31, 9) In North Carolina, the US Environmental Protection Agency sampled three fields for lead multiple times. Total extractable lead concentrations in the crumb rubber infill ranged from 11 to 61 mg/kg between samples, with up to a fourfold difference within samples.⁽³¹⁾ In New York State, concentrations of lead were less than 6 mg/kg in four field samples, however one field had lead concentrations in excess of 50 mg/kg.⁽⁹⁾ Based on results from this study and others, the heterogeneity of the turf and crumb rubber infill can be large and multiple samples from the same field may be needed to accurately characterize lead exposure.

One new fiber sample did contain large concentration of lead (4400 mg/kg) and chromium (820 mg/kg) which exceeded the NJ DEP soil cleanup levels (400 mg/kg and 20 mg/kg respectively). This finding is consistent with another study that sampled turf fibers for lead and found concentrations as large as 700 mg/kg.⁽³¹⁾ It is likely that lead-chromate was used as the colorization agent in the turf material, though the Pb/Cr ratio was 5.38, which exceeds the theoretical ratio of lead chromate of 3.98; which may be suggestive of additional lead compounds present in the pigment. The presence of lead and chromium in a new turf material reinforces the need to independently check new fiber materials for the presence of lead-chromate paint before purchase and installation. Further, use of that type of coloring agent should be banned from use in turf/infill. As the turf material degrades from weathering the lead could be released, potentially exposing young children.

This study adds to the growing volume of literature regarding potential exposure to metals and SVOCs from synthetic turf fields. We sampled seven fields, with varying age throughout NJ, as well as unused crumb rubber and fiber samples. Our study is unique in that it considered the bio-accessibility of PAHs, SVOCs, and metal for dermal, ingestion, and inhalation exposure using artificial body fluids for various samples. Results from our study are consistent and expands upon previous studies that have found small concentrations

of SVOCs and metals in the infill and fiber material. In addition to quantitative measurements we qualified the risk to metals from chronic exposure across different age strata.

Limitations to this study include possible selection bias and the small number of fields analyzed for comparisons. Since weathering and temperature has been shown to influence concentrations, field measurements may only be generalizable to areas and ages of the fields similar to our study. Additionally, a large amount of variability was found between field samples and different locales may use older or another version of crumb rubber in fill that contains different concentrations of compounds that may still be concern.

5. Conclusions

A comprehensive study was conducted to examine what could be extracted in biofluids from infill and turf products that have been placed on fields and the associated risk from metal and SVOC exposure to children and adult athletes. The extraction procedures included total extraction for metals and SVOCs as well as synthetic sweat, lung, and digestive fluids. Concentrations of PAHs were generally below the limit of detection for all targeted compounds. The SVOCs identified based on library matches of their mass spectra were not present in toxicological databases evaluated and many are ubiquitous part of consumer products. Similarly, the metal concentrations measured in field samples indicate that the risk would be *de minimus* among all populations expected to use artificial turf fields. However, since there were detectable levels of lead, it is prudent to reemphasize the need to avoid lead-based pigments in these materials as coloring agents and ensure that lead is not in the turf prior to purchase and installation. In the future, the types of bio-accessibility studies conducted as part of these experiments should be completed for all new turf/infill products.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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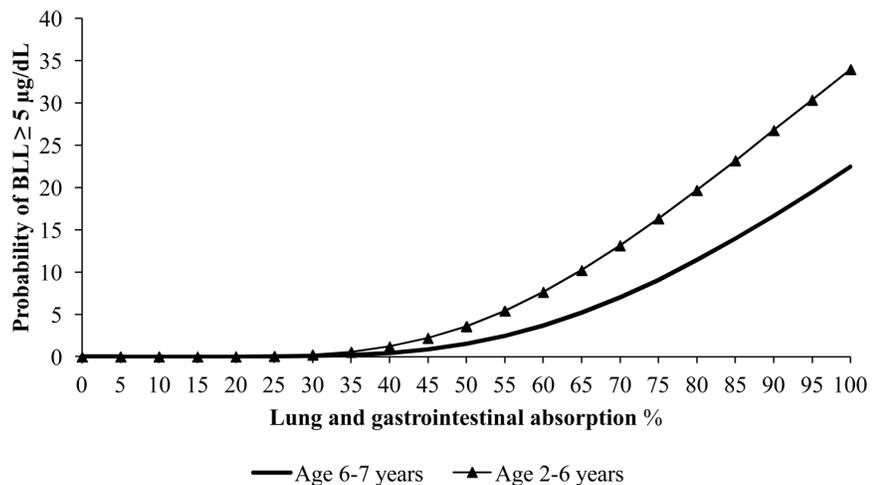


Figure 1. Lung and gastrointestinal absorption % vs. probability of blood lead level (BLL) $\geq 5 \mu\text{g/dL}$ for each age group

Table I

Composition of the Synthetic Biofluids

Synthetic Biofluid	Composition
Ingestion – Digestive Fluid	Saliva: 4mM Calcium Chloride Dehydrate, 0.4% w/v Mucin, 5mM Potassium Chloride, 7mM Sodium Chloride, 4mM Sodium Phosphate Dibasic, and 17mM Urea Gastric: 30mM Sodium Chloride, 84mM Hydrochloric Acid, and 0.32%(w/v) Pepsin Intestinal: 200mM Sodium Bicarbonate
Dermal – Sweat	340mM Sodium Chloride, 330mM Ammonium Chloride, 83mM Urea, 170mM Lactic Acid, and 42mM Glacial Acetic Acid
Inhalation - Lung	10mM Magnesium Chloride, 150mM Sodium Chloride, 4mM Potassium Chloride, 1mM Disodium Phosphate, 5mM Sodium Sulfate, 25mM Calcium Chloride, 7mM Sodium Acetate, 24mM Sodium Bicarbonate, 3mM Sodium Citrate and 0.20% 9(w/v) Dipalmitoyl Lecithin

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Table II

Maximum Concentration (mg/kg) of PAHs specifically quantified in the study

Compound	Sweat	Lung	Digestive	Total Extract
Acenaphthene	<0.11	<0.05	<0.56	<0.03
Acenaphthylene	<0.17	<0.09	<0.68	2.48
Anthracene	<0.08	<0.04	<0.42	<0.02
Azobenzene	<0.49	<0.24	<2.5	<0.12
Benzo[a] anthracene	<0.31	<0.16	<1.7	<0.08
Benzo[a]pyrene	<1.4	<0.74	<7.6	<0.37
Benzo[b] fluoranthene	<1.2	<0.56	<6.4	<0.31
Benzo[k] fluoranthene	<1.9	<0.69	<7.2	<0.34
Carbazole	<0.35	<0.18	<1.9	<0.09
Chrysene	<1.1	<0.54	<5.5	<0.27
Dibenzo[a,h] anthracene	<2.0	<0.98	<10	<0.49
Fluoranthene	<0.11	<0.06	<0.62	<0.03
Fluorene	<.07	<0.03	<0.35	<0.02
Naphthalene	<0.03	<0.02	<0.12	0.27
Phenanthrene	<0.10	<0.05	<0.52	<0.02
Pyrene	<0.10	<0.05	<0.52	<0.02

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Table III

Number and range (mg/kg) of metal concentrations by extract

Metal	Sweat Bio-fluid Extract			New Infill			New Fiber			Field Sample		
	n (< LOD)	Range (mg/kg)	n (< LOD)	n (< LOD)	Range (mg/kg)	n (< LOD)	n (< LOD)	Range (mg/kg)	n (< LOD)	Range (mg/kg)	n (< LOD)	Range (mg/kg)
Arsenic	9 (9)	<0.50	7 (7)	7 (7)	<0.10	7 (1)	7 (1)	1.4–1.7				
Beryllium	9 (9)	<0.20	7 (7)	7 (7)	<0.20	7 (7)	7 (7)	<0.20				<0.20
Cadmium	9 (8)	<0.090–0.11	7 (7)	7 (7)	<0.030	7 (7)	7 (7)	<0.20				<0.20
Chromium	9 (0)	0.70–1.2	7 (0)	7 (0)	0.10–1.3	7 (1)	7 (1)	2.1–2.7				2.1–2.7
Copper	9 (5)	<0.080–0.54	7 (0)	7 (0)	0.030–1.6	7 (1)	7 (1)	1.8–2.2				1.8–2.2
Lead	9 (0)	0.090–1.6	7 (0)	7 (0)	0.030–1.2	7 (1)	7 (1)	<0.20–1.5				<0.20–1.5
Magnesium	9 (2)	<7.0–980	7 (0)	7 (0)	3.3–18	7 (7)	7 (7)	<10				<10
Selenium	9 (9)	<1.9	7 (7)	7 (7)	<0.60	7 (7)	7 (7)	<0.70				<0.70
Silver	9 (9)	<0.10	7 (7)	7 (7)	<0.060	7 (7)	7 (7)	<0.70				<0.70
Titanium	9 (0)	0.60–1.3	7 (0)	7 (0)	0.10–1.1	7 (0)	7 (0)	3.2–4.0				3.2–4.0
Vanadium	9 (0)	6.0–21	7 (0)	7 (0)	0.50–1.6	7 (0)	7 (0)	15–18				15–18
Digestive Bio-fluid Extract												
Arsenic	6 (3)	<0.10–0.48	7 (7)	7 (7)	<0.040	7 (7)	7 (7)	<3.0				<3.0
Beryllium	6 (6)	<0.40	7 (7)	7 (7)	<0.40	7 (7)	7 (7)	<0.40				<0.40
Cadmium	6 (6)	<4.0	7 (7)	7 (7)	<0.30	7 (0)	7 (0)	2.5–11				2.5–11
Chromium	6 (6)	<7.0	7 (6)	7 (6)	<0.60–0.74	7 (7)	7 (7)	<6.0				<6.0
Copper	6 (2)	<20–32	7 (6)	7 (6)	<1.0–1.6	7 (7)	7 (7)	<20				<20
Lead	6 (0)	5.3–66	7 (3)	7 (3)	<0.30–4.7	7 (0)	7 (0)	2.5–260				2.5–260
Magnesium	6 (5)	<1000–4600	7 (7)	7 (7)	<90	7 (7)	7 (7)	<900				<900
Selenium	6 (5)	<0.90–1.5	7 (7)	7 (7)	<0.10	7 (7)	7 (7)	<2.0				<2.0
Silver	6 (3)	<0.20–0.23	7 (7)	7 (7)	<0.20	7 (6)	7 (6)	<0.40–0.90				<0.40–0.90
Titanium	6 (6)	<10	7 (7)	7 (7)	<0.10	7 (7)	7 (7)	<10				<10
Vanadium	6 (6)	<1.0	7 (3)	7 (3)	<0.10–0.12	7 (7)	7 (7)	<1.0				<1.0
Lung Bio-fluid Extract												
Arsenic	9 (9)	<0.50	4 (4)	4 (4)	<0.20	7 (7)	7 (7)	<0.050				<0.050

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Metal	Sweat Bio-fluid Extract					
	New Infill		New Fiber		Field Sample	
	n (< LOD)	Range (mg/kg)	n (< LOD)	Range (mg/kg)	n (< LOD)	Range (mg/kg)
Beryllium	9 (9)	<0.50	4 (4)	<0.20	7 (7)	<0.030
Cadmium	9 (9)	<0.20	4 (4)	<0.090	7 (7)	<0.090
Chromium	9 (7)	<0.20-0.66	4 (1)	<0.090-0.12	7 (7)	<0.050
Copper	9 (7)	<0.40-0.58	4 (3)	<0.2-2.0	7 (7)	<0.20
Lead	9 (7)	<0.20-0.26	4 (2)	<0.02-0.61	7 (5)	<0.020-0.023
Magnesium	9 (0)	650-970	4 (0)	77-300	7 (7)	<100
Selenium	9 (9)	<2.0	4 (4)	<0.90	7 (7)	<0.10
Silver	9 (9)	<0.50	4 (4)	<0.20	7 (7)	<0.10
Titanium	9 (0)	1.5-6.7	4 (0)	0.20-0.96	7 (7)	<0.40
Vanadium	9 (0)	0.65- 3.0	4 (0)	0.39-1.5	7 (7)	<0.70
Nitric Acid Digestion						
Arsenic	9 (8)	<0.70-0.80	8 (5)	<0.040-4.0	7 (7)	<0.70
Beryllium	9 (9)	<0.70	8 (6)	<0.040-0.51	7 (7)	<0.70
Cadmium	9 (7)	<0.70-1.1	8 (8)	<0.50	7 (7)	<0.70
Chromium	9 (2)	<0.70-16	8 (0)	0.34-820	7 (5)	<0.70-0.92
Copper	9 (1)	<0.70-36	8 (0)	0.69-110	7 (0)	8.8-59
Lead	9 (3)	<0.010-17	8 (0)	0.53-4400	7 (0)	4.1-140
Magnesium	9 (2)	<7.0-7800	8 (2)	<30-12000	7 (3)	<70-160
Selenium	9 (9)	<1.0	8 (6)	<0.10-2.9	7 (6)	<0.60-1.3
Silver	9 (9)	<10	8 (8)	<8.0	7 (7)	<10
Titanium	9 (1)	<0.70-18	8 (0)	0.81-820	7 (0)	1.9-9.6
Vanadium	9 (3)	<0.10-2.1	8 (8)	<40	7 (1)	<0.80-0.74

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Table IV

Repeated measurements of field sample (mg/kg)

Metal	Nitric Acid (50%) Extract			Destructive Nitric Acid		
	A	B	C	A	B	C
Arsenic	0.800*	0.800*	0.800*	1.40	1.86	1.57
Beryllium	0.200*	0.200*	0.200*	0.100*	0.100*	0.100*
Cadmium	0.100*	0.144	0.22	0.446	0.455	0.452
Chromium	0.503	1.15	0.832	1.84	1.85	1.16
Copper	5.87	7.58	8.73	9.48	15.8	5.66
Lead	0.362	19.1	2.29	6.68	16.2	7.52
Magnesium	50.0	56.6	60.1	17.9	17.5	13.8
Selenium	0.800*	0.800*	0.800*	5.72	8.34	6.1
Silver	0.300*	0.300*	0.300*	0.200*	0.200*	0.200*
Titanium	4.12	6.07	3.09	16.7	15.1	19.2
Vanadium	0.338	0.387	0.300*	1.62	1.71	1.44

* Below the LOD

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Table V

Dermal reference dose (RfD), dermal average daily dose, and hazard quotient (HQ) by metal and age group

Metal	RfD* mg/kg-day	Age 6 to < 11 years		Age 11 to < 16 years		Age 16 to < 19 years		Age 19 years	
		Dose mg/kg-day	HQ	Dose mg/kg-day	HQ	Dose mg/kg-day	HQ	Dose mg/kg-day	HQ
Arsenic	3.00E-04 ^a	2.56E-07	8.53E-04	2.09E-07	6.97E-04	1.86E-07	6.20E-04	5.37E-08	1.79E-04
Cadmium	5.00E-05 ^a	1.00E-09	2.00E-05	8.21E-10	1.64E-05	7.30E-10	1.46E-05	2.10E-10	4.21E-06
Chromium	7.80E-05 ^a	1.35E-07	1.73E-03	1.11E-07	1.42E-03	9.86E-08	1.26E-03	2.84E-08	3.64E-04
Copper	2.70E-02 ^b	1.10E-07	4.07E-06	9.03E-08	3.34E-06	8.03E-08	2.97E-06	2.32E-08	8.58E-07
Vanadium	2.60E-04 ^c	9.02E-07	3.47E-03	7.39E-07	2.84E-03	6.57E-07	2.53E-03	1.89E-07	7.29E-04

* Dermal reference doses were derived from the product of the oral reference dose and the gastrointestinal absorption fraction:

^aEPA Integrated Risk Information System chronic oral reference dose

^bEPA Health Effects Assessment Summary Tables chronic oral reference dose

^cAgency for Toxic Substances and Disease Registry Minimal Risk Levels intermediate oral dose.

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Table VI

Ingestion reference dose (RfD), ingestion average daily dose, and hazard quotient (HQ) by metal and age group

Metal	RfD* mg/kg-day	Age 6 to < 11 years		Age 11 to < 16 years		Age 16 to < 19 years		Age 19 years	
		Dose mg/kg-day	HQ	Dose mg/kg-day	HQ	Dose mg/kg-day	HQ	Dose mg/kg-day	HQ
Arsenic	3.00E-04 ^a	2.10E-07	7.00E-04	1.18E-07	3.93E-04	9.33E-08	3.11E-04	3.34E-08	1.11E-04
Cadmium	1.00E-03 ^a	7.70E-07	7.70E-04	4.31E-07	4.31E-04	3.42E-07	3.42E-04	1.22E-07	1.22E-04
Chromium	3.00E-03 ^a	4.20E-07	1.40E-04	2.35E-07	7.83E-05	1.87E-07	6.23E-05	6.68E-08	2.23E-05
Copper	4.00E-02 ^b	1.40E-06	3.50E-05	7.84E-07	1.96E-05	6.22E-07	1.56E-05	2.23E-07	5.58E-06
Vanadium	1.00E-02 ^c	1.40E-07	1.40E-05	7.84E-08	7.84E-06	6.22E-08	6.22E-06	2.23E-08	2.23E-06

* Oral reference doses are from the following sources:

^aEPA Integrated Risk Information System chronic oral reference dose

^bEPA Health Effects Assessment Summary Tables chronic oral reference dose

^cAgency for Toxic Substances and Disease Registry Minimal Risk Levels intermediate oral dose.

Table VII

Inhalation reference dose (RfD), inhalation average daily dose, and hazard quotient (HQ) by metal and age group

Metal	RfD* mg/kg-day	Age 6 to < 11 years		Age 11 to < 16 years		Age 16 to < 19 years		Age 19 years	
		Dose mg/kg-day	HQ	Dose mg/kg-day	HQ	Dose mg/kg-day	HQ	Dose mg/kg-day	HQ
Arsenic	4.29E-06 ^a	3.98E-11	9.29E-06	2.53E-11	5.90E-06	1.20E-11	2.81E-06	2.08E-11	4.86E-06
Cadmium	2.86E-06 ^b	7.17E-11	2.51E-05	4.55E-11	1.59E-05	2.17E-11	7.58E-06	5.16E-13	1.81E-07
Chromium	2.86E-05 ^c	3.98E-11	1.39E-06	2.53E-11	8.85E-07	1.20E-11	4.21E-07	2.87E-13	1.00E-08
Copper	2.86E-02 ^d	1.59E-10	5.57E-09	1.01E-10	3.54E-09	4.81E-11	1.68E-09	1.15E-12	4.02E-11
Vanadium	2.86E-05 ^b	5.57E-10	1.95E-05	3.54E-10	1.24E-05	1.68E-10	5.90E-06	4.02E-12	1.41E-07

* Inhalation reference doses were derived from the following reference concentrations:

^a California EPA chronic inhalation reference concentration

^b ATSDR chronic inhalation reference concentration

^c EPA Reference Concentration for Chronic Inhalation Exposure

^d California EPA acute inhalation reference concentration

Table VIII

Hazard index (HI) by metal and age group

Metal	Age 6 to < 11 years		Age 11 to < 16 years		Age 16 to < 19 years		Adult	
	HI	HI	HI	HI	HI	HI	HI	HI
Arsenic	1.56E-03	1.10E-03	9.34E-04	2.95E-04	9.34E-04	2.95E-04	2.95E-04	2.95E-04
Cadmium	8.15E-04	4.63E-04	3.64E-04	1.26E-04	3.64E-04	1.26E-04	1.26E-04	1.26E-04
Chromium	1.87E-03	1.50E-03	1.32E-03	3.87E-04	1.32E-03	3.87E-04	3.87E-04	3.87E-04
Copper	3.91E-05	2.29E-05	1.86E-05	6.44E-06	1.86E-05	6.44E-06	6.44E-06	6.44E-06
Vanadium	3.50E-03	2.86E-03	2.54E-03	7.31E-04	2.54E-03	7.31E-04	7.31E-04	7.31E-04

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Appendix E2

Modeling Multi-Route Exposure to Chemicals Released from Synthetic Turf Materials



Modeling Multi-Route Exposure to Chemicals Released from Synthetic Turf Materials

Artificial biofluid extractions of synthetic turf materials may be used to simulate ingestion, inhalation, and dermal and eye contact exposures to chemicals released from these materials. Examples of extraction procedures and composition of extraction fluids are provided below.

Ingestion Exposure Modeling

A series of artificial gastrointestinal fluids may be used to simulate the transfer of chemicals from crumb rubber or artificial turf into the body following ingestion of the material. 200 mg crumb rubber or a 4 cm x 4 cm piece of synthetic turf will be mechanically agitated in 8 mL of artificial saliva with mechanical agitation at 30 rpm at a representative body temperature of 37°C for 5 minutes to simulate the duration in the mouth and esophagus, before the addition of 100 mL artificial gastric juice to the mixture components. The combination of the gastric juice and saliva will be allowed to incubate for a duration which would be representative of the residence time in the stomach. Various references (Pavilonis, *et al.*, 2014 and Hamel *et al.*, 2009) use a 2-hour duration with mechanical agitation at 30 rpm at a representative body temperature of 37°C to simulate stomach action. After simulating residence time in the stomach, 100 ml of artificial intestinal juice would be combined with the saliva, gastric juice, and sample mixture, to simulate these contents moving into the intestines. Various references (Pavilonis, *et al.*, 2014 and Hamel *et al.*, 2009) use a 2-hour duration with mechanical agitation at 30 rpm at a representative body temperature of 37°C to simulate intestinal action. An example of composition for each gastrointestinal biofluid is shown in the following table.

Artificial Gastrointestinal Fluid Compositions (Pavilonis, <i>et al.</i>, 2014)		
Saliva	Gastric Juice	Intestinal Fluid
4 mM calcium chlorate dehydrate	30 mM sodium chloride	200 mM sodium bicarbonate
0.4% (w/v) mucin	84 mM hydrochloric acid	
5 mM potassium chloride	0.32% (w/v) pepsin	
7 mM sodium chloride		
4 mM sodium phosphate dibasic		
17 mM urea		

Inhalation Exposure Modeling

An artificial lung secretion may be used to simulate the transfer of chemicals from airborne particulate matter into lung tissues following inhalation. New crumb rubber will be extracted at size of manufacture; field particle samples, which may contain smaller particles than newly manufactured material, will be collected on glass fiber filters and the filter will be extracted. 100 mg of crumb rubber or a piece of glass fiber filter will be extracted in 10 mL of artificial lung secretion for a 24-hour duration with mechanical agitation at 30 rpm at a representative body temperature of 37°C (Pavilonis, et al 2014). An example of artificial lung secretion composition is shown in the following table.

Artificial Lung Fluid Composition (Pavilonis, et al., 2014)	
10 mM magnesium chloride	25 mM calcium chloride
150 mM sodium chloride	7 mM sodium acetate
4mM potassium chloride	24 mM sodium bicarbonate
1 mM disodium phosphate	3mM sodium citrate
5 mM sodium sulfate	0.20% (w/v) dipalmitoyl lectin

Dermal Exposure Modeling

An artificial sweat may be used to simulate the transfer of chemicals from crumb rubber or artificial turf into the skin after dermal contact. 200 mg crumb rubber or a 4 cm x 4 cm piece of synthetic turf will be extracted in 20 mL of artificial sweat for a 1-hour duration with mechanical agitation at 30 rpm at a representative body temperature of 37°C (Pavilonis, et al 2014). An example of sweat composition is presented in the following table.

Artificial Sweat Composition (Pavilonis, et al., 2014)	
340 mM sodium chloride	170 mM lactic acid
330 mM ammonium chloride	42 mM glacial acetic acid
83 mM urea	

Eye Contact

An artificial lacrimal fluid may be used to simulate the transfer of chemicals from fine turf dust particles into the eye following incidental eye contact of these fine dust particles. An example of artificial lacrimal fluid composition is provided in the following table.

Artificial Lacrimal Fluid Composition (Tiffany, 1997)	
110.5 mM sodium chloride	27 mM sodium bicarbonate
4.3 mM potassium chloride	2.3 mM calcium chloride
0.2 mM magnesium chloride	0.8 mg/mL glucose
40 – 48 mg/mL albumen	

Reference

Hamel S C, Ellickson KM, Lioy PJ (1999). "The estimation of the bioaccessibility of heavy metals in soils using artificial biofluids by two novel methods: mass-balance and soil recapture." *The Science of the Total Environment* **243/244**: 273-283.

Pavilonis BT, Weisel CP, Buckley B and Lioy PJ (2013). Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers. *Risk Anal* **34**:44-55.

<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038666/pdf/nihms565643.pdf>

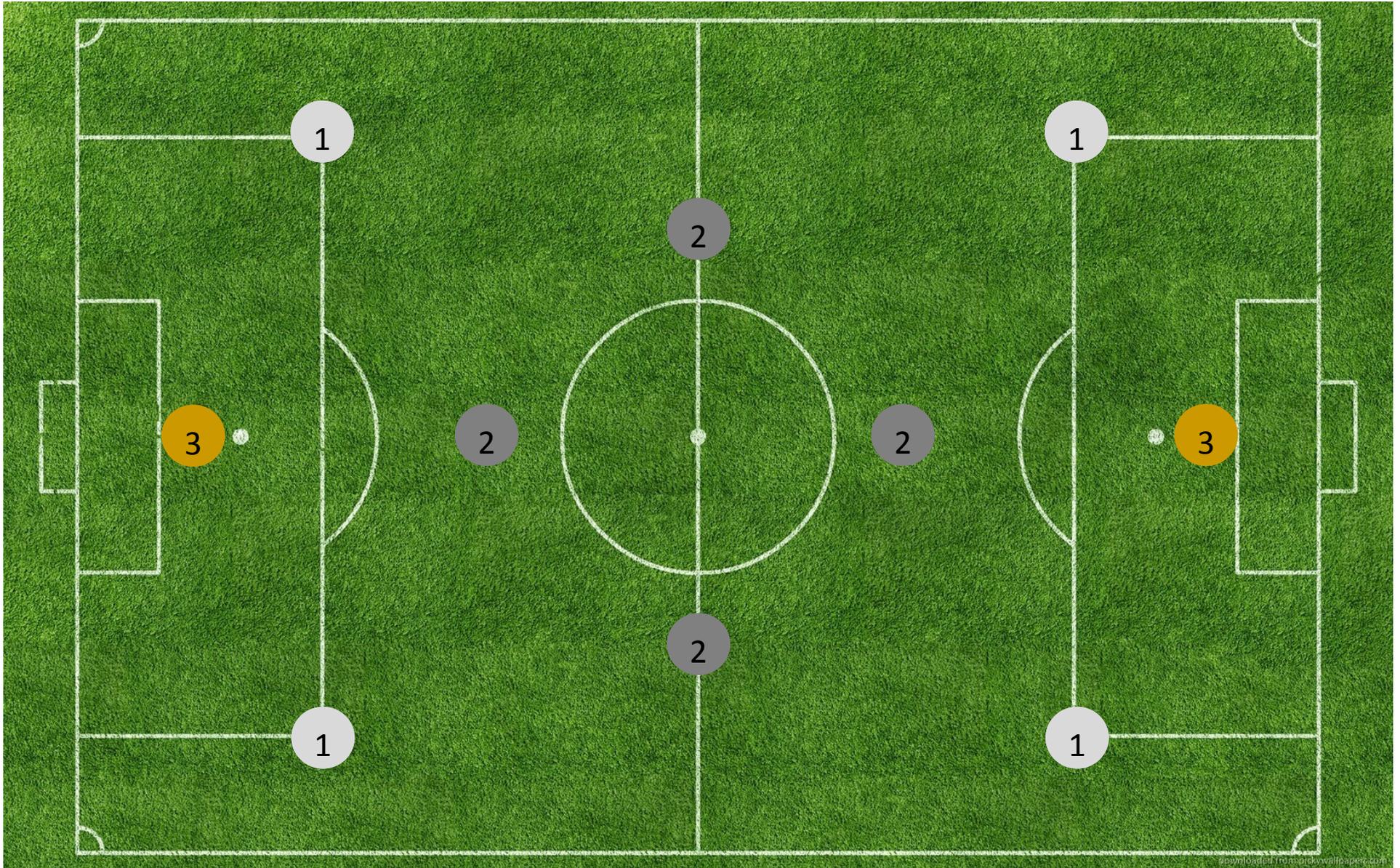
Tiffany JM, (1997) Tears and conjunctiva in Biochemistry of the eye (ed. J.J. Harding), Chapman and Hall, London.

(<http://kirschner.med.harvard.edu/files/bionumbers/Composition%20of%20lacrimal%20fluid.pdf>)

Appendix F

An Example of Soccer Field Sampling Locations

Appendix F. An Example of Soccer Field Sampling Locations



Appendix G

California Climate Zones and Field Locations

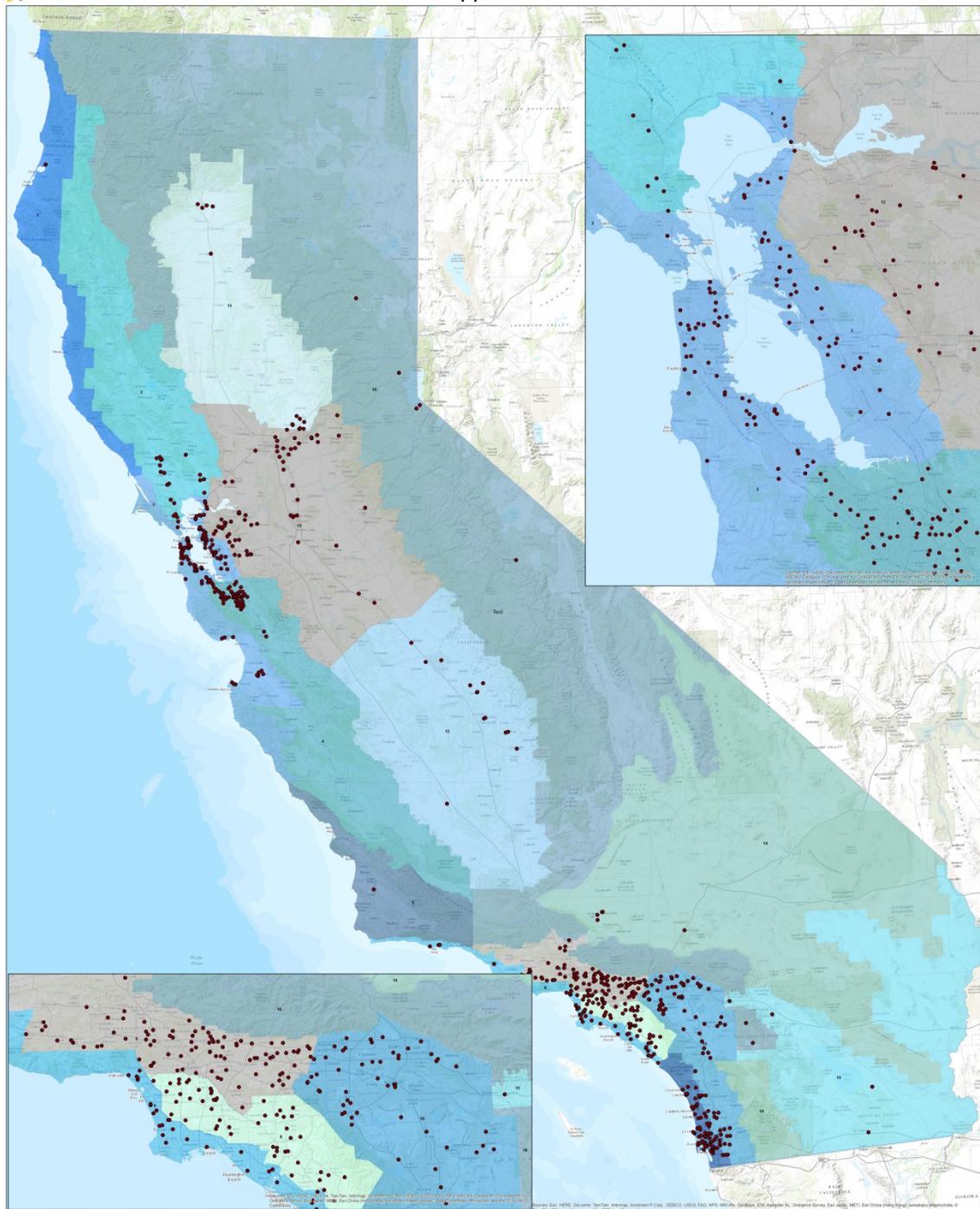


Figure illustrates the 16 California Building Climate Zone Areas (updated February 2015)¹ developed by the California Energy Commission. Locations of 902 synthetic turf field containing crumb rubber infill are shown on the map; the information is provided by several major field installers in California.

¹ http://www.energy.ca.gov/maps/renewable/building_climate_zones.html

Appendix H
US EPA Standard Methods
For Targeted Chemical Analyses



US EPA Standard Methods for Targeted Chemical Analyses

EPA Method 8260B: Volatile Organic Compounds By Gas Chromatography/Mass Spectrometry (GC/MS)

EPA Method TO-15: Determination of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography/Mass Spectrometry (GC/MS)

EPA Method TO-17: Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling Onto Sorbent Tubes

EPA Method 8270D: Semivolatile Organic Compounds By Gas Chromatography/Mass Spectrometry (GC/MS)

EPA Method TO-13A: Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)

CAM-17:

EPA Method 200.7: Trace Elements In Water, Solids, And Biosolids By Inductively Coupled Plasma-Atomic Emission Spectrometry

EPA Method 6010C: Inductively Coupled Plasma-Atomic Emission Spectrometry for Trace Elements in Solution

EPA Method 245.1: Determination Of Mercury In Water By Cold Vapor Atomic Absorption Spectrometry

EPA Method 7470A: Mercury in Liquid Waste (Manual Cold-Vapor Technique)

EPA Method 7471B: Mercury In Solid Or Semisolid Waste (Manual Cold-Vapor Technique)

US EPA Method 8260B

Volatile Organic Compounds By Gas Chromatography/ Mass Spectrometry (GC/MS)

<http://www3.epa.gov/epawaste/hazard/testmethods/sw846/pdfs/8260b.pdf>

METHOD 8260B
VOLATILE ORGANIC COMPOUNDS BY GAS CHROMATOGRAPHY/
 MASS SPECTROMETRY (GC/MS)

1.0 SCOPE AND APPLICATION

1.1 Method 8260 is used to determine volatile organic compounds in a variety of solid waste matrices. This method is applicable to nearly all types of samples, regardless of water content, including various air sampling trapping media, ground and surface water, aqueous sludges, caustic liquors, acid liquors, waste solvents, oily wastes, mousses, tars, fibrous wastes, polymeric emulsions, filter cakes, spent carbons, spent catalysts, soils, and sediments. The following compounds can be determined by this method:

Compound	CAS No. ^b	Appropriate Preparation Technique ^a					Direct Inject.
		5030/ 5035	5031	5032	5021	5041	
Acetone	67-64-1	pp	c	c	nd	c	c
Acetonitrile	75-05-8	pp	c	nd	nd	nd	c
Acrolein (Propenal)	107-02-8	pp	c	c	nd	nd	c
Acrylonitrile	107-13-1	pp	c	c	nd	c	c
Allyl alcohol	107-18-6	ht	c	nd	nd	nd	c
Allyl chloride	107-05-1	c	nd	nd	nd	nd	c
Benzene	71-43-2	c	nd	c	c	c	c
Benzyl chloride	100-44-7	c	nd	nd	nd	nd	c
Bis(2-chloroethyl)sulfide	505-60-2	pp	nd	nd	nd	nd	c
Bromoacetone	598-31-2	pp	nd	nd	nd	nd	c
Bromochloromethane	74-97-5	c	nd	c	c	c	c
Bromodichloromethane	75-27-4	c	nd	c	c	c	c
4-Bromofluorobenzene (surr)	460-00-4	c	nd	c	c	c	c
Bromoform	75-25-2	c	nd	c	c	c	c
Bromomethane	74-83-9	c	nd	c	c	c	c
n-Butanol	71-36-3	ht	c	nd	nd	nd	c
2-Butanone (MEK)	78-93-3	pp	c	c	nd	nd	c
t-Butyl alcohol	75-65-0	pp	c	nd	nd	nd	c
Carbon disulfide	75-15-0	pp	nd	c	nd	c	c
Carbon tetrachloride	56-23-5	c	nd	c	c	c	c
Chloral hydrate	302-17-0	pp	nd	nd	nd	nd	c
Chlorobenzene	108-90-7	c	nd	c	c	c	c
Chlorobenzene-d ₅ (IS)		c	nd	c	c	c	c
Chlorodibromomethane	124-48-1	c	nd	c	nd	c	c
Chloroethane	75-00-3	c	nd	c	c	c	c
2-Chloroethanol	107-07-3	pp	nd	nd	nd	nd	c
2-Chloroethyl vinyl ether	110-75-8	c	nd	c	nd	nd	c
Chloroform	67-66-3	c	nd	c	c	c	c
Chloromethane	74-87-3	c	nd	c	c	c	c
Chloroprene	126-99-8	c	nd	nd	nd	nd	c
3-Chloropropionitrile	542-76-7	l	nd	nd	nd	nd	pc

(continued)

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Compound	CAS No. ^b	Appropriate Preparation Technique ^a					Direct Inject.
		5030/ 5035	5031	5032	5021	5041	
Crotonaldehyde	4170-30-3	pp	c	nd	nd	nd	c
1,2-Dibromo-3-chloropropane	96-12-8	pp	nd	nd	c	nd	c
1,2-Dibromoethane	106-93-4	c	nd	nd	c	nd	c
Dibromomethane	74-95-3	c	nd	c	c	c	c
1,2-Dichlorobenzene	95-50-1	c	nd	nd	c	nd	c
1,3-Dichlorobenzene	541-73-1	c	nd	nd	c	nd	c
1,4-Dichlorobenzene	106-46-7	c	nd	nd	c	nd	c
1,4-Dichlorobenzene-d ₄ (IS)		c	nd	nd	c	nd	c
cis-1,4-Dichloro-2-butene	1476-11-5	c	nd	c	nd	nd	c
trans-1,4-Dichloro-2-butene	110-57-6	pp	nd	c	nd	nd	c
Dichlorodifluoromethane	75-71-8	c	nd	c	c	nd	c
1,1-Dichloroethane	75-34-3	c	nd	c	c	c	c
1,2-Dichloroethane	107-06-2	c	nd	c	c	c	c
1,2-Dichloroethane-d ₄ (surr)		c	nd	c	c	c	c
1,1-Dichloroethene	75-35-4	c	nd	c	c	c	c
trans-1,2-Dichloroethene	156-60-5	c	nd	c	c	c	c
1,2-Dichloropropane	78-87-5	c	nd	c	c	c	c
1,3-Dichloro-2-propanol	96-23-1	pp	nd	nd	nd	nd	c
cis-1,3-Dichloropropene	10061-01-5	c	nd	c	nd	c	c
trans-1,3-Dichloropropene	10061-02-6	c	nd	c	nd	c	c
1,2,3,4-Diepoxybutane	1464-53-5	c	nd	nd	nd	nd	c
Diethyl ether	60-29-7	c	nd	nd	nd	nd	c
1,4-Difluorobenzene (IS)	540-36-3	nd	nd	nd	nd	c	nd
1,4-Dioxane	123-91-1	pp	c	c	nd	nd	c
Epichlorohydrin	106-89-8	l	nd	nd	nd	nd	c
Ethanol	64-17-5	l	c	c	nd	nd	c
Ethyl acetate	141-78-6	l	c	nd	nd	nd	c
Ethylbenzene	100-41-4	c	nd	c	c	c	c
Ethylene oxide	75-21-8	pp	c	nd	nd	nd	c
Ethyl methacrylate	97-63-2	c	nd	c	nd	nd	c
Fluorobenzene (IS)	462-06-6	c	nd	nd	nd	nd	nd
Hexachlorobutadiene	87-68-3	c	nd	nd	c	nd	c
Hexachloroethane	67-72-1	l	nd	nd	nd	nd	c
2-Hexanone	591-78-6	pp	nd	c	nd	nd	c
2-Hydroxypropionitrile	78-97-7	l	nd	nd	nd	nd	pc
Iodomethane	74-88-4	c	nd	c	nd	c	c
Isobutyl alcohol	78-83-1	pp	c	nd	nd	nd	c
Isopropylbenzene	98-82-8	c	nd	nd	c	nd	c
Malononitrile	109-77-3	pp	nd	nd	nd	nd	c
Methacrylonitrile	126-98-7	pp	l	nd	nd	nd	c
Methanol	67-56-1	l	c	nd	nd	nd	c
Methylene chloride	75-09-2	c	nd	c	c	c	c
Methyl methacrylate	80-62-6	c	nd	nd	nd	nd	c
4-Methyl-2-pentanone (MIBK)	108-10-1	pp	c	c	nd	nd	c
Naphthalene	91-20-3	c	nd	nd	c	nd	c

(continued)

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Compound	CAS No. ^b	Appropriate Preparation Technique ^a					Direct Inject.
		5030/ 5035	5031	5032	5021	5041	
Nitrobenzene	98-95-3	c	nd	nd	nd	nd	c
2-Nitropropane	79-46-9	c	nd	nd	nd	nd	c
N-Nitroso-di-n-butylamine	924-16-3	pp	c	nd	nd	nd	c
Paraldehyde	123-63-7	pp	c	nd	nd	nd	c
Pentachloroethane	76-01-7	l	nd	nd	nd	nd	c
2-Pentanone	107-87-9	pp	c	nd	nd	nd	c
2-Picoline	109-06-8	pp	c	nd	nd	nd	c
1-Propanol	71-23-8	pp	c	nd	nd	nd	c
2-Propanol	67-63-0	pp	c	nd	nd	nd	c
Propargyl alcohol	107-19-7	pp	l	nd	nd	nd	c
β-Propiolactone	57-57-8	pp	nd	nd	nd	nd	c
Propionitrile (ethyl cyanide)	107-12-0	ht	c	nd	nd	nd	pc
n-Propylamine	107-10-8	c	nd	nd	nd	nd	c
Pyridine	110-86-1	l	c	nd	nd	nd	c
Styrene	100-42-5	c	nd	c	c	c	c
1,1,1,2-Tetrachloroethane	630-20-6	c	nd	nd	c	c	c
1,1,2,2-Tetrachloroethane	79-34-5	c	nd	c	c	c	c
Tetrachloroethene	127-18-4	c	nd	c	c	c	c
Toluene	108-88-3	c	nd	c	c	c	c
Toluene-d ₈ (surr)	2037-26-5	c	nd	c	c	c	c
o-Toluidine	95-53-4	pp	c	nd	nd	nd	c
1,2,4-Trichlorobenzene	120-82-1	c	nd	nd	c	nd	c
1,1,1-Trichloroethane	71-55-6	c	nd	c	c	c	c
1,1,2-Trichloroethane	79-00-5	c	nd	c	c	c	c
Trichloroethene	79-01-6	c	nd	c	c	c	c
Trichlorofluoromethane	75-69-4	c	nd	c	c	c	c
1,2,3-Trichloropropane	96-18-4	c	nd	c	c	c	c
Vinyl acetate	108-05-4	c	nd	c	nd	nd	c
Vinyl chloride	75-01-4	c	nd	c	c	c	c
o-Xylene	95-47-6	c	nd	c	c	c	c
m-Xylene	108-38-3	c	nd	c	c	c	c
p-Xylene	106-42-3	c	nd	c	c	c	c

^a See Sec. 1.2 for other appropriate sample preparation techniques

^b Chemical Abstract Service Registry Number

c = Adequate response by this technique
ht = Method analyte only when purged at 80°C
nd = Not determined
l = Inappropriate technique for this analyte
pc = Poor chromatographic behavior
pp = Poor purging efficiency resulting in high Estimated Quantitation Limits
surr = Surrogate
IS = Internal Standard

1.2 There are various techniques by which these compounds may be introduced into the GC/MS system. The more common techniques are listed in the table above. Purge-and-trap, by Methods 5030 (aqueous samples) and 5035 (solid and waste oil samples), is the most commonly used technique for volatile organic analytes. However, other techniques are also appropriate and necessary for some analytes. These include direct injection following dilution with hexadecane (Method 3585) for waste oil samples; automated static headspace by Method 5021 for solid samples; direct injection of an aqueous sample (concentration permitting) or injection of a sample concentrated by azeotropic distillation (Method 5031); and closed system vacuum distillation (Method 5032) for aqueous, solid, oil and tissue samples. For air samples, Method 5041 provides methodology for desorbing volatile organics from trapping media (Methods 0010, 0030, and 0031). In addition, direct analysis utilizing a sample loop is used for sub-sampling from Tedlar® bags (Method 0040). Method 5000 provides more general information on the selection of the appropriate introduction method.

1.3 Method 8260 can be used to quantitate most volatile organic compounds that have boiling points below 200°C. Volatile, water soluble compounds can be included in this analytical technique by the use of azeotropic distillation or closed-system vacuum distillation. Such compounds include low molecular weight halogenated hydrocarbons, aromatics, ketones, nitriles, acetates, acrylates, ethers, and sulfides. See Tables 1 and 2 for analytes and retention times that have been evaluated on a purge-and-trap GC/MS system. Also, the method detection limits for 25-mL sample volumes are presented. The following compounds are also amenable to analysis by Method 8260:

Bromobenzene	1,3-Dichloropropane
n-Butylbenzene	2,2-Dichloropropane
sec-Butylbenzene	1,1-Dichloropropene
tert-Butylbenzene	p-Isopropyltoluene
Chloroacetonitrile	Methyl acrylate
1-Chlorobutane	Methyl-t-butyl ether
1-Chlorohexane	Pentafluorobenzene
2-Chlorotoluene	n-Propylbenzene
4-Chlorotoluene	1,2,3-Trichlorobenzene
Dibromofluoromethane	1,2,4-Trimethylbenzene
cis-1,2-Dichloroethene	1,3,5-Trimethylbenzene

1.4 The estimated quantitation limit (EQL) of Method 8260 for an individual compound is somewhat instrument dependent and also dependent on the choice of sample preparation/introduction method. Using standard quadrupole instrumentation and the purge-and-trap technique, limits should be approximately 5 µg/kg (wet weight) for soil/sediment samples, 0.5 mg/kg (wet weight) for wastes, and 5 µg/L for ground water (see Table 3). Somewhat lower limits may be achieved using an ion trap mass spectrometer or other instrumentation of improved design. No matter which instrument is used, EQLs will be proportionately higher for sample extracts and samples that require dilution or when a reduced sample size is used to avoid saturation of the detector.

1.5 This method is restricted to use by, or under the supervision of, analysts experienced in the use of gas chromatograph/mass spectrometers, and skilled in the interpretation of mass spectra and their use as a quantitative tool.

2.0 SUMMARY OF METHOD

2.1 The volatile compounds are introduced into the gas chromatograph by the purge-and-trap method or by other methods (see Sec. 1.2). The analytes are introduced directly to a wide-bore capillary column or cryofocussed on a capillary pre-column before being flash evaporated to a narrow-bore capillary for analysis. The column is temperature-programmed to separate the analytes, which are then detected with a mass spectrometer (MS) interfaced to the gas chromatograph (GC).

2.2 Analytes eluted from the capillary column are introduced into the mass spectrometer via a jet separator or a direct connection. (Wide-bore capillary columns normally require a jet separator, whereas narrow-bore capillary columns may be directly interfaced to the ion source). Identification of target analytes is accomplished by comparing their mass spectra with the electron impact (or electron impact-like) spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five-point calibration curve.

2.3 The method includes specific calibration and quality control steps that supersede the general requirements provided in Method 8000.

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US EPA Method TO-15

Determination of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography/Mass Spectrometry (GC/MS)

<http://www3.epa.gov/ttnamti1/files/ambient/airtox/to-15r.pdf>

METHOD TO-15**Determination of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography/ Mass Spectrometry (GC/MS)****1. Scope**

1.1 This method documents sampling and analytical procedures for the measurement of subsets of the 97 volatile organic compounds (VOCs) that are included in the 189 hazardous air pollutants (HAPs) listed in Title III of the Clean Air Act Amendments of 1990. VOCs are defined here as organic compounds having a vapor pressure greater than 10^{-1} Torr at 25°C and 760 mm Hg. Table 1 is the list of the target VOCs along with their CAS number, boiling point, vapor pressure and an indication of their membership in both the list of VOCs covered by Compendium Method TO-14A (1) and the list of VOCs in EPA's Contract Laboratory Program (CLP) document entitled: *Statement-of-Work (SOW) for the Analysis of Air Toxics from Superfund Sites (2)*.

Many of these compounds have been tested for stability in concentration when stored in specially-prepared canisters (see Section 8) under conditions typical of those encountered in routine ambient air analysis. The stability of these compounds under all possible conditions is not known. However, a model to predict compound losses due to physical adsorption of VOCs on canister walls and to dissolution of VOCs in water condensed in the canisters has been developed (3). Losses due to physical adsorption require only the establishment of equilibrium between the condensed and gas phases and are generally considered short term losses, (i.e., losses occurring over minutes to hours). Losses due to chemical reactions of the VOCs with cocollected ozone or other gas phase species also account for some short term losses. Chemical reactions between VOCs and substances inside the canister are generally assumed to cause the gradual decrease of concentration over time (i.e., long term losses over days to weeks). Loss mechanisms such as aqueous hydrolysis and biological degradation (4) also exist. No models are currently known to be available to estimate and characterize all these potential losses, although a number of experimental observations are referenced in Section 8. Some of the VOCs listed in Title III have short atmospheric lifetimes and may not be present except near sources.

1.2 This method applies to ambient concentrations of VOCs above 0.5 ppbv and typically requires VOC enrichment by concentrating up to one liter of a sample volume. The VOC concentration range for ambient air in many cases includes the concentration at which continuous exposure over a lifetime is estimated to constitute a 10^{-6} or higher lifetime risk of developing cancer in humans. Under circumstances in which many hazardous VOCs are present at 10^{-6} risk concentrations, the total risk may be significantly greater.

1.3 This method applies under most conditions encountered in sampling of ambient air into canisters. However, the composition of a gas mixture in a canister, under unique or unusual conditions, will change so that the sample is known not to be a true representation of the ambient air from which it was taken. For example, low humidity conditions in the sample may lead to losses of certain VOCs on the canister walls, losses that would not happen if the humidity were higher. If the canister is pressurized, then condensation of water from high humidity samples may cause fractional losses of water-soluble compounds. Since the canister surface area is limited, all gases are in competition for the available active sites. Hence an absolute storage stability cannot be assigned to a specific gas. Fortunately, under conditions of normal usage for sampling ambient air, most VOCs can be recovered from canisters near their original concentrations after storage times of up to thirty days (see Section 8).

1.4 Use of the Compendium Method TO-15 for many of the VOCs listed in Table 1 is likely to present two difficulties: (1) what calibration standard to use for establishing a basis for testing and quantitation, and (2) how

to obtain an audit standard. In certain cases a chemical similarity exists between a thoroughly tested compound and others on the Title III list. In this case, what works for one is likely to work for the other in terms of making standards. However, this is not always the case and some compound standards will be troublesome. The reader is referred to the Section 9.2 on standards for guidance. Calibration of compounds such as formaldehyde, diazomethane, and many of the others represents a challenge.

1.5 Compendium Method TO-15 should be considered for use when a subset of the 97 Title III VOCs constitute the target list. Typical situations involve ambient air testing associated with the permitting procedures for emission sources. In this case sampling and analysis of VOCs is performed to determine the impact of dispersing source emissions in the surrounding areas. Other important applications are prevalence and trend monitoring for hazardous VOCs in urban areas and risk assessments downwind of industrialized or source-impacted areas.

1.6 Solid adsorbents can be used in lieu of canisters for sampling of VOCs, provided the solid adsorbent packings, usually multisorbent packings in metal or glass tubes, can meet the performance criteria specified in Compendium Method TO-17 which specifically addresses the use of multisorbent packings. The two sample collection techniques are different but become the same upon movement of the sample from the collection medium (canister or multisorbent tubes) onto the sample concentrator. Sample collection directly from the atmosphere by automated gas chromatographs can be used in lieu of collection in canisters or on solid adsorbents.

2. Summary of Method

2.1 The atmosphere is sampled by introduction of air into a specially-prepared stainless steel canister. Both subatmospheric pressure and pressurized sampling modes use an initially evacuated canister. A pump ventilated sampling line is used during sample collection with most commercially available samplers. Pressurized sampling requires an additional pump to provide positive pressure to the sample canister. A sample of air is drawn through a sampling train comprised of components that regulate the rate and duration of sampling into the pre-evacuated and passivated canister.

2.2 After the air sample is collected, the canister valve is closed, an identification tag is attached to the canister, and the canister is transported to the laboratory for analysis.

2.3 Upon receipt at the laboratory, the canister tag data is recorded and the canister is stored until analysis. Storage times of up to thirty days have been demonstrated for many of the VOCs (5).

2.4 To analyze the sample, a known volume of sample is directed from the canister through a solid multisorbent concentrator. A portion of the water vapor in the sample breaks through the concentrator during sampling, to a degree depending on the multisorbent composition, duration of sampling, and other factors. Water content of the sample can be further reduced by dry purging the concentrator with helium while retaining target compounds. After the concentration and drying steps are completed, the VOCs are thermally desorbed, entrained in a carrier gas stream, and then focused in a small volume by trapping on a reduced temperature trap or small volume multisorbent trap. The sample is then released by thermal desorption and carried onto a gas chromatographic column for separation.

As a simple alternative to the multisorbent/dry purge water management technique, the amount of water vapor in the sample can be reduced below any threshold for affecting the proper operation of the analytical system by

reducing the sample size. For example, a small sample can be concentrated on a cold trap and released directly to the gas chromatographic column. The reduction in sample volume may require an enhancement of detector sensitivity.

Other water management approaches are also acceptable as long as their use does not compromise the attainment of the performance criteria listed in Section 11. A listing of some commercial water management systems is provided in Appendix A. One of the alternative ways to dry the sample is to separate VOCs from condensate on a low temperature trap by heating and purging the trap.

2.5 The analytical strategy for Compendium Method TO-15 involves using a high resolution gas chromatograph (GC) coupled to a mass spectrometer. If the mass spectrometer is a linear quadrupole system, it is operated either by continuously scanning a wide range of mass to charge ratios (SCAN mode) or by monitoring select ion monitoring mode (SIM) of compounds on the target list. If the mass spectrometer is based on a standard ion trap design, only a scanning mode is used (note however, that the Selected Ion Storage (SIS) mode for the ion trap has features of the SIM mode). Mass spectra for individual peaks in the total ion chromatogram are examined with respect to the fragmentation pattern of ions corresponding to various VOCs including the intensity of primary and secondary ions. The fragmentation pattern is compared with stored spectra taken under similar conditions, in order to identify the compound. For any given compound, the intensity of the primary fragment is compared with the system response to the primary fragment for known amounts of the compound. This establishes the compound concentration that exists in the sample.

Mass spectrometry is considered a more definitive identification technique than single specific detectors such as flame ionization detector (FID), electron capture detector (ECD), photoionization detector (PID), or a multidetector arrangement of these (see discussion in Compendium Method TO-14A). The use of both gas chromatographic retention time and the generally unique mass fragmentation patterns reduce the chances for misidentification. If the technique is supported by a comprehensive mass spectral database and a knowledgeable operator, then the correct identification and quantification of VOCs is further enhanced.

TABLE 1. VOLATILE ORGANIC COMPOUNDS ON THE TITLE III CLEAN AIR AMENDMENT LIST--
MEMBERSHIP IN COMPENDIUM METHOD TO-14A LIST AND THE SOW-CLP LIST OF VOCs

Compound	CAS No.	BP (°C)	v.p. (mmHg) ¹	MW ¹	TO-14A	CLP-SOW
Methyl chloride (chloromethane); CH ₃ Cl	74-87-3	-23.7	3.8 x 10	50.5	X	X
Carbonyl sulfide; COS	463-58-1	-50.0	3.7 x 10	60.1		
Vinyl chloride (chloroethene); C ₂ H ₃ Cl	75-01-4	-14.0	3.2 x 10	62.5	X	X
Diazomethane; CH ₂ N ₂	334-88-3	-23.0	2.8 x 10	42.1		
Formaldehyde; CH ₂ O	50-00-0	-19.5	2.7 x 10	30		
1,3-Butadiene; C ₄ H ₆	106-99-0	-4.5	2.0 x 10	54		X
Methyl bromide (bromomethane); CH ₃ Br	74-83-9	3.6	1.8 x 10	94.9	X	X
Phosgene; CCl ₂ O	75-44-5	8.2	1.2 x 10	99		
Vinyl bromide (bromoethene); C ₂ H ₃ Br	593-60-2	15.8	1.1 x 10	107		
Ethylene oxide; C ₂ H ₄ O	75-21-8	10.7	1.1 x 10	44		
Ethyl chloride (chloroethane); C ₂ H ₅ Cl	75-00-3	12.5	1.0 x 10	64.5	X	X
Acetaldehyde (ethanal); C ₂ H ₄ O	75-07-0	21.0	952	44		
Vinylidene chloride (1,1-dichloroethylene); C ₂ H ₂ Cl ₂	75-35-4	31.7	500	97	X	X
Propylene oxide; C ₃ H ₆ O	75-56-9	34.2	445	58		
Methyl iodide (iodomethane); CH ₃ I	74-88-4	42.4	400	141.9		
Methylene chloride; CH ₂ Cl ₂	75-09-2	40.0	349	84.9	X	X
Methyl isocyanate; C ₂ H ₃ NO	624-83-9	59.6	348	57.1		
Allyl chloride (3-chloropropene); C ₃ H ₅ Cl	107-05-1	44.5	340	76.5	X	X
Carbon disulfide; CS ₂	75-15-0	46.5	260	76		
Methyl tert-butyl ether; C ₅ H ₁₂ O	1634-04-4	55.2	249	86		
Propionaldehyde; C ₂ H ₅ CHO	123-38-6	49.0	235	58.1		
Ethylidene dichloride (1,1-dichloroethane); C ₂ H ₄ Cl ₂	75-34-3	57.0	230	99	X	

Method TO-15

VOCs

TABLE 1. (continued)

Compound	CAS No.	BP (°C)	v.p. (mmHg)	MW ¹	TO-14A	CLP-SOW
Chloroprene (2-chloro-1,3-butadiene); C ₄ H ₅ Cl	126-99-8	59.4	226	88.5		
Chloromethyl methyl ether; C ₂ H ₅ ClO	107-30-2	59.0	224	80.5		
Acrolein (2-propenal); C ₃ H ₄ O	107-02-8	52.5	220	56		X
1,2-Epoxybutane (1,2-butylene oxide); C ₄ H ₈ O	106-88-7	63.0	163	72		
Chloroform; CHCl ₃	67-66-3	61.2	160	119	X	X
Ethyleneimine (aziridine); C ₂ H ₅ N	151-56-4	56	160.0	43		
1,1-Dimethylhydrazine; C ₂ H ₈ N ₂	57-14-7	63	157.0	60.0		
Hexane; C ₆ H ₁₄	110-54-3	69.0	120	86.2	X	
1,2-Propyleneimine (2-methylaziridine); C ₃ H ₇ N	75-55-8	66.0	112	57.1		
Acrylonitrile (2-propenenitrile); C ₃ H ₃ N	107-13-1	77.3	100	53	X	
Methyl chloroform (1,1,1-trichloroethane); C ₂ H ₃ Cl ₃	71-55-6	74.1	100	133.4	X	X
Methanol; CH ₄ O	67-56-1	65.0	92.0	32		X
Carbon tetrachloride; CCl ₄	56-23-5	76.7	90.0	153.8	X	X
Vinyl acetate; C ₄ H ₆ O ₂	108-05-4	72.2	83.0	86		X
Methyl ethyl ketone (2-butanone); C ₄ H ₈ O	78-93-3	79.6	77.5	72		X
Benzene; C ₆ H ₆	71-43-2	80.1	76.0	78	X	X
Acetonitrile (cyanomethane); C ₂ H ₃ N	75-05-8	82	74.0	41.0		X
Ethylene dichloride (1,2-dichloroethane); C ₂ H ₄ Cl ₂	107-06-2	83.5	61.5	99	X	X
Triethylamine; C ₆ H ₁₅ N	121-44-8	89.5	54.0	101.2		
Methylhydrazine; CH ₆ N ₂	60-34-4	87.8	49.6	46.1		
Propylene dichloride (1,2-dichloropropane); C ₃ H ₆ Cl ₂	78-87-5	97.0	42.0	113	X	X
2,2,4-Trimethyl pentane C ₈ H ₁₈	540-84-1	99.2	40.6	114		
1,4-Dioxane (1,4-Diethylene oxide); C ₄ H ₈ O ₂	123-91-1	101	37.0	88		
Bis(chloromethyl) ether; C ₂ H ₄ Cl ₂ O	542-88-1	104	30.0	115		
Ethyl acrylate; C ₅ H ₈ O ₂	140-88-5	100	29.3	100		
Methyl methacrylate; C ₅ H ₈ O ₂	80-62-6	101	28.0	100.1		

TABLE 1. (continued)

Compound	CAS No.	BP (°C)	v.p. (mmHg) ¹	MW ¹	TO-14A	CLP-SOW
Methyl methacrylate; C ₅ H ₈ O ₂	80-62-101	101	28.0	100.1		
1,3-Dichloropropene; C ₃ H ₄ Cl ₂ (cis)	542-75-6	112	27.8	111	X	X
Toluene; C ₇ H ₈	108-88-3	111	22.0	92	X	X
Trichloroethylene; C ₂ HCl ₃	79-01-6	87.0	20.0	131.4	X	X
1,1,2-Trichloroethane; C ₂ H ₃ Cl ₃	79-00-5	114	19.0	133.4	X	X
Tetrachloroethylene; C ₂ Cl ₄	127-18-4	121	14.0	165.8	X	X
Epichlorohydrin (1-chloro-2,3-epoxy propane); C ₃ H ₅ ClO	106-89-8	117	12.0	92.5		
Ethylene dibromide (1,2-dibromoethane); C ₂ H ₄ Br ₂	106-93-4	132	11.0	187.9	X	X
N-Nitroso-N-methylurea; C ₂ H ₅ N ₃ O ₂	684-93-5	124	10.0	103		
2-Nitropropane; C ₃ H ₇ NO ₂	79-46-9	120	10.0	89		
Chlorobenzene; C ₆ H ₅ Cl	108-90-7	132	8.8	112.6	X	X
Ethylbenzene; C ₈ H ₁₀	100-41-4	136	7.0	106	X	X
Xylenes (isomer & mixtures); C ₈ H ₁₀	1330-20-7	142	6.7	106.2	X	X
Styrene; C ₈ H ₈	100-42-5	145	6.6	104	X	X
p-Xylene; C ₈ H ₁₀	106-42-3	138	6.5	106.2	X	X
m-Xylene; C ₈ H ₁₀	108-38-3	139	6.0	106.2	X	X
Methyl isobutyl ketone (hexone); C ₆ H ₁₂ O	108-10-1	117	6.0	100.2		
Bromoform (tribromomethane); CHBr ₃	75-25-2	149	5.6	252.8		
1,1,2,2-Tetrachloroethane; C ₂ H ₂ Cl ₄	79-34-5	146	5.0	167.9	X	X
o-Xylene; C ₈ H ₁₀	95-47-6	144	5.0	106.2	X	X
Dimethylcarbamyl chloride; C ₃ H ₆ ClNO	79-44-7	166	4.9	107.6		
N-Nitrosodimethylamine; C ₂ H ₆ N ₂ O	62-75-9	152	3.7	74		
Beta-Propiolactone; C ₃ H ₄ O ₂	57-57-8	Decomposes at 162	3.4	72		
Cumene (isopropylbenzene); C ₉ H ₁₂	98-82-8	153	3.2	120		

TABLE 1. (continued)

Compound	CAS No.	BP (°C)	V.p. (mmHg) ¹	MW ¹	TO-14A	CLP-SOW
Cumene (isopropylbenzene); C9H12	98-82-8	153	3.2	120		
Acrylic acid; C3H4O2	79-10-7	141	3.2	72		
N,N-Dimethylformamide; C3H7NO	68-12-2	153	2.7	73		
1,3-Propane sultone; C3H6O3S	1120-71-4	180/30mm	2.0	122.1		
Acetophenone; C8H8O	98-86-2	202	1.0	120		
Dimethyl sulfate; C2H6O4S	77-78-1	188	1.0	126.1		
Benzyl chloride (a-chlorotoluene); C7H7Cl	100-44-7	179	1.0	126.6	X	X
1,2-Dibromo-3-chloropropane; C3H5Br2Cl	96-12-8	196	0.80	236.4		
Bis(2-Chloroethyl)ether; C4H8Cl2O	111-44-4	178	0.71	143		
Chloroacetic acid; C2H3ClO2	79-11-8	189	0.69	94.5		
Aniline (aminobenzene); C6H7N	62-53-3	184	0.67	93		
1,4-Dichlorobenzene (p-); C6H4Cl2	106-46-7	173	0.60	147	X	X
Ethyl carbamate (urethane); C3H7NO2	51-79-6	183	0.54	89		
Acrylamide; C3H5NO	79-06-1	125/25 mm	0.53	71		
N,N-Dimethylamine; C8H11N	121-69-7	192	0.50	121		
Hexachloroethane; C2Cl6	67-72-1	Sublimes at 186	0.40	236.7		
Hexachlorobutadiene; C4Cl6	87-68-3	215	0.40	260.8	X	X
Isophorone; C9H14O	78-59-1	215	0.38	138.2		
N-Nitrosomorpholine; C4H8N2O2	59-89-2	225	0.32	116.1		
Styrene oxide; C8H8O	96-09-3	194	0.30	120.2		
Diethyl sulfate; C4H10O4S	64-67-5	208	0.29	154		
Cresylic acid (cresol isomer mixture); C7H8O	1319-77-3	202	0.26	108		
o-Cresol; C7H8O	95-48-7	191	0.24	108		
Catechol (o-hydroxyphenol); C6H6O2	120-80-9	240	0.22	110		
Phenol; C6H6O	108-95-2	182	0.20	94		

US EPA Method TO-17

Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling Onto Sorbent Tubes

<http://www3.epa.gov/ttnamti1/files/ambient/airtox/to-17r.pdf>

METHOD TO-17

Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling Onto Sorbent Tubes

1. Scope

1.1 This document describes a sorbent tube/thermal desorption/gas chromatographic-based monitoring method for volatile organic compounds (VOCs) in ambient air at 0.5 to 25 parts per billion (ppbv) concentration levels. Performance criteria are provided as part of the method in Section 14. EPA has previously published Compendium Method TO-1 describing the use of the porous polymer Tenax® GC for sampling nonpolar VOCs and Compendium Method TO-2 describing the use of carbon molecular sieve for highly volatile, nonpolar organics (1). Since these methods were developed, a new generation of thermal desorption systems as well as new types of solid adsorbents have become available commercially. These sorbents are used singly or in multisorbent packings. Tubes with more than one sorbent, packed in order of increasing sorbent strength are used to facilitate quantitative retention and desorption of VOCs over a wide volatility range. The higher molecular weight compounds are retained on the front, least retentive sorbent; the more volatile compounds are retained farther into the packing on a stronger adsorbent. The higher molecular weight compounds never encounter the stronger adsorbents, thereby improving the efficiency of the thermal desorption process.

1.2 A large amount of data on solid adsorbents is available through the efforts of the Health and Safety Laboratory, Health and Safety Executive (HSE), Sheffield, United Kingdom (UK). This group has provided written methods for use of solid adsorbent packings in monitoring workplace air. Some of their documents on the subject are referenced in Section 2.2. Also, a table of information on safe sampling volumes from their research is provided in Appendix 1.

1.3 EPA has developed data on the use of solid sorbents in multisorbent tubes for concentration of VOCs from the ambient air as part of its program for methods development of automated gas chromatographs. The experiments required to validate the use of these sorbent traps include capture and release efficiency studies for given sampling volumes. These studies establish the validity of using solid adsorbents for target sets of VOCs with minimal (at most one hour) storage time. Although questions related to handling, transport and storage of samples between the times of sampling and analysis are not addressed, these studies provide information on safe sampling volumes. Appendix 2 delineates the results of sampling a mixture of humidified zero air and the target VOCs specified in the Compendium Method TO-14 (2) using a specific multisorbent.

1.4 An EPA workshop was convened in November of 1995 to determine if a consensus could be reached on the use of solid sorbent tubes for ambient air analysis. The draft method available at the workshop has evolved through several reviews and modifications into the current document. The method is supported by data reported in the scientific literature as cited in the text, and by recent experimental tests performed as a consequence of the workshop (see Table 1).

1.5 The analytical approach using gas chromatography/mass spectroscopy (GC/MS) is identical to that mentioned in Compendium Method TO-15 and, as noted later, is adapted for this method once the sample has been thermally desorbed from the adsorption tube onto the focusing trap of the analytical system.

1.6 Performance criteria are given in Section 14 to allow acceptance of data obtained with any of the many variations of sampling and analytical approaches.

2. Summary of Method

2.1 The monitoring procedure involves pulling a volume of air through a sorbent packing to collect VOCs followed by a thermal desorption-capillary GC/MS analytical procedure.

2.2 Conventional detectors are considered alternatives for analysis subject to the performance criteria listed in Section 14 but are not covered specifically in this method text.

2.3 Key steps of this method are listed below.

2.3.1 Selection of a sorbent or sorbent mix tailored for a target compound list, data quality objectives and sampling environment.

2.3.2 Screening the sampling location for VOCs by taking single tube samples to allow estimates of the nature and amount of sample gases.

2.3.3 Initial sampling sequences with two tubes at nominally 1 and 4 liter total sample volumes (or appropriate proportional scaling of these volumes to fit the target list and monitoring objectives).

2.3.4 Analysis of the samples and comparison to performance criteria.

2.3.5 Acceptance or rejection of the data.

2.3.6 If rejection, then review of the experimental arrangement including repeat analysis or repeat analysis with backup tubes and/or other QC features.

[Note: EPA requires the use of distributed volume pairs (see Section 14.4) for monitoring to insure high quality data. However, in situations where acceptable data have been routinely obtained through use of distributed volume pairs and the ambient air is considered well characterized, cost considerations may warrant single tube sampling. Any attendant risk to data quality objectives is the responsibility of the project's decision maker.]

2.4 Key steps in sample analysis are listed below.

2.4.1 Dry purge of the sorbent tube with dry, inert gas before analysis to remove water vapor and air. The sorbent tube can be held at temperatures above ambient for the dry purge.

2.4.2 Thermal desorption of the sorbent tube (primary desorption).

2.4.3 Analyte refocusing on a secondary trap.

2.4.4 Rapid desorption of the trap and injection/transfer of target analytes into the gas chromatograph (secondary desorption).

2.4.5 Separation of compounds by high resolution capillary gas chromatography (GC).

2.4.6 Measurement by mass spectrometry (MS) or conventional GC detectors (only the MS approach is explicitly referred to in Compendium Method TO-17; an FID/ECD detector combination or other GC detector can be used if Section 14 criteria are met. However, no explicit QA guidelines are given here for those alternatives).

2.5 The target compound list (TCL) is the same as listed in Compendium Method TO-15 (i.e., subsets of the 97 VOCs listed as hazardous pollutants in Title III of the Clean Air Act Amendments of 1990). Only a portion of these compounds has been monitored by the use of solid adsorbents. This method provides performance criteria to demonstrate acceptable performance of the method (or modifications of the method) for monitoring a given compound or set of compounds.

APPENDIX 1.

The following list includes safe sampling volume data generated by the UK Health and Safety Executive (4) on single sorbent bed 1/4 inch O.D. stainless steel tubes and compatible with a thermal desorption - capillary GC analytical procedure. It is provided as a resource to readers only. The recommendation for Tube Style 2 is based on the specific tube referenced in Section 6.1.2 and Table 3. Where tubes are not listed with safe sample volumes they have not been tested and their inclusion represents a suggestion only. Application to air sampling is subject to criteria listed in Section 14 of Compendium Method TO-17.

[*Note: Combination tubes 1, 2, and 3 referenced in this Appendix are those adsorbent tubes described in Section 9.1.3.*]

Compound	Suitable sorbents and SSV's where available
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Hydrocarbons

This procedure is suitable for all aliphatic, aromatic and cyclic hydrocarbons less volatile than ethane and more volatile than n-C20. These include:

n-Butane	CS III, C 1000, Combination Tubes 2 or 3 or Spherocarb (SSV 820L).
n-Pentane	CS III, C 1000, Spherocarb (SSV 30,000L), Combination Tubes 2 or 3 or Chromosorb 106 (SSV 5.5L).
n-Hexane	Carbopack™ B, Combination Tubes 1, 2, 3 or Chromosorb 106 (SSV 30L).
Benzene	Carbopack™ B, Combination Tubes 1, 2, 3 or Chromosorb 106 (SSV 26L) or Tenax (SSV 6L).
n-Heptane	Carbopack™ B, Tenax (SSV 17L), Combination Tubes 1, 2, 3 or Chromosorb 106 (SSV 160L).
Toluene	Carbopack™ B, Tenax (SSV 38L), Combination Tubes 1, 2, 3 or Chromosorb 106 (SSV 80L).
n-Octane	Carbopack™ B, Tenax (SSV 700L) Combination Tubes 1, 2, 3 or Chromosorb 106 (SSV 1000L).
Ethylbenzene	Carbopack™ B, Tenax (SSV 180L), Combination Tubes 1, 2, 3 or Chromosorb 106 (SSV 360L).
all Xylenes	Carbopack™ B, Tenax (SSV 300L), Combination Tubes 1, 2, 3 or Chromosorb 106 (SSV 770L).
n-Nonane	Carbopack™ C/B, Tenax (SSV 700L), Combination Tubes 1, 2 or 3 or Chromosorb 106 (SSV 7000L).
Styrene	Carbopack™ C/B, Tenax (SSV 300L) or Combination Tubes 1, 2 or 3.
Isopropylbenzene	Carbopack™ C/B, Tenax (SSV 480L) or Combination Tubes 1, 2 or 3.
n-Propylbenzene	Carbopack™ C/B, Tenax (SSV 850L) or Combination Tubes 1, 2 or 3.
1-Methyl-3-ethylbenzene	Carbopack™ C/B, Tenax (SSV 1000L) or Combination Tubes 1, 2 or 3.
1-Methyl-4-ethylbenzene	Carbopack™ C/B, Tenax (SSV 1000L) or Combination Tubes 1, 2 or 3.

Method TO-17**VOCs**

Compound	Suitable sorbents and SSV's where available
1,3,5-Trimethylbenzene	Carbopack™ C/B, Tenax (SSV 1800L), Combination Tubes 1, 2 or 3 or Chromosorb 106 (SSV 2800).
Methylstyrene	Carbopack™ C/B, Tenax (SSV 1200L) or Combination Tubes 1, 2 or 3.
Methyl-2-ethylbenzene	Carbopack™ C/B, Tenax (SSV 1000L) or Combination Tubes 1, 2 or 3.
1,2,4-Trimethylbenzene	Carbopack™ C/B, Tenax (SSV 1800L) or Combination Tubes 1, 2 or 3.
n-Decane	Carbopack™ C/B, Tenax (SSV 2100L), Combination Tubes 1, 2 or 3 or Chromosorb 106 (SSV 37,000L).
1,2,3-Trimethylbenzene	Carbopack™ C/B, Tenax (SSV 1800L) or Combination Tubes 1, 2 or 3.
n-Undecane	Carbopack™ C/B, Tenax (SSV 12,000L) or Combination Tubes 1, 2 or 3.
n-Dodecane	Carbopack™ C, Tenax (SSV 63,000L) or Combination Tubes 1 or 3.

Halogenated Hydrocarbons including PCBs

This procedure is suitable for all aliphatic, aromatic and cyclic halogenated hydrocarbons more volatile than n-C20. Examples include:

Dichloromethane	CS III, C 1000, Spherocarb (SSV 200L) or Combination Tubes 2 or 3.
1,2-Dichloroethane	CS III, C 1000, Spherocarb, Chrom. 106 (SSV 17L), Carbopack™ B, Tenax (SSV 5.4L) or Combination Tubes 1, 2 or 3.
1,1,1-Trichloroethane	Spherocarb (SSV 8,000L), Chrom. 106 (SSV 8L), Carbopack™ B, or Combination Tubes 1, 2 or 3.
Carbontetrachloride	Chrom. 106 (SSV 22L), Carbopack™ B, Tenax (SSV 6.2L) or Combination Tubes 1, 2 or 3.
Trichloroethylene	Chrom. 106, Carbopack™ B, Tenax (SSV 5.6L) or Combination Tubes 1, 2 or 3.
1,1,2-Trichloroethane	Chrom. 106, Carbopack™ B, Tenax (SSV 34L) or Combination Tubes 1, 2 or 3.
Tetrachloroethylene	Chrom. 106, Carbopack™ B, Tenax (SSV 48L) or Combination Tubes 1, 2 or 3.
Chlorobenzene	Chrom. 106, Carbopack™ B, Tenax (SSV 26L) or Combination Tubes 1, 2 or 3.
1,1,1,2-Tetrachloroethane	Chrom. 106, Carbopack™ B, Tenax (SSV 78L) or Combination Tubes 1, 2 or 3.
1,1,2,2-Tetrachloroethane	Chrom. 106, Carbopack™ B, Tenax (SSV 170L) or Combination Tubes 1, 2 or 3.

Compound	Suitable sorbents and SSV's where available
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Alcohols

This procedure is suitable for alcohols more volatile than n-C20 and sufficiently stable to be analyzed by conventional GC techniques. Examples include:

Methanol	CSIII, C1000, Spherocarb (SSV 130L) or Combination Tubes 2 or 3.
Ethanol	CSIII, C1000, Spherocarb (SSV 3500L) or Combination Tubes 2 or 3.
n-Propanol	Porapak N (SSV 20L), Chrom 106 (SSV 8L), Carbopack™ B or Combination Tubes 1, 2 or 3.
Isopropanol	Chrom 106 (SSV 44L), Carbopack™ B or Combination Tubes 1, 2 or 3.
n-Butanol	Chrom 106 (SSV 50L), Carbopack™ B, Porapak N (SSV 5L), Tenax (SSV 5L) or Combination Tubes 1, 2 or 3.
iso-Butanol	Chrom 106 (SSV 30L), Carbopack™ B, Tenax (SSV 2.8L) or Combination Tubes 1, 2 or 3.
Octanol	Tenax (SSV 1400L), Carbopack™ C or Combination Tubes 1 or 3.

Esters and Glycol Ethers

This procedure is suitable for all esters and glycol ethers more volatile than n-C20 and sufficiently stable to be analyzed by conventional GC techniques. Examples include:

Methylacetate	Chromosorb 106 (SSV 2.6L), Carbopack™ B or Combination Tubes 1, 2 or 3.
Ethylacetate	Chromosorb 106 (SSV 20L), Carbopack™ B, Tenax (SSV 3.6L) or Combination Tubes 1, 2 or 3.
Propylacetate	Chromosorb 106 (SSV 150L), Carbopack™ B, Tenax (SSV 18L) or Combination Tubes 1, 2 or 3.
Isopropylacetate	Chromosorb 106 (SSV 75L), Carbopack™ B, Tenax (SSV 6L) or Combination Tubes 1, 2 or 3.
Butylacetate	Chromosorb 106 (SSV 730L), Carbopack™ B, Tenax (SSV 85L) or Combination Tubes 1, 2 or 3.
Isobutylacetate	Chromosorb 106 (SSV 440L), Carbopack™ B, Tenax (SSV 130L) or Combination Tubes 1, 2 or 3.
Methyl-t-butyl ether	Chromosorb 106 (SSV >6L), Carbopack™ B or Combination Tubes 1, 2 or 3.
t-Butylacetate	Chromosorb 106 (SSV 160L), Carbopack™ B or Combination Tubes 1, 2 or 3.
Methylacrylate	Chromosorb 106, Carbopack™ B, Tenax (SSV 6.5L) or Combination Tubes 1, 2 or 3.

Method TO-17**VOCs**

Compound	Suitable sorbents and SSV's where available
Ethylacrylate	Chromosorb 106, Carbopack™ B, Tenax (SSV 60L) or Combination Tubes 1, 2 or 3.
Methylmethacrylate	Chromosorb 106, Carbopack™ B, Tenax (SSV 27L) or Combination Tubes 1, 2 or 3.
Methoxyethanol	Chromosorb 106 (SSV 5L), Carbopack™ B, Tenax (SSV 3L) or Combination Tubes 1, 2 or 3.
Ethoxyethanol	Chromosorb 106 (SSV 75L), Carbopack™ B, Tenax (SSV 5L) or Combination Tubes 1, 2 or 3.
Butoxyethanol	Chromosorb 106, Carbopack™ B, Tenax (SSV 35L) or Combination Tubes 1, 2 or 3.
Methoxypropanol	Chromosorb 106, Carbopack™ B, Tenax (SSV 13L) or Combination Tubes 1, 2 or 3.
Methoxyethylacetate	Chromosorb 106 (SSV 860L), Carbopack™ B, Tenax (SSV 8L) or Combination Tubes 1, 2 or 3.
Ethoxyethylacetate	Chromosorb 106 (SSV 4000L), Carbopack™ B, Tenax (SSV 15L) or Combination Tubes 1, 2 or 3.
Butoxyethylacetate	Chromosorb 106, Carbopack™ B, Tenax (SSV 150L) or Combination Tubes 1, 2 or 3.

Aldehydes and Ketones

This procedure is suitable for all aldehydes and ketones more volatile than n-C20 and sufficiently stable to be analyzed using conventional GC techniques. Examples include:

Acetone	CSIII, C1000, Spherocarb, Chrom 106 (SSV 1.5L) or Combination Tubes 2 or 3.
Methylethylketone (2-butanone)	Chromosorb 106 (SSV 10L), Tenax (SSV 3.2L), Porapak N (SSV 50L) Carbopack™ B or Combination Tubes 1, 2 or 3.
n-Butanal	Chromosorb 106, Carbopack™ B, Porapak N (SSV 50L) or Combination Tubes 1, 2 or 3.
Methylisobutylketone	Chromosorb 106 (SSV 250L), Tenax (SSV 26L), Carbopack™ B or Combination Tubes 1, 2 or 3.
Cyclohexanone	Chromosorb 106, Tenax (SSV 170L), Carbopack™ B or Combination Tubes 1, 2 or 3.
3,5,5-Trimethylcyclohex-2-enone	Tenax (SSV 5600L), Carbopack™ B or Combination Tubes 1 or 3.
Furfural	Tenax (SSV 300L), Carbopack™ B or Combination Tubes 1, 2 or 3.

Compound	Suitable sorbents and SSV's where available
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Miscellaneous VOCs

This procedure is suitable for the analysis of most VOCs in air. It is generally compatible with all organics less volatile than ethane, more volatile than n-C20 and sufficiently stable to be analyzed using conventional GC techniques. Examples include:

Acetonitrile	Porapak N (SSV 3.5L), CSIII, C1000 or Combination Tubes 2 or 3.
Acrylonitrile	Porapak N (SSV 8L), Carbopack™ B or Combination Tubes 1, 2 or 3.
Propionitrile	Porapak N (SSV 11L), Carbopack™ B or Combination Tubes 1, 2 or 3.
Maleic anhydride ^a	Tenax (SSV 88L), Chrom. 106, Carbopack™ B or Combination Tubes 1, 2 or 3.
Pyridine	Tenax (SSV 8L), Porapak N (SSV 200L) Chrom. 106, Carbopack™ B or Combination Tubes 1, 2 or 3.
Aniline	Tenax (SSV 220L), Chrom. 106, Carbopack™ B or Combination Tubes 1, 2 or 3.
Nitrobenzene	Tenax (SSV 14,000L) Carbopack™ C or Combination Tubes 1 or 3.
Acetic acid	Porapak N (SSV 50L), Carbotrap™ B or Combination Tubes 1, 2 or 3.
Phenol	Tenax (SSV 240L) or combination tube 1.

US EPA Method 8270D
Semivolatile Organic Compounds By Gas
Chromatography/Mass Spectrometry (GC/MS)

<http://www3.epa.gov/epawaste/hazard/testmethods/sw846/pdfs/8260b.pdf>

METHOD 8270D

SEMIVOLATILE ORGANIC COMPOUNDS
BY GAS CHROMATOGRAPHY/MASS SPECTROMETRY

SW-846 is not intended to be an analytical training manual. Therefore, method procedures are written based on the assumption that they will be performed by analysts who are formally trained in at least the basic principles of chemical analysis and in the use of the subject technology.

In addition, SW-846 methods, with the exception of required method use for the analysis of method defined parameters (MDPs), are intended to be guidance methods that contain general information on how to perform an analytical procedure or technique, which a laboratory can use as a basic starting point for generating its own detailed standard operating procedure (SOP), either for its own general use or for a specific project application. The performance data included in this method are for guidance purposes only, and are not intended to be and must not be used as absolute quality control (QC) acceptance criteria for purposes of laboratory accreditation.

1.0 SCOPE AND APPLICATION

1.1 This method is used to determine the concentration of semivolatile organic compounds in extracts prepared from many types of solid waste matrices, soils, air sampling media and water samples. Direct injection of a sample may be used in limited applications. The following Resource Conservation and Recovery Act (RCRA) analytes have been determined by this method:

Compounds	CAS No ^a	Appropriate Preparation Techniques ^b				
		3510	3520	3540/ 3541	3550	3580
Acenaphthene	83-32-9	X	X	X	X	X
Acenaphthylene	208-96-8	X	X	X	X	X
Acetophenone	98-86-2	X	ND	ND	ND	X
2-Acetylaminofluorene	53-96-3	X	ND	ND	ND	X
1-Acetyl-2-thiourea	591-08-2	LR	ND	ND	ND	LR
Aldrin	309-00-2	X	X	X	X	X
2-Aminoanthraquinone	117-79-3	X	ND	ND	ND	X
Aminoazobenzene	60-09-3	X	ND	ND	ND	X
4-Aminobiphenyl	92-67-1	X	ND	ND	ND	X
3-Amino-9-ethylcarbazole	132-32-1	X	X	ND	ND	ND
Anilazine	101-05-3	X	ND	ND	ND	X
Aniline	62-53-3	X	X	ND	X	X
o-Anisidine	90-04-0	X	ND	ND	ND	X
Anthracene	120-12-7	X	X	X	X	X
Aramite	140-57-8	HS	ND	ND	ND	X
Aroclor 1016	12674-11-2	X	X	X	X	X
Aroclor 1221	11104-28-2	X	X	X	X	X
Aroclor 1232	11141-16-5	X	X	X	X	X
Aroclor 1242	53469-21-9	X	X	X	X	X
Aroclor 1248	12672-29-6	X	X	X	X	X
Aroclor 1254	11097-69-1	X	X	X	X	X
Aroclor 1260	11096-82-5	X	X	X	X	X

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Compounds	CAS No ^a	Appropriate Preparation Techniques ^b				
		3510	3520	3540/ 3541	3550	3580
Azinphos-methyl	86-50-0	HS	ND	ND	ND	X
Barban	101-27-9	LR	ND	ND	ND	LR
Benzidine	92-87-5	CP	CP	CP	CP	CP
Benzoic acid	65-85-0	X	X	ND	X	X
Benzo(a)anthracene	56-55-3	X	X	X	X	X
Benzo(b)fluoranthene	205-99-2	X	X	X	X	X
Benzo(k)fluoranthene	207-08-9	X	X	X	X	X
Benzo(g,h,i)perylene	191-24-2	X	X	X	X	X
Benzo(a)pyrene	50-32-8	X	X	X	X	X
p-Benzoquinone	106-51-4	OE	ND	ND	ND	X
Benzyl alcohol	100-51-6	X	X	ND	X	X
α-BHC	319-84-6	X	X	X	X	X
β-BHC	319-85-7	X	X	X	X	X
δ-BHC	319-86-8	X	X	X	X	X
γ-BHC (Lindane)	58-89-9	X	X	X	X	X
Bis(2-chloroethoxy)methane	111-91-1	X	X	X	X	X
Bis(2-chloroethyl)ether	111-44-4	X	X	X	X	X
Bis(2-chloro-1-methylethyl)ether ^c	108-60-1	X	X	X	X	X
Bis(2-ethylhexyl)phthalate	117-81-7	X	X	X	X	X
4-Bromophenyl phenyl ether	101-55-3	X	X	X	X	X
Bromoxynil	1689-84-5	X	ND	ND	ND	X
Butyl benzyl phthalate	85-68-7	X	X	X	X	X
Captafol	2425-06-1	HS	ND	ND	ND	X
Captan	133-06-2	HS	ND	ND	ND	X
Carbaryl	63-25-2	X	ND	ND	ND	X
Carbofuran	1563-66-2	X	ND	ND	ND	X
Carbophenothion	786-19-6	X	ND	ND	ND	X
Chlordane (NOS)	57-74-9	X	X	X	X	X
Chlorfenvinphos	470-90-6	X	ND	ND	ND	X
4-Chloroaniline	106-47-8	X	ND	ND	ND	X
Chlorobenzilate	510-15-6	X	ND	ND	ND	X
5-Chloro-2-methylaniline	95-79-4	X	ND	ND	ND	X
4-Chloro-3-methylphenol	59-50-7	X	X	X	X	X
3-(Chloromethyl)pyridine hydrochloride	6959-48-4	X	ND	ND	ND	X
1-Chloronaphthalene	90-13-1	X	X	X	X	X
2-Chloronaphthalene	91-58-7	X	X	X	X	X
2-Chlorophenol	95-57-8	X	X	X	X	X
4-Chloro-1,2-phenylenediamine	95-83-0	X	X	ND	ND	ND
4-Chloro-1,3-phenylenediamine	5131-60-2	X	X	ND	ND	ND
4-Chlorophenyl phenyl ether	7005-72-3	X	X	X	X	X
Chrysene	218-01-9	X	X	X	X	X
Coumaphos	56-72-4	X	ND	ND	ND	X
p-Cresidine	120-71-8	X	ND	ND	ND	X
Crotoxyphos	7700-17-6	X	ND	ND	ND	X
2-Cyclohexyl-4,6-dinitro-phenol	131-89-5	X	ND	ND	ND	LR
4,4'-DDD	72-54-8	X	X	X	X	X
4,4'-DDE	72-55-9	X	X	X	X	X
4,4'-DDT	50-29-3	X	X	X	X	X
Demeton-O	298-03-3	HS	ND	ND	ND	X
Demeton-S	126-75-0	X	ND	ND	ND	X

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Compounds	CAS No ^a	Appropriate Preparation Techniques ^b				
		3510	3520	3540/ 3541	3550	3580
Diallate (cis or trans)	2303-16-4	X	ND	ND	ND	X
2,4-Diaminotoluene	95-80-7	DC, OE	ND	ND	ND	X
Dibenz(a,j)acridine	224-42-0	X	ND	ND	ND	X
Dibenz(a,h)anthracene	53-70-3	X	X	X	X	X
Dibenzofuran	132-64-9	X	X	ND	X	X
Dibenzo(a,e)pyrene	192-65-4	ND	ND	ND	ND	X
1,2-Dibromo-3-chloropropane	96-12-8	X	X	ND	ND	ND
Di-n-butyl phthalate	84-74-2	X	X	X	X	X
Dichlone	117-80-6	OE	ND	ND	ND	X
1,2-Dichlorobenzene	95-50-1	X	X	X	X	X
1,3-Dichlorobenzene	541-73-1	X	X	X	X	X
1,4-Dichlorobenzene	106-46-7	X	X	X	X	X
3,3'-Dichlorobenzidine	91-94-1	X	X	X	X	X
2,4-Dichlorophenol	120-83-2	X	X	X	X	X
2,6-Dichlorophenol	87-65-0	X	ND	ND	ND	X
Dichlorovos	62-73-7	X	ND	ND	ND	X
Dicrotophos	141-66-2	X	ND	ND	ND	X
Dieldrin	60-57-1	X	X	X	X	X
Diethyl phthalate	84-66-2	X	X	X	X	X
Diethylstilbestrol	56-53-1	AW, OS	ND	ND	ND	X
Diethyl sulfate	64-67-5	LR	ND	ND	ND	LR
Dimethoate	60-51-5	HE, HS	ND	ND	ND	X
3,3'-Dimethoxybenzidine	119-90-4	X	ND	ND	ND	LR
Dimethylaminoazobenzene	60-11-7	X	ND	ND	ND	X
7,12-Dimethylbenz(a)-anthracene	57-97-6	CP	ND	ND	ND	CP
3,3'-Dimethylbenzidine	119-93-7	X	ND	ND	ND	X
α,α-Dimethylphenethylamine	122-09-8	ND	ND	ND	ND	X
2,4-Dimethylphenol	105-67-9	X	X	X	X	X
Dimethyl phthalate	131-11-3	X	X	X	X	X
1,2-Dinitrobenzene	528-29-0	X	ND	ND	ND	X
1,3-Dinitrobenzene	99-65-0	X	ND	ND	ND	X
1,4-Dinitrobenzene	100-25-4	HE	ND	ND	ND	X
4,6-Dinitro-2-methylphenol	534-52-1	X	X	X	X	X
2,4-Dinitrophenol	51-28-5	X	X	X	X	X
2,4-Dinitrotoluene	121-14-2	X	X	X	X	X
2,6-Dinitrotoluene	606-20-2	X	X	X	X	X
Dinocap	39300-45-3	CP, HS	ND	ND	ND	CP
Dinoseb	88-85-7	X	ND	ND	ND	X
Diphenylamine	122-39-4	X	X	X	X	X
5,5-Diphenylhydantoin	57-41-0	X	ND	ND	ND	X
1,2-Diphenylhydrazine	122-66-7	X	X	X	X	X
Di-n-octyl phthalate	117-84-0	X	X	X	X	X
Disulfoton	298-04-4	X	ND	ND	ND	X
Endosulfan I	959-98-8	X	X	X	X	X
Endosulfan II	33213-65-9	X	X	X	X	X
Endosulfan sulfate	1031-07-8	X	X	X	X	X
Endrin	72-20-8	X	X	X	X	X
Endrin aldehyde	7421-93-4	X	X	X	X	X
Endrin ketone	53494-70-5	X	X	ND	X	X
EPN	2104-64-5	X	ND	ND	ND	X
Ethion	563-12-2	X	ND	ND	ND	X
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Compounds	CAS No ^a	Appropriate Preparation Techniques ^b				
		3510	3520	3540/ 3541	3550	3580
Ethyl carbamate	51-79-6	DC	ND	ND	ND	X
Ethyl methanesulfonate	62-50-0	X	ND	ND	ND	X
Famphur	52-85-7	X	ND	ND	ND	X
Fensulfothion	115-90-2	X	ND	ND	ND	X
Fenthion	55-38-9	X	ND	ND	ND	X
Fluchloralin	33245-39-5	X	ND	ND	ND	X
Fluoranthene	206-44-0	X	X	X	X	X
Fluorene	86-73-7	X	X	X	X	X
2-Fluorobiphenyl (surr)	321-60-8	X	X	X	X	X
2-Fluorophenol (surr)	367-12-4	X	X	X	X	X
Heptachlor	76-44-8	X	X	X	X	X
Heptachlor epoxide	1024-57-3	X	X	X	X	X
Hexachlorobenzene	118-74-1	X	X	X	X	X
Hexachlorobutadiene	87-68-3	X	X	X	X	X
Hexachlorocyclopentadiene	77-47-4	X	X	X	X	X
Hexachloroethane	67-72-1	X	X	X	X	X
Hexachlorophene	70-30-4	AW, CP	ND	ND	ND	CP
Hexachloropropene	1888-71-7	X	ND	ND	ND	X
Hexamethylphosphoramide	680-31-9	X	ND	ND	ND	X
Hydroquinone	123-31-9	ND	ND	ND	ND	X
Indeno(1,2,3-cd)pyrene	193-39-5	X	X	X	X	X
Isodrin	465-73-6	X	ND	ND	ND	X
Isophorone	78-59-1	X	X	X	X	X
Isosafrole	120-58-1	DC	ND	ND	ND	X
Kepone	143-50-0	X	ND	ND	ND	X
Leptophos	21609-90-5	X	ND	ND	ND	X
Malathion	121-75-5	HS	ND	ND	ND	X
Maleic anhydride	108-31-6	HE	ND	ND	ND	X
Mestranol	72-33-3	X	ND	ND	ND	X
Methapyrilene	91-80-5	X	ND	ND	ND	X
Methoxychlor	72-43-5	X	ND	ND	ND	X
3-Methylcholanthrene	56-49-5	X	ND	ND	ND	X
4,4'-Methylenebis(2-chloroaniline)	101-14-4	OE, OS	ND	ND	ND	LR
4,4'-Methylenebis(N,N-dimethyl-aniline)	101-61-1	X	X	ND	ND	ND
Methyl methanesulfonate	66-27-3	X	ND	ND	ND	X
2-Methylnaphthalene	91-57-6	X	X	ND	X	X
Methyl parathion	298-00-0	X	ND	ND	ND	X
2-Methylphenol	95-48-7	X	ND	ND	ND	X
3-Methylphenol	108-39-4	X	ND	ND	ND	X
4-Methylphenol	106-44-5	X	ND	ND	ND	X
Mevinphos	7786-34-7	X	ND	ND	ND	X
Mexacarbate	315-18-4	HE, HS	ND	ND	ND	X
Mirex	2385-85-5	X	ND	ND	ND	X
Monocrotophos	6923-22-4	HE	ND	ND	ND	X
Naled	300-76-5	X	ND	ND	ND	X
Naphthalene	91-20-3	X	X	X	X	X
1,4-Naphthoquinone	130-15-4	X	ND	ND	ND	X
1-Naphthylamine	134-32-7	OS	ND	ND	ND	X
2-Naphthylamine	91-59-8	X	ND	ND	ND	X
Nicotine	54-11-5	DC	ND	ND	ND	X

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Compounds	CAS No ^a	Appropriate Preparation Techniques ^b				
		3510	3520	3540/ 3541	3550	3580
5-Nitroacenaphthene	602-87-9	X	ND	ND	ND	X
2-Nitroaniline	88-74-4	X	X	ND	X	X
3-Nitroaniline	99-09-2	X	X	ND	X	X
4-Nitroaniline	100-01-6	X	X	ND	X	X
5-Nitro-o-anisidine	99-59-2	X	ND	ND	ND	X
Nitrobenzene	98-95-3	X	X	X	X	X
4-Nitrobiphenyl	92-93-3	X	ND	ND	ND	X
Nitrofen	1836-75-5	X	ND	ND	ND	X
2-Nitrophenol	88-75-5	X	X	X	X	X
4-Nitrophenol	100-02-7	X	X	X	X	X
5-Nitro-o-toluidine	99-55-8	X	X	ND	ND	X
Nitroquinoline-1-oxide	56-57-5	X	ND	ND	ND	X
N-Nitrosodi-n-butylamine	924-16-3	X	ND	ND	ND	X
N-Nitrosodiethylamine	55-18-5	X	ND	ND	ND	X
N-Nitrosodimethylamine	62-75-9	X	X	X	X	X
N-Nitrosodiphenylamine	86-30-6	X	X	X	X	X
N-Nitrosodi-n-propylamine	621-64-7	X	X	X	X	X
N-Nitrosomethylethylamine	10595-95-6	X	ND	ND	ND	X
N-Nitrosomorpholine	59-89-2	ND	ND	ND	ND	X
N-Nitrosopiperidine	100-75-4	X	ND	ND	ND	X
N-Nitrosopyrrolidine	930-55-2	X	ND	ND	ND	X
Octamethyl pyrophosphoramidate	152-16-9	LR	ND	ND	ND	LR
4,4'-Oxydianiline	101-80-4	X	ND	ND	ND	X
Parathion	56-38-2	X	X	ND	ND	X
Pentachlorobenzene	608-93-5	X	ND	ND	ND	X
Pentachloronitrobenzene	82-68-8	X	ND	ND	ND	X
Pentachlorophenol	87-86-5	X	X	X	X	X
Phenacetin	62-44-2	X	ND	ND	ND	X
Phenanthrene	85-01-8	X	X	X	X	X
Phenobarbital	50-06-6	X	ND	ND	ND	X
Phenol	108-95-2	DC	X	X	X	X
1,4-Phenylenediamine	106-50-3	X	ND	ND	ND	X
Phorate	298-02-2	X	ND	ND	ND	X
Phosalone	2310-17-0	HS	ND	ND	ND	X
Phosmet	732-11-6	HS	ND	ND	ND	X
Phosphamidon	13171-21-6	HE	ND	ND	ND	X
Phthalic anhydride	85-44-9	CP, HE	ND	ND	ND	CP
2-Picoline (2-Methylpyridine)	109-06-8	X	X	ND	ND	ND
Piperonyl sulfoxide	120-62-7	X	ND	ND	ND	X
Pronamide	23950-58-5	X	ND	ND	ND	X
Propylthiouracil	51-52-5	LR	ND	ND	ND	LR
Pyrene	129-00-0	X	X	X	X	X
Resorcinol	108-46-3	DC, OE	ND	ND	ND	X
Safrole	94-59-7	X	ND	ND	ND	X
Strychnine	57-24-9	AW, OS	ND	ND	ND	X
Sulfallate	95-06-7	X	ND	ND	ND	X
Terbufos	13071-79-9	X	ND	ND	ND	X
1,2,4,5-Tetrachlorobenzene	95-94-3	X	ND	ND	ND	X
2,3,4,6-Tetrachlorophenol	58-90-2	X	ND	ND	ND	X
Tetrachlorvinphos	961-11-5	X	ND	ND	ND	X
Tetraethyl dithiopyrophosphate	3689-24-5	X	X	ND	ND	ND

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Compounds	CAS No ^a	Appropriate Preparation Techniques ^b				
		3510	3520	3540/ 3541	3550	3580
Tetraethyl pyrophosphate	107-49-3	X	ND	ND	ND	X
Thionazine	297-97-2	X	ND	ND	ND	X
Thiophenol (Benzenethiol)	108-98-5	X	ND	ND	ND	X
Toluene diisocyanate	584-84-9	HE	ND	ND	ND	X
o-Toluidine	95-53-4	X	ND	ND	ND	X
Toxaphene	8001-35-2	X	X	X	X	X
1,2,4-Trichlorobenzene	120-82-1	X	X	X	X	X
2,4,5-Trichlorophenol	95-95-4	X	X	ND	X	X
2,4,6-Trichlorophenol	88-06-2	X	X	X	X	X
Trifluralin	1582-09-8	X	ND	ND	ND	X
2,4,5-Trimethylaniline	137-17-7	X	ND	ND	ND	X
Trimethyl phosphate	512-56-1	HE	ND	ND	ND	X
1,3,5-Trinitrobenzene	99-35-4	X	ND	ND	ND	X
Tris(2,3-dibromopropyl)phosphate	126-72-7	X	ND	ND	ND	LR
Tri-p-tolyl phosphate	78-32-0	X	ND	ND	ND	X
O,O,O-Triethyl phosphorothioate	126-68-1	X	ND	ND	ND	X

^a Chemical Abstract Service (CAS) Registry Number

^b See Sec. 1.2 for other acceptable preparation methods.

^c Chemical name was changed by the Integrated Risk Information System (IRIS) on November 30, 2007 from Bis(2-chloroisopropyl)ether to Bis(2-chloro-1-methylethyl)ether (common name). This compound is also known as 2,2'-oxybis(1-chloropropane) (CAS index name). See the link at <http://www.epa.gov/iris/subst/0407.htm>, Section VII for the "Revision History" and Section VIII, for "Synonyms" of this chemical.

KEY TO ANALYTE LIST

- AW = Adsorption to walls of glassware during extraction and storage
- CP = Non-reproducible chromatographic performance
- DC = Unfavorable distribution coefficient
- HE = Hydrolysis during extraction accelerated by acidic or basic conditions
- HS = Hydrolysis during storage potential
- LR = Low response
- ND = Not determined
- OE = Oxidation during extraction accelerated by basic conditions
- OS = Oxidation during storage potential
- X = Historically, adequate recovery can be obtained by this technique. However, actual recoveries may vary depending on the extraction efficiency, the number of constituents being analyzed concurrently, and the analytical instrumentation.

1.2 In addition to the sample preparation methods listed in the above analyte list, Method 3535 describes a solid-phase extraction (SPE) procedure that may be applied to the extraction of semivolatiles from toxicity characteristic leaching procedure (TCLP) leachates (see Tables 16 and 17 of this method for performance data). Method 3542 describes sample preparation for semivolatile organic compounds in air sampled by Method 0010 (see Table 10 of this method for surrogate performance data), Method 3545 describes an automated solvent extraction (ASE) device for semivolatiles in solids (see Table 11 of this method for performance data), Method 3561 describes a supercritical fluid extraction (SFE) device for the extraction of polynuclear aromatic hydrocarbons (PAHs) from solids (see Tables 12, 13, and 14 of this

method for performance data), and Method 3546 provides an extraction procedure employing commercially available microwave equipment to extract semivolatiles while using less solvent and taking less time than procedures such as a Soxhlet extraction (see Tables 18 through 22 of this method for the applicable performance data). The tabulated data are provided for guidance purposes only.

1.3 This method can be used to quantitate most neutral, acidic, and basic organic compounds that are soluble in methylene chloride (or other suitable solvents provided that the desired performance data can be generated) and are capable of being eluted, without derivatization, as sharp peaks from a gas chromatographic fused-silica capillary column coated with a slightly polar silicone. Such compounds include PAHs, chlorinated hydrocarbons and pesticides, phthalate esters, organophosphate esters, nitrosamines, haloethers, aldehydes, ethers, ketones, anilines, pyridines, quinolines, aromatic nitro compounds, and phenols, including nitrophenols. See Table 1 for a list of compounds and their characteristic ions that have been evaluated.

In most cases, this method is not appropriate for the quantitation of multicomponent analytes (e.g., Aroclors, toxaphene, chlordane, etc.) because of limited sensitivity for those analytes. When these analytes have been identified by another technique, Method 8270 may be appropriate for confirmation of the identification of these analytes when concentration in the extract permits. Refer to Methods 8081 and 8082 for guidance on calibration and quantitation of multicomponent analytes such as the Aroclors, Toxaphene, and Chlordane.

1.4 The following compounds may require special treatment when being determined by this method:

1.4.1 Benzidine may be subject to oxidative losses during solvent concentration and its chromatographic behavior is poor.

1.4.2 Under the alkaline conditions of the extraction step from aqueous matrices, α -BHC, γ -BHC, endosulfan I and II, and endrin are subject to decomposition. Neutral extraction should be performed if these compounds are expected to be present.

1.4.3 Hexachlorocyclopentadiene is subject to thermal decomposition in the inlet of the gas chromatograph, chemical reaction in acetone solution, and photochemical decomposition.

1.4.4 N-Nitrosodimethylamine is difficult to separate from the solvent under the chromatographic conditions described.

1.4.5 N-Nitrosodiphenylamine decomposes in the gas chromatographic inlet and cannot be separated from diphenylamine. For this reason, it is acceptable to report the combined result for n-nitrosodiphenylamine and diphenylamine for either of these compounds as a combined concentration.

1.4.6 1,2-Diphenylhydrazine is unstable even at room temperature and readily converts to azobenzene. Given the stability problems, it would be acceptable to calibrate for 1,2-diphenylhydrazine using azobenzene. Under these poor compound separation circumstances the results for either of these compounds should be reported as a combined concentration.

1.4.7 Pentachlorophenol, 2,4-dinitrophenol, 4-nitrophenol, benzoic acid, 4,6-dinitro-2-methylphenol, 4-chloro-3-methylphenol, 2-nitroaniline, 3-nitroaniline, 4-

nitroaniline, and benzyl alcohol are subject to erratic chromatographic behavior, especially if the gas chromatograph (GC) system is contaminated with high boiling material.

1.4.8 Pyridine may perform poorly at the GC injection port temperatures listed in this method. Lowering the injection port temperature may reduce the amount of degradation. However, the analyst must use caution in modifying the injection port temperature, as the performance of other analytes may be adversely affected. Therefore, if pyridine is to be determined in addition to other target analytes, it may be necessary to perform separate analyses. In addition, pyridine may be lost during the evaporative concentration of the sample extract. As a result, many of the extraction methods listed above may yield low recoveries unless great care is exercised during the concentration steps. For this reason, analysts may wish to consider the use of extraction techniques such as pressurized fluid extraction (Method 3545), microwave extraction (Method 3546), or supercritical fluid extraction, which involve smaller extract volumes, thereby reducing or eliminating the need for evaporative concentration techniques for many applications.

1.4.9 Toluene diisocyanate rapidly hydrolyzes in water (it has a half-life of less than 30 min). Therefore, recoveries of this compound from aqueous matrices should not be expected. In addition, in solid matrices, toluene diisocyanate often reacts with alcohols and amines to produce urethane and ureas and consequently cannot usually coexist in a solution containing these materials.

1.4.10 In addition, analytes in the list provided above are flagged when there are limitations caused by sample preparation and/or chromatographic problems.

1.5 The lower limits of quantitation (LLOQ) for this method when determining an individual compound are approximately 660 µg/kg (wet weight) for soil/sediment samples, 1-200 mg/kg for wastes (dependent on matrix and method of preparation), and 10 µg/L for groundwater samples (see Table 2). LLOQ will be proportionately higher for sample extracts that require dilution to avoid saturation of the detector. The lower limits of quantitation listed in Table 2 are provided for guidance and may not always be achievable.

1.6 Prior to employing this method, analysts are advised to consult the base method for each type of procedure that may be employed in the overall analysis (e.g., Methods 3500, 3600, 5000, and 8000) for additional information on QC procedures, development of QC acceptance criteria, calculations, and general guidance. Analysts also should consult the disclaimer statement at the front of the manual and the information in Chapter Two for guidance on the intended flexibility in the choice of methods, apparatus, materials, reagents, and supplies, and on the responsibilities of the analyst for demonstrating that the techniques employed are appropriate for the analytes of interest, in the matrix of interest, and at the levels of concern.

In addition, analysts and data users are advised that, except where explicitly specified in a regulation, the use of SW-846 methods is *not* mandatory in response to Federal testing requirements. The information contained in this method is provided by Environmental Protection Agency (EPA or the Agency) as guidance to be used by the analyst and the regulated community in making judgments necessary to generate results that meet the data quality objectives (DQOs) for the intended application.

1.7 Use of this method is restricted to use by, or under supervision of, personnel appropriately experienced and trained in the use of the GC/mass spectrometer (MS) and skilled in the interpretation of mass spectra. Each analyst must demonstrate the ability to generate acceptable results with this method.

2.0 SUMMARY OF METHOD

2.1 The samples are prepared for analysis by GC/MS using the appropriate sample preparation (refer to Method 3500) and, if necessary, sample cleanup procedures (refer to Method 3600).

2.2 The semivolatile compounds are introduced into the GC/MS by injecting the sample extract into a GC equipped with a narrow-bore fused-silica capillary column. The GC column is temperature-programmed to separate the analytes, which are then detected with an MS connected to the GC.

2.3 Analytes eluted from the capillary column are introduced into the MS via a jet separator or a direct connection. Identification of target analytes is accomplished by comparing their mass spectra with the electron impact (or electron impact like) spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using an appropriate calibration curve for the intended application.

2.4 This method includes specific calibration and QC steps that supersede the general recommendations provided in Method 8000.

US EPA Method TO-13A

Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)

<http://www3.epa.gov/ttnamti1/files/ambient/airtox/to-13arr.pdf>

METHOD TO-13A**Determination of Polycyclic Aromatic Hydrocarbons (PAHs)
in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)****1. Scope**

1.1 Polycyclic aromatic hydrocarbons (PAHs) have received increased attention in recent years in air pollution studies because some of these compounds are highly carcinogenic or mutagenic. In particular, benzo[a]pyrene (B[a]P) has been identified as being highly carcinogenic. To understand the extent of human exposure to B[a]P and other PAHs, reliable sampling and analytical methods are necessary. This document describes a sampling and analysis procedure for common PAHs involving the use of a combination of quartz filter and sorbent cartridge with subsequent analysis by gas chromatography with mass spectrometry (GC/MS) detection. The analytical methods are modifications of EPA Test Method 610 and 625, *Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater*, and Methods 8000, 8270, and 8310, *Test Methods for Evaluation of Solid Waste*.

1.2 Fluorescence methods were among the very first methods used for detection of B[a]P and other PAHs as carcinogenic constituents of coal tar (1-7). Fluorescence methods are capable of measuring subnanogram quantities of PAHs, but tend to be fairly non-selective. The normal spectra obtained are often intense and lack resolution. Efforts to overcome this difficulty led to the use of ultraviolet (UV) absorption spectroscopy (8) as the detection method coupled with pre-speciated techniques involving liquid chromatography (LC) and thin layer chromatography (TLC) to isolate specific PAHs, particularly B[a]P. As with fluorescence spectroscopy, the individual spectra for various PAHs are unique, although portions of spectra for different compounds may be the same. As with fluorescence techniques, the possibility of spectral overlap requires complete separation of sample components to ensure accurate measurement of component levels. Hence, the use of UV absorption coupled with pre-speciation involving LC and TLC and fluorescence spectroscopy declined and was replaced with the more sensitive high performance liquid chromatography (HPLC) with UV/fluorescence detection (9) or highly sensitive and specific gas chromatography/mass spectrometry (GC/MS) for detection (10-11).

1.3 The choice of GC/MS as the recommended procedure for analysis of B[a]P and other PAHs was influenced by its sensitivity and selectivity, along with its ability to analyze complex samples.

1.4 The analytical methodology has consequently been defined, but the sampling procedures can reduce the validity of the analytical results. Recent studies (12-17) have indicated that non-volatile PAHs (vapor pressure $<10^{-8}$ mm Hg) may be trapped on the filter, but post-collection volatilization problems may distribute the PAHs downstream of the filter to the back-up sorbent. A wide variety of sorbents such as Tenax®, XAD-2® and polyurethane foam (PUF) have been used to sample common PAHs. All sorbents have demonstrated high collection efficiency for B[a]P in particular. In general, XAD-2® resin has a higher collection efficiency (18-21) for volatile PAHs than PUF, as well as a higher retention efficiency. PUF cartridges, however, are easier to handle in the field and maintain better flow characteristics during sampling. Likewise, PUF has demonstrated (22) its capability in sampling organochlorine pesticides, polychlorinated biphenyls (22), and polychlorinated dibenzo-p-dioxins (23). PUF also has demonstrated a lower recovery efficiency and storage capability for naphthalene than XAD-2®. There have been no significant losses of PAHs up to 30 days of storage at room temperature (23 °C) using XAD-2®. It also appears that XAD-2® resin has a higher collection efficiency for volatile PAHs than PUF, as well as a higher retention efficiency for both volatile and reactive PAHs.

Consequently, while the literature cites weaknesses and strengths of using either XAD-2® or PUF, this method includes the utilization of PUF as the primary sorbent.

1.5 This method includes the qualitative and quantitative analysis of the following PAHs (see Figure 1) specifically by utilizing PUF as the sorbent followed by GC/MS analysis:

Acenaphthene (low collection efficiency; see Section 6.1.3)	Coronene
Acenaphthylene (low collection efficiency; see Section 6.1.3)	Dibenz(a,h)anthracene
Anthracene	Fluoranthene
Benz(a)anthracene	Fluorene
Benzo(a)pyrene	Benzo(b)fluoranthene
Benzo(e)pyrene	Indeno(1,2,3-cd)pyrene
Benzo(g,h,i)perylene	Naphthalene (low collection efficiency; see Section 6.1.3)
Benzo(k)fluoranthene	Phenanthrene
Chrysene	Pyrene
	Perylene

The GC/MS method is applicable to the determination of PAHs compounds involving three member rings or higher. Naphthalene, acenaphthylene, and acenaphthene have only ~35 percent recovery when using PUF as the sorbent. Nitro-PAHs have *not* been fully evaluated using this procedure; therefore, they are not included in this method.

1.6 With optimization to reagent purity and analytical conditions, the detection limits for the GC/MS method range from 1 ng to 10 pg based on field experience.

2. Summary of Method

2.1 Filters and sorbent cartridges (containing PUF or XAD-2®) are cleaned in solvents and vacuum dried. The filters and sorbent cartridges are stored in screw-capped jars wrapped in aluminum foil (or otherwise protected from light) before careful installation on the sampler.

2.2 Approximately 300 m³ of air is drawn through the filter and sorbent cartridge using a high-volume flow rate air sampler or equivalent.

2.3 The amount of air sampled through the filter and sorbent cartridge is recorded, and the filter and cartridge are placed in an appropriately labeled container and shipped along with blank filter and sorbent cartridges to the analytical laboratory for analysis.

2.4 The filters and sorbent cartridge are extracted by Soxhlet extraction with appropriate solvent. The extract is concentrated by Kuderna-Danish (K-D) evaporator, followed by silica gel cleanup using column chromatography to remove potential interferences prior to analysis by GC/MS.

2.5 The eluent is further concentrated by K-D evaporation, then analyzed by GC/MS. The analytical system is verified to be operating properly and calibrated with five concentration calibration solutions.

2.6 A preliminary analysis of the sample extract is performed to check the system performance and to ensure that the samples are within the calibration range of the instrument. If the preliminary analysis indicates non - performance, then recalibrate the instrument, adjust the amount of the sample injected, adjust the calibration solution concentration, and adjust the data processing system to reflect observed retention times, etc.

2.7 The samples and the blanks are analyzed and used (along with the amount of air sampled) to calculate the concentration of PAHs in the air sample.

CAM-17

US EPA Method 200.7

Trace Elements In Water, Solids, And Biosolids By Inductively Coupled Plasma-Atomic Emission Spectrometry

<http://nepis.epa.gov/Exe/ZyPDF.cgi/P1002CW0.PDF?Dockey=P1002CW0.PDF>

Method 200.7

Trace Elements in Water, Solids, and Biosolids by Inductively Coupled Plasma-Atomic Emission Spectrometry

1.0 Scope and Application

- 1.1 Inductively coupled plasma-atomic emission spectrometry (ICP-AES) is used to determine metals and some nonmetals in solution. This method is a consolidation of existing methods for water, wastewater, and solid wastes (References 1-4). For analysis of petroleum products see References 5 and 6. This method is applicable to the following analytes:

Analyte		Chemical Abstract Services Registry Number (CASRN)
Aluminum	(Al)	7429-90-5
Antimony	(Sb)	7440-36-0
Arsenic	(As)	7440-38-2
Barium	(Ba)	7440-39-3
Beryllium	(Be)	7440-41-7
Boron	(B)	7440-42-8
Cadmium	(Cd)	7440-43-9
Calcium	(Ca)	7440-70-2
Cerium ^a	(Ce)	7440-45-1
Chromium	(Cr)	7440-47-3
Cobalt	(Co)	7440-48-4
Copper	(Cu)	7440-50-8
Iron	(Fe)	7439-89-6
Lead	(Pb)	7439-92-1
Lithium	(Li)	7439-93-2
Magnesium	(Mg)	7439-95-4
Manganese	(Mn)	7439-96-5
Mercury	(Hg)	7439-97-6
Molybdenum	(Mo)	7439-98-7
Nickel	(Ni)	7440-02-0
Phosphorus	(P)	7723-14-0
Potassium	(K)	7440-09-7
Selenium	(Se)	7782-49-2
Silica ^b	(SiO ₂)	7631-86-9
Silver	(Ag)	7440-22-4

Analyte		Chemical Abstract Services Registry Number (CASRN)
Sodium	(Na)	7440-23-5
Strontium	(Sr)	7440-24-6
Thallium	(Tl)	7440-28-0
Tin	(Sn)	7440-31-5
Titanium	(Ti)	7440-32-6
Vanadium	(V)	7440-62-2
Yttrium	(Y)	7440-65-5
Zinc	(Zn)	7440-66-6

^aCerium has been included as a method analyte for correction of potential inter-element spectral interference.

^bThis method is not suitable for the determination of silica in solids.

- 1.2** To confirm approval of this method for use in compliance monitoring programs [e.g., Clean Water Act (NPDES) or Safe Drinking Water Act (SDWA)] consult both the appropriate sections of the Code of Federal Regulation (40 CFR Part 136 Table 1B for NPDES, and Part 141 § 141.23 for drinking water) and the latest Federal Register announcements.
- 1.3** ICP-AES can be used to determine dissolved analytes in aqueous samples after suitable filtration and acid preservation. To reduce potential interferences, dissolved solids should be <0.2% (w/v) (Section 4.2).
- 1.4** With the exception of silver, where this method is approved for the determination of certain metal and metalloid contaminants in drinking water, aqueous samples may be analyzed directly by pneumatic nebulization without acid digestion if the sample has been properly preserved with acid and has turbidity of <1 NTU at the time of analysis. This total recoverable determination procedure is referred to as "direct analysis." However, in the determination of some primary drinking water metal contaminants, preconcentration of the sample may be required prior to analysis in order to meet drinking water acceptance performance criteria (Sections 11.2.2 through 11.2.7).
- 1.5** For the determination of total recoverable analytes in aqueous, biosolids (municipal sewage sludge), and solid samples, a digestion/extraction is required prior to analysis when the elements are not in solution (e.g., soil, sludge, sediment, and aqueous samples that may contain particulate and suspended solids). Aqueous samples containing total suspended solids $\geq 1\%$ (w/v) should be extracted as a solid type sample.

- 1.6** When determining boron and silica in aqueous samples, only plastic, PTFE or quartz labware should be used from time of sample collection to completion of analysis. For accurate determination of boron in solid and sludge samples, only quartz or PTFE beakers should be used during acid extraction with immediate transfer of an extract aliquot to a plastic centrifuge tube following dilution of the extract to volume. When possible, borosilicate glass should be avoided to prevent contamination of these analytes.
- 1.7** Silver is only slightly soluble in the presence of chloride unless there is a sufficient chloride concentration to form the soluble chloride complex. Therefore, low recoveries of silver may occur in samples, fortified sample matrices and even fortified blanks if determined as a dissolved analyte or by "direct analysis" where the sample has not been processed using the total recoverable mixed acid digestion. For this reason it is recommended that samples be digested prior to the determination of silver. The total recoverable sample digestion procedure given in this method is suitable for the determination of silver in aqueous samples containing concentrations up to 0.1 mg/L. For the analysis of wastewater samples containing higher concentrations of silver, succeeding smaller volume, well-mixed aliquots should be prepared until the analysis solution contains <0.1 mg/L silver. The extraction of solid or sludge samples containing concentrations of silver >50 mg/kg should be treated in a similar manner.

NOTE: *When analyzing samples containing high levels of silver as might occur in the photographic manufacturing industries, EPA Method 272.1 can be used for silver determinations. Based on the use of cyanogen iodide (CNI) as a stabilizing agent, Method 272.1 can be used on samples containing up to 4 mg/L of Ag. However, it should be recognized that CNI is an extremely hazardous and environmentally toxic reagent, and should be used with the utmost caution.*

- 1.8** The extraction of tin from solid or sludge samples should be prepared using aliquots <1 g when determined sample concentrations exceed 1%.
- 1.9** The total recoverable sample digestion procedures given in this method will solubilize and hold in solution only minimal concentrations of barium in the presence of free sulfate. For the analysis of barium in samples having varying and unknown concentrations of sulfate, analysis should be completed as soon as possible after sample preparation.
- 1.10** The total recoverable sample digestion procedure given in this method is not suitable for the determination of volatile organo-mercury compounds. However, if digestion is not required (turbidity <1 NTU), the combined concentrations of inorganic and organo-mercury in solution can be determined by "direct analysis" pneumatic nebulization provided the sample solution is adjusted to contain the

same mixed acid (HNO₃ + HCl) matrix as the total recoverable calibration standards and blank solutions.

- 1.11** This method will be validated in biosolids for those analytes regulated under 40 CFR Part 503 only. It is believed to be applicable for the analysis of biosolids for all analytes listed in Section 1.1. There may be difficulties in analyzing molybdenum in biosolids with a radial ICP, thus the determination of some analytes in biosolids may require the use of an axial ICP. More information will be provided by the validation study.
- 1.12** Detection limits and linear ranges for the elements will vary with the wavelength selected, the spectrometer, and the matrices. Method detection limits (MDLs; 40 CFR 136, appendix B) and minimum levels (MLs) when no interferences are present will be determined for this method through a validation study. Preliminary MDL values are given in Table 4. The ML for each analyte can be calculated by multiplying the MDL by 3.18 and rounding to the nearest (2, 5, or 10 X 10ⁿ) where n is an integer.
- 1.13** Users of the method data should state the data-quality objectives prior to analysis. Users of the method must document and have on file the required initial demonstration performance data described in Section 9.2 prior to using the method for analysis.

2.0 Summary of Method

- 2.1** An aliquot of a well-mixed, homogeneous sample is accurately weighed or measured for sample processing. For total recoverable analysis of a solid or an aqueous sample containing undissolved material, analytes are solubilized by gentle refluxing with HNO₃ and HCl. For the total recoverable analysis of a sludge sample containing <1% total suspended solids, analytes are solubilized by successive refluxing with HNO₃ and HCl. For total recoverable analysis of a sludge sample containing total suspended solids ≥1% (w/v), analytes are solubilized by refluxing with HNO₃, background organic materials are oxidized with peroxide, and analytes are further solubilized by refluxing with HCl. After cooling, the sample is made up to volume, mixed and then centrifuged or allowed to settle overnight prior to analysis. For the determination of dissolved analytes in a filtered aqueous sample aliquot, or for the "direct analysis" total recoverable determination of analytes in drinking water where sample turbidity is <1 NTU, the sample is made ready for analysis by the addition of the appropriate volume of HNO₃, and then diluted to a predetermined volume and mixed before analysis.
- 2.2** The analysis described in this method involves multi-elemental determinations by ICP-AES using sequential or simultaneous instruments. The instruments measure characteristic atomic-line emission spectra by optical spectrometry.

Samples are nebulized and the resulting aerosols are transported to the plasma torch. Element specific emission spectra are produced by a radio-frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and the intensities of the line spectra are monitored at specific wavelengths by a photosensitive device. Photocurrents from the photosensitive device are processed and controlled by a computer system. A background correction technique is required to compensate for variable background contribution to the determination of the analytes. The background must be measured adjacent to an analyte wavelength during analysis. Interferences must be considered and addressed appropriately as discussed in Sections 4.0, 7.0, 9.0, and 11.0.

CAM-17

US EPA Method 6010C

Inductively Coupled Plasma-Atomic Emission Spectrometry

<http://www.epa.gov/sites/production/files/2015-07/documents/epa-6010c.pdf>

METHOD 6010C

INDUCTIVELY COUPLED PLASMA-ATOMIC EMISSION SPECTROMETRY

1.0 SCOPE AND APPLICATION

1.1 Inductively coupled plasma-atomic emission spectrometry (ICP-AES) may be used to determine trace elements in solution. The method is applicable to all of the elements listed below. With the exception of groundwater samples, all aqueous and solid matrices require acid digestion prior to analysis. Groundwater samples that have been prefiltered and acidified will not need acid digestion. Samples which are not digested require either an internal standard or should be matrix-matched with the standards. If either option is used, instrument software should be programmed to correct for intensity differences of the internal standard between samples and standards. Refer to Chapter Three for the appropriate digestion procedures.

Element	Symbol	CAS Number	Element	Symbol	CAS Number
Aluminum	Al	7429-90-5	Mercury	Hg	7439-97-6
Antimony	Sb	7440-36-0	Molybdenum	Mo	7439-98-7
Arsenic	As	7440-38-2	Nickel	Ni	7440-02-0
Barium	Ba	7440-39-3	Phosphorus	P	7723-14-0
Beryllium	Be	7440-41-7	Potassium	K	7440-09-7
Boron	B	7440-42-8	Selenium	Se	7782-49-2
Cadmium	Cd	7440-43-9	Silica	SiO ₂	7631-86-9
Calcium	Ca	7440-70-2	Silver	Ag	7440-22-4
Chromium	Cr	7440-47-3	Sodium	Na	7440-23-5
Cobalt	Co	7440-48-4	Strontium	Sr	7440-24-6
Copper	Cu	7440-50-8	Thallium	Tl	7440-28-0
Iron	Fe	7439-89-6	Tin	Sn	7440-31-5
Lead	Pb	7439-92-1	Titanium	Ti	7440-32-6
Lithium	Li	7439-93-2	Vanadium	V	7440-62-2
Magnesium	Mg	7439-95-4	Zinc	Zn	7440-66-6
Manganese	Mn	7439-96-5			

1.2 Table 1 lists the elements for which this method has been validated. The sensitivity and the optimum and linear ranges for each element will vary with the wavelength, spectrometer, matrix, and operating conditions. Table 1 lists the recommended analytical wavelengths and estimated instrumental detection limits for the elements in clean aqueous matrices with insignificant background interferences. Other elements and matrices may be analyzed by this method if performance at the concentrations of interest (see Sec. 9.0) is demonstrated.

1.3 In addition, method detection limits (MDLs) should be empirically established annually, at a minimum, for each matrix type analyzed (refer to Chapters One and Three for guidance) and are required for each preparatory/determinative method combination used. MDLs are instrument-specific, so an MDL study must be conducted for each instrument in a laboratory.

1.4 Analysts should clearly understand the data quality objectives prior to analysis and must document and have on file the required initial demonstration performance data described in the following sections prior to using the method for analysis.

1.5 Analysts should consult the disclaimer statement at the front of the manual and the information in Chapter Two, Sec. 2.1, for guidance on the intended flexibility in the choice of methods, apparatus, materials, reagents, and supplies, and on the responsibilities of the analyst for demonstrating that the techniques employed are appropriate for the analytes of interest, in the matrix of interest, and at the levels of concern.

In addition, analysts and data users are advised that, except where explicitly specified in a regulation, the use of SW-846 methods is *not* mandatory in response to Federal testing requirements. The information contained in this method is provided by EPA as guidance to be used by the analyst and the regulated community in making judgments necessary to generate results that meet the data quality objectives for the intended application.

1.6 Use of this method is restricted to spectroscopists who are knowledgeable in the correction of spectral, chemical, and physical interferences described in this method.

2.0 SUMMARY OF METHOD

2.1 Prior to analysis, samples must be solubilized or digested using the appropriate sample preparation methods (see Chapter Three). When analyzing groundwater samples for dissolved constituents, acid digestion is not necessary if the samples are filtered and acid preserved prior to analysis (refer to Sec. 1.1).

2.2 This method describes multielemental determinations by ICP-AES using sequential or simultaneous optical systems and axial or radial viewing of the plasma. The instrument measures characteristic emission spectra by optical spectrometry. Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by a radio-frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and the intensities of the emission lines are monitored by photosensitive devices.

2.3 Background correction is required for trace element determination. Background emission must be measured adjacent to analyte lines on samples during analysis. The position selected for the background-intensity measurement, on either or both sides of the analytical line, will be determined by the complexity of the spectrum adjacent to the analyte line. The position used should be as free as possible from spectral interference and should reflect the same change in background intensity as occurs at the analyte wavelength measured. Background correction is not required in cases of line broadening where a background correction measurement would actually degrade the analytical result. The possibility of additional interferences identified in Sec. 4.0 should also be recognized and appropriate corrections made; tests for their presence are described in Secs. 9.5 and 9.6. Alternatively, users may choose multivariate calibration methods. In this case, point selections for background correction are superfluous since whole spectral regions are processed.

CAM-17

US EPA Method 245.1

Determination Of Mercury In Water By Cold Vapor Atomic Absorption Spectrometry

<http://www.epa.gov/sites/production/files/2015-06/documents/epa-245.1.pdf>

**DETERMINATION OF MERCURY IN WATER
BY COLD VAPOR ATOMIC ABSORPTION SPECTROMETRY**

1.0 SCOPE AND APPLICATION

1.1 This procedure¹ measures total mercury (organic + inorganic) in drinking, surface, ground, sea, brackish waters, industrial and domestic wastewater.

Analyte	Chemical Abstracts Service Registry Number (CASRN)
Mercury	7439-97-6

1.2 The range of the method is 0.2-10 µg Hg/L. The range may be extended above or below the normal range by increasing or decreasing sample size. However, the actual method detection limit and linear working range will be dependent on the sample matrix, type of instrumentation configuration, and selected operating conditions.

1.3 Reduced volume or semi-automated versions of this method, that use the same reagents and molar ratios, are acceptable provided they meet the quality control and performance requirements stated in the method (Section 9.0).

1.4 For reference where this method is approved for use in compliance monitoring programs [e.g., Clean Water Act (NPDES) or Safe Drinking Water Act (SDWA)] consult both the appropriate sections of the Code of Federal Regulation (40 CFR Part 136 Table 1B for NPDES, and Part 141 § 141.23 for drinking water), and the latest Federal Register announcements.

2.0 SUMMARY OF METHOD

2.1 A known portion of a water sample is transferred to a BOD bottle, equivalent ground glass stoppered flask or other suitable closed container. It is digested in diluted potassium permanganate-potassium persulfate solutions and oxidized for two hours at 95°C. Mercury in the digested water sample is reduced with stannous chloride to elemental mercury and measured by the conventional cold vapor atomic absorption technique.

3.0 DEFINITIONS

CAM-17

US EPA Method 7470A

Mercury in Liquid Waste (Manual Cold-Vapor Technique)

<http://www3.epa.gov/epawaste/hazard/testmethods/sw846/pdfs/7470a.pdf>

MERCURY IN LIQUID WASTE (MANUAL COLD-VAPOR TECHNIQUE)

1.0 SCOPE AND APPLICATION

1.1 Method 7470 is a cold-vapor atomic absorption procedure approved for determining the concentration of mercury in mobility-procedure extracts, aqueous wastes, and ground waters. (Method 7470 can also be used for analyzing certain solid and sludge-type wastes; however, Method 7471 is usually the method of choice for these waste types.) All samples must be subjected to an appropriate dissolution step prior to analysis.

2.0 SUMMARY OF METHOD

2.1 Prior to analysis, the liquid samples must be prepared according to the procedure discussed in this method.

2.2 Method 7470, a cold-vapor atomic absorption technique, is based on the absorption of radiation at 253.7-nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) is measured as a function of mercury concentration.

2.3 The typical detection limit for this method is 0.0002 mg/L.

CAM-17

US EPA Method 7471B

Mercury In Solid Or Semisolid Waste (Manual Cold-Vapor Technique)

<http://www3.epa.gov/epawaste/hazard/testmethods/sw846/pdfs/7471b.pdf>

METHOD 7471B

MERCURY IN SOLID OR SEMISOLID WASTE (MANUAL COLD-VAPOR TECHNIQUE)

1.0 SCOPE AND APPLICATION

1.1 Method 7471 is approved for measuring total mercury (organic and inorganic) in soils, sediments, bottom deposits, and sludge-type materials. All samples must be subjected to an appropriate dissolution step prior to analysis. If this dissolution procedure is not sufficient to dissolve a specific matrix type or sample, then this method is not applicable for that matrix.

2.0 SUMMARY OF METHOD

2.1 Prior to analysis, the solid or semi-solid samples must be prepared according to the procedures discussed in this method.

2.2 This method is a cold-vapor atomic absorption method and is based on the absorption of radiation at the 253.7-nm wavelength by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) is measured as a function of mercury concentration.

2.3 The typical instrument detection limit (IDL) for this method is 0.0002 mg/L.

Appendix I

List of Literature Reviewed by OEHHA



List of Literature Reviewed by OEHHHA

Anderson ME, Kirkland KH, Guidotti TL and Rose C (2006). A Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist. *Environ Health Perspect* **114**:1-3.

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Appendix J

A Handy Guide to

The Bagley-Keene Open Meeting Act 2004

http://www.aq.ca.gov/publications/bagleykeene2004_ada.pdf