California Environmental Protection Agency

Office of Environmental Health Hazard Assessment

Synthetic Turf Study

Synthetic Turf
Scientific Advisory Panel Meeting

March 10, 2017

MEETING MATERIALS

Table of Contents

Agenda

Synthetic Turf Scientific Advisory Panel Meeting

Friday, March 10, 2017, 10:00 a.m. – 5:00 p.m.
1001 I Street, CalEPA Headquarters Building, Sacramento
Sierra Hearing Room

1. Welcome and Opening Remarks

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

   John Balmes, M.D., SAP Chair; Professor, School of Medicine, University of California (UC) San Francisco; and School of Public Health, UC Berkeley

2. Updates on Synthetic Turf Studies

   David Ting, Ph.D., Branch Chief, Pesticide and Environmental Toxicology Branch, OEHHA

   Patty Wong, Ph.D., Section Chief, Special Investigations Section, PETB, OEHHA

3. Scientific Discussions of Study Components

   On each topic, scientists of OEHHA and Lawrence Berkeley National Laboratory (LBNL) will provide a brief overview, followed by panel discussion

   3.1. Chemical Identification for Field Study
   - 3.1.1. Identification of Synthetic Turf Chemical for Targeted Chemical Analysis
   - 3.1.2. Supplementary Information for Chemical Identification

   3.2. Exposure Pathways Studies
   - 3.2.1. Time-Activity Behavior Study
   - 3.2.2. Emission Modeling of Synthetic Turf Chemicals

   3.3. Bioaccessibility Study
   - 3.3.1. Biofluid Compositions
   - 3.3.2. Bioaccessibility Study Setup

3.4. Field Study

- 3.4.1. Phase 1 Field Study
- 3.4.2. Phase 2 Field Study
- 3.4.3. Phase 3 Field Study

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

6. Closing Remarks and Adjournment

An Update of the OEHHA Synthetic Turf Study

March 2017

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 study is comprised of separate tasks: 1) expert, public, and interagency consultation and input, 2) hazard identification, 3) exposure scenario development, 4) sampling and analysis of new and in-field synthetic turf, 5) personal monitoring or biomonitoring study protocol development, and 6) a health risk assessment. OEHHA will use the information obtained in conducting these tasks to conduct the final task, an assessment of the potential health impacts of the use of synthetic turf. The study started in June 2015 and this document provides an update of the study.

Task 1: Expert, public, and interagency consultation and input
In order to ensure the study uses the most appropriate scientific approach and technology, OEHHA has established a Scientific Advisory Panel (SAP) to provide advice and inputs to the study. The SAP held its first public meeting on February 8, 2016. It reviewed a study proposal from OEHHA and provided advice on improvements in a number of areas, including on: 1) the extraction of chemicals from crumb rubber, 2) the composition of biofluids for the bioacccessibility simulation study, and 3) the assessment of exposure to airborne particulate matter. In response to this advice, OEHHA has modified and expanded the study plan, with details described in Task 4a. The second meeting of the SAP is being held on March 10, 2017.

OEHHA has consulted with several federal agencies as well as other academic research institutions in the United States and overseas. OEHHA also met with the Rubber Manufacturers Association and the Carbon Black Association.

The focus of federal and other research efforts relating to crumb rubber and synthetic turf is provided below.

- US Environmental Protection Agency (US EPA) — Released federal research action plan on recycled tire crumb used on playing fields and playgrounds (study protocol released February 2016 and status report released December 2016).
- Consumer Product Safety Commission — Conducting a national survey on children’s behaviors on playgrounds and identifying exposure factors.

- The National Institute for Occupational Safety and Health — Exploring the feasibility of studying worker exposure.
- National Toxicology Program — Conducting research on synthetic turf and recycled crumb rubber in response to a request from OEHHA.
- European Union:
    - National Institute for Public Health and the Environment (RIVM), Ministry of Health, Welfare and Sport, The Netherlands — Released a study in December 2016, which concluded that "*Playing sports on synthetic turf fields with rubber granulate is safe*" after investigating 100+ fields in the Netherlands.
    - European Chemical Agency (ECHA) — Finished literature review risk assessment on synthetic turf fields containing crumb rubber (report released in February 2017).

Task 2: Hazard Identification

OEHHA has conducted a scientific literature search to identify chemicals that can be released from synthetic turf and crumb rubber or are used in tire manufacturing. The supplemental information compiled will be used to assist the identification of chemicals released from crumb rubber.

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. In order to obtain exposure information specific to sports commonly played on synthetic turf fields:

- OEHHA has commissioned a study with the University of California, Davis Extension Collaboration Center on exposure scenarios of young soccer players, hours played on synthetic turf by soccer and football players, and design considerations of a more detailed exposure study. A final report was received on May 31, 2016. (Appendix B)
- OEHHA has been consulting with experts in academia to conduct a time-activity behavior pattern study of sport participants and bystanders on/near synthetic turf fields

Task 4: Sampling and Analysis of New and In-field Synthetic Turf

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

OEHHA is working with Lawrence Berkeley National Laboratory (LBNL) to develop procedures for analyzing chemicals that can be released or extracted from crumb rubber. Based on the advice from the SAP, OEHHA has added extraction with aqueous and organic solvents of different polarities to expand the range of chemicals that can be detected. In addition, OEHHA has added lipids and proteins to the artificial biofluids to better emulate human saliva, gastric fluids, lung fluids, and sweat. Sophisticated instruments such as gas chromatography/mass spectroscopy (GC/MS) and liquid chromatography/mass spectroscopy (LC/MS) and a computer database with the fragmentation pattern of more than 240,000 chemicals will be used in this process.

In order to better evaluate the potential hazard of inhalation of particles when playing on the synthetic turf fields, the SAP advised characterization of airborne particles. OEHHA is working with LBNL to measure the particle size distribution of airborne particulate matter over synthetic turf fields with simulated human activities.

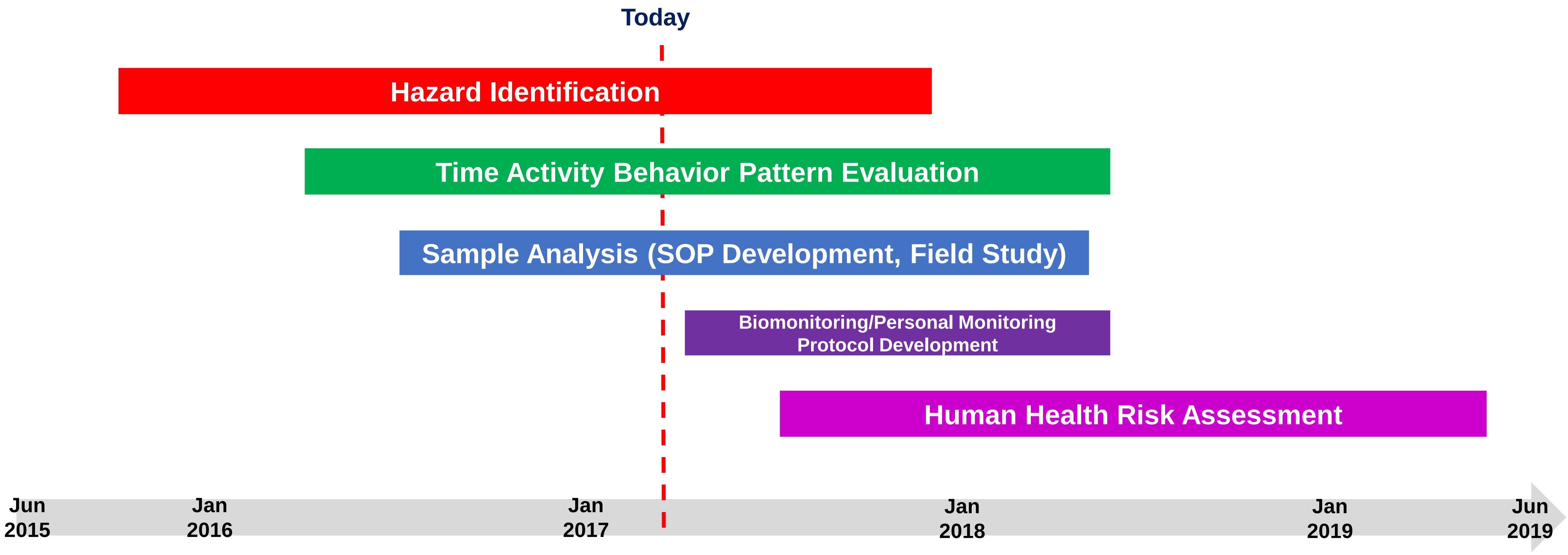
Task 5: Personal Monitoring and Biomonitoring Study Protocol Development

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. OEHHA is consulting with experts in academia to investigate possible protocols and to conduct a feasibility evaluation of personal monitoring and biomonitoring studies. Details on this task will be discussed in the future meeting(s).

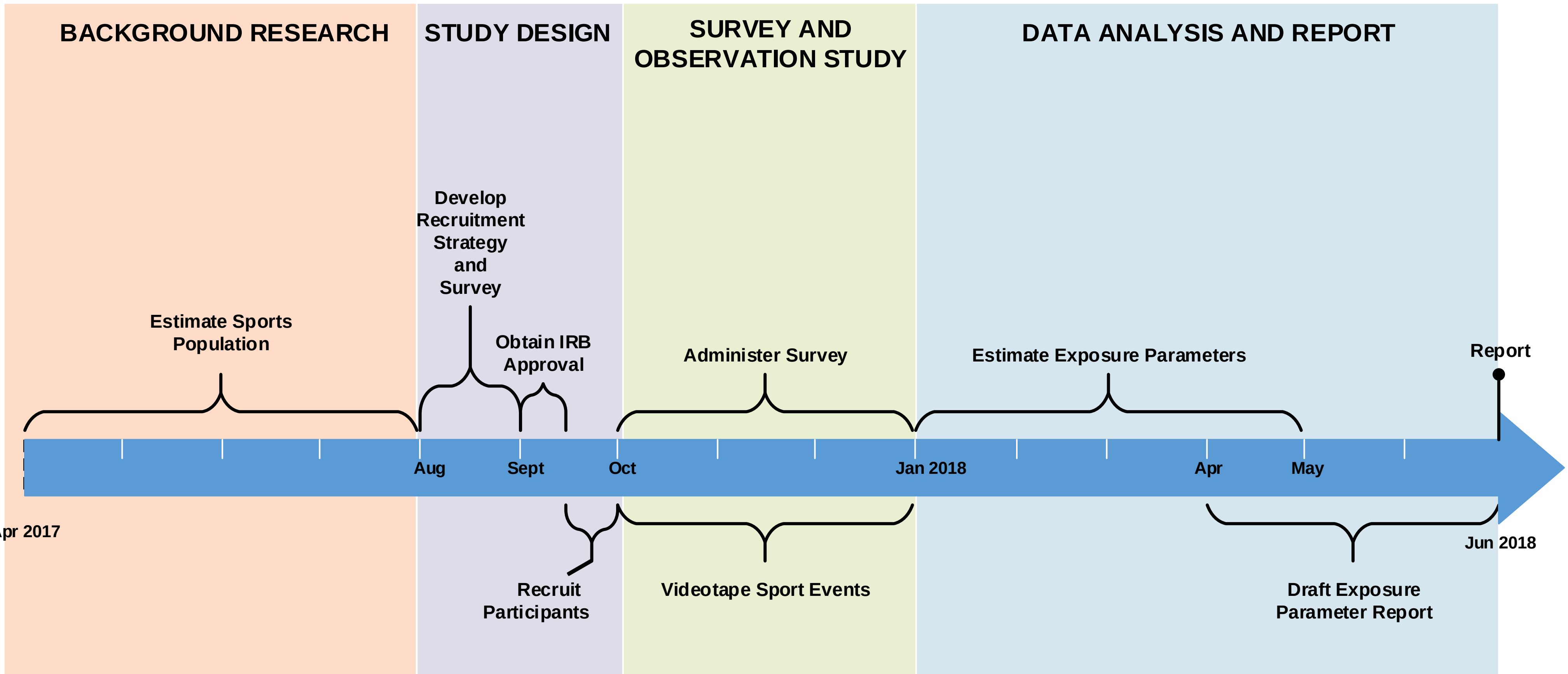
Task 6: Health Assessment from play on synthetic turf fields and playground mats

Using the results of previous tasks 1-5, OEHHA will conduct a health risk assessment of the potential health impacts associated with the use of synthetic turf fields and playground mats.

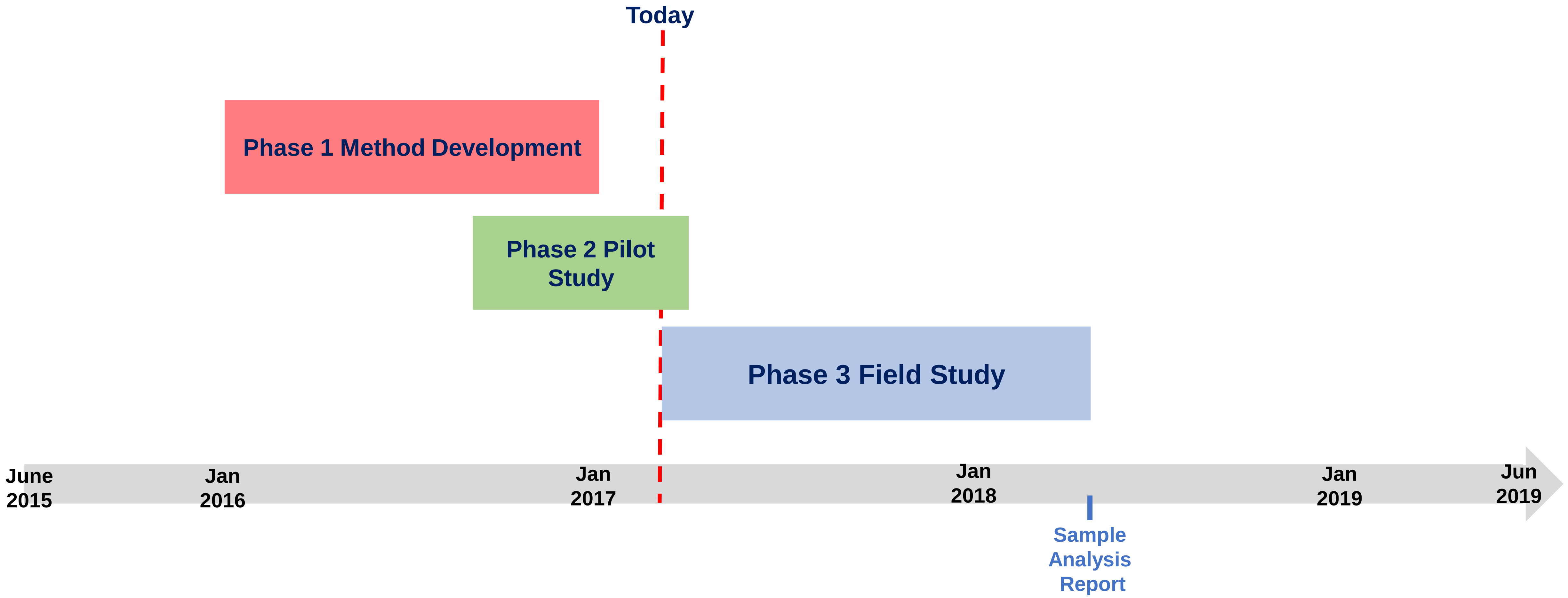
Overall OEHHA Synthetic Turf Study Timeline



Task 3
Time Activity Behavior Pattern Study Timeline



Task 4
Field Study Timeline



Section 1

Chemical Identification for Field Study

Section 1A

Identification of Synthetic Turf Chemicals for Targeted Chemical Analysis

Section 1A. Synthetic Turf (ST) Chemical Identification

Step 1. Build List of Potential ST Chemicals

- comprehensive literature review to identify chemicals used in/with/on ST components
- reduce comprehensive list to include chemicals “detected” in/with/on ST components

Step 2. Build List of Identified ST Chemicals

- using crumb rubber samples from Phase 1 (uninstalled and limited field samples in 2 age groups)
- using range or measurement and detection methods

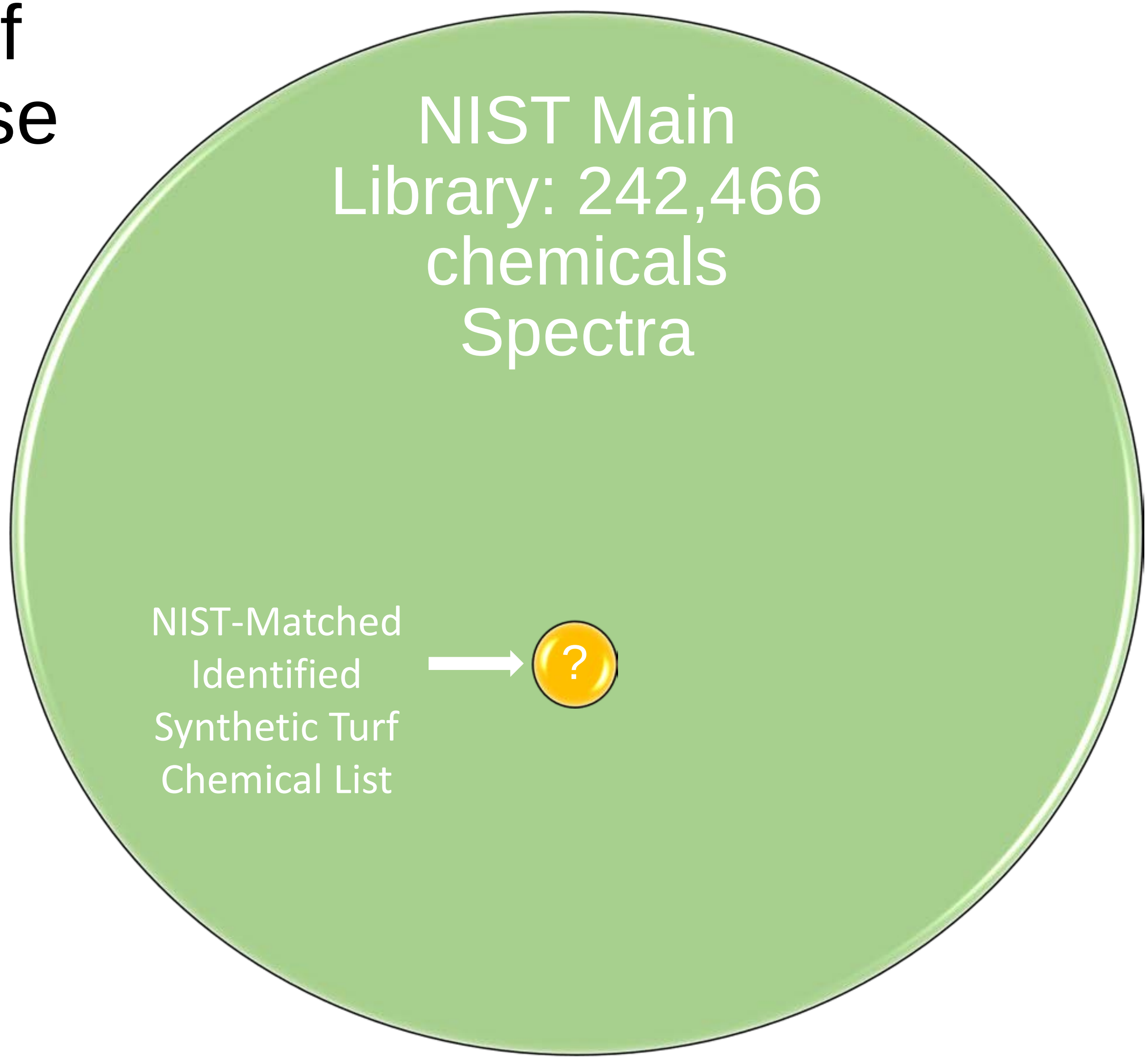
Step 3. Expanding List with Unknown ST Chemicals

- based on chemicals identified in Phases 2 and 3 field samples (representative field samples throughout CA)
- based on aged ST components

Step 1. Build the Potential ST Chemicals

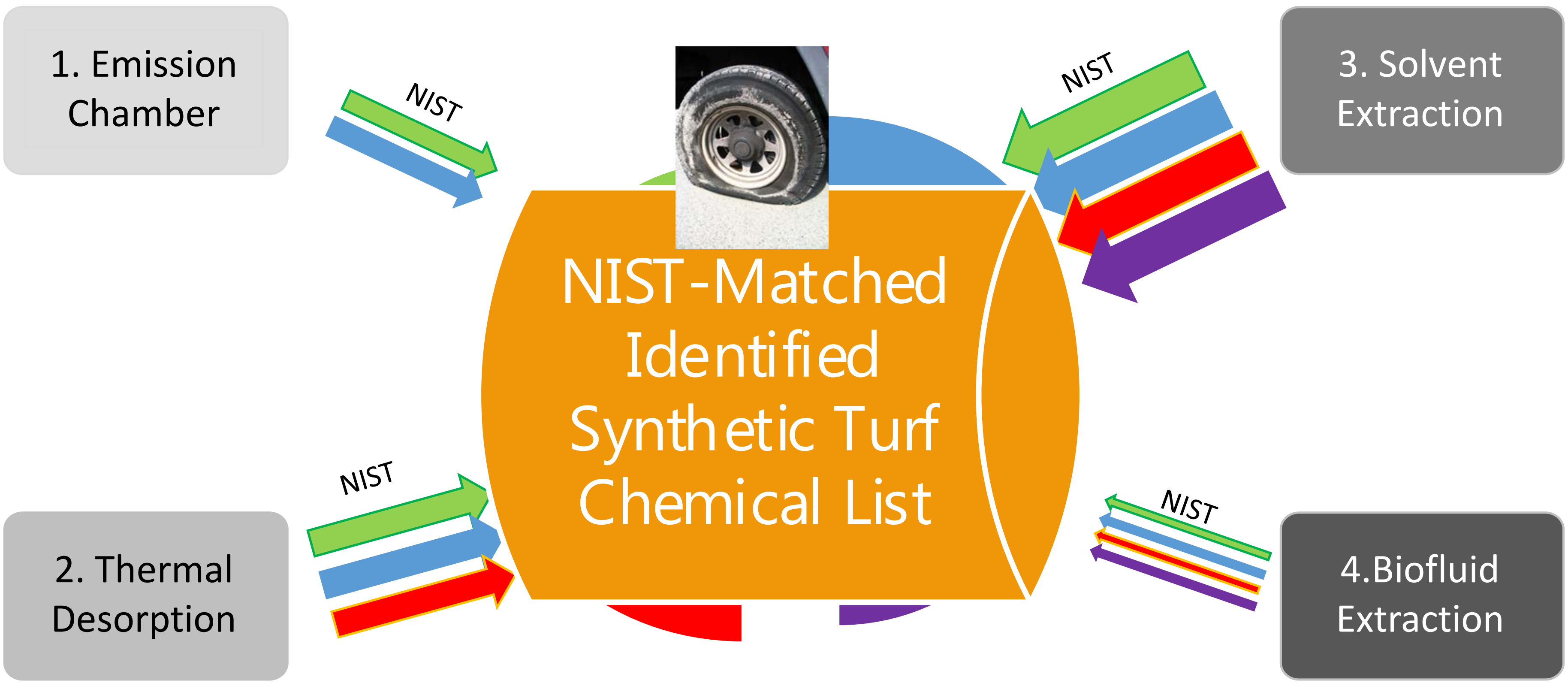
Step 2: Use of NIST Database

- **National Institute of Standards and Technology/US Environmental Protection Agency/National Institute of Health (NIST/EPA/NIH) Mass Spectral Library**
- **Data Version: NIST 14 Software Version: 2.2g**
- **Main Electron Ionization Mass Spectral (EI MS0 Library**
- **Computer spectra matching (e.g., mass to charge ratio (m/z), fragmentation fingerprint)**
- **Deconvolution of complex peaks as needed prior to spectral matching**

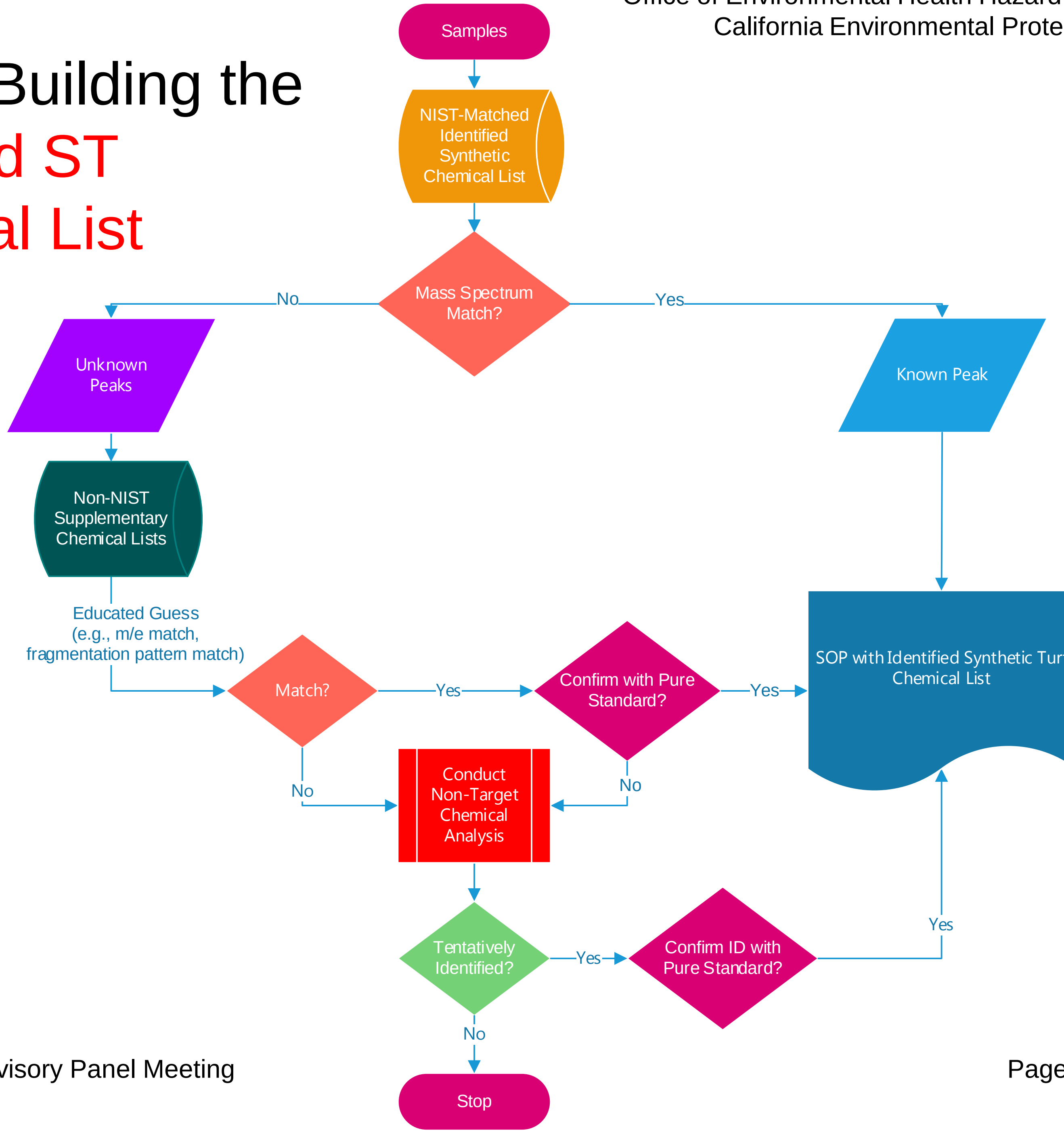


NIST/EPA/NIH MS Library v 2.2 (NIST 14 database)

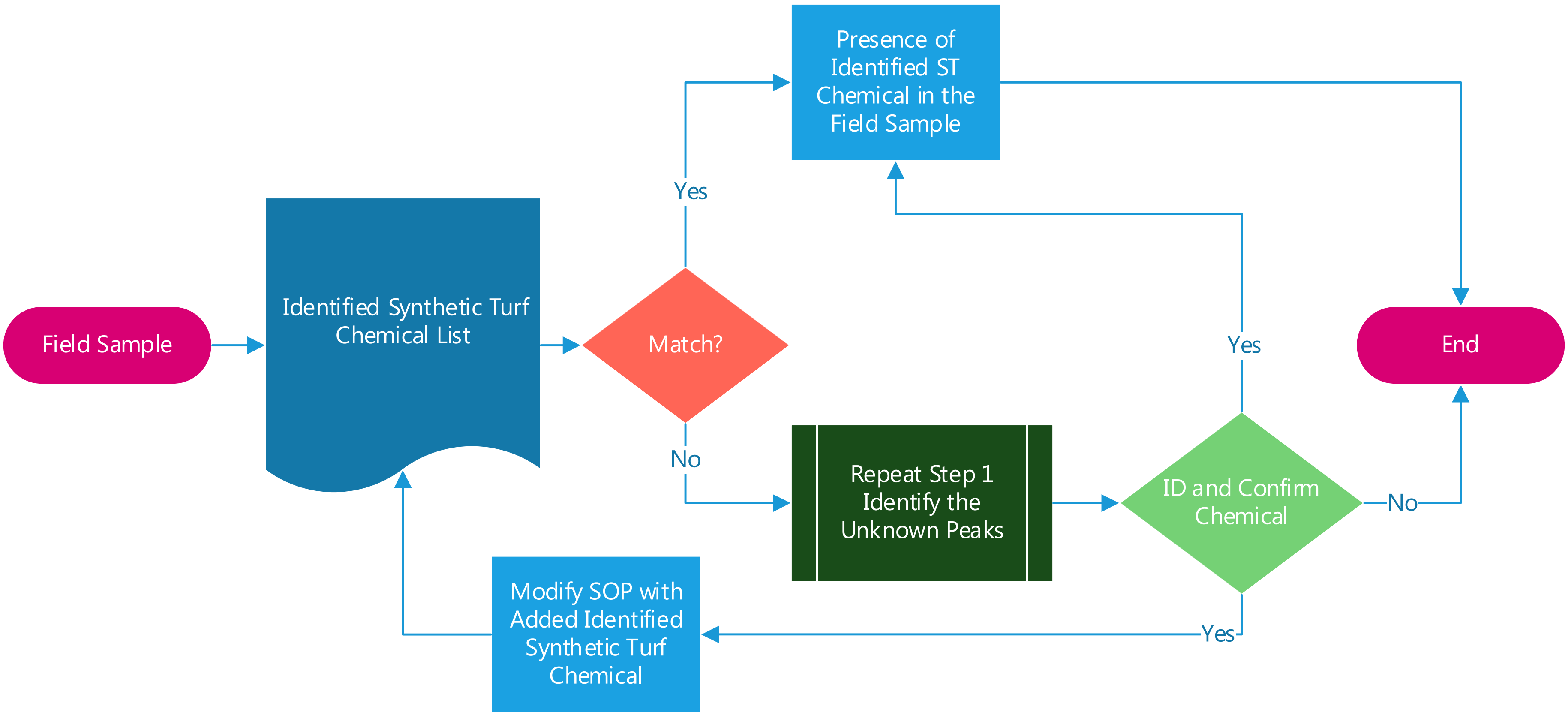
How to Compile: Identified ST Chemical List
Step 2. Matching against NIST Database



Step 3. Building the Identified ST Chemical List



Step 3. Expanding the Identified Synthetic Turf Chemical List



Section 1B

Supplementary Information for Chemical Identification

Section 1B. Supplemental Chemical List

A critical component of OEHHA's synthetic turf study is the process and capacity to identify chemicals that are emitted or extracted from crumb rubber materials used in synthetic turf fields and playgrounds. This is an important step in assessing the potential health risks from exposure to these chemicals.

The Lawrence Berkeley National Laboratory (LBNL), a contractor with OEHHA on this study, plans to use a database of chemicals developed by the National Institute of Standards and Technology (NIST) (NIST, online) for this process. This database contains molecular weight, and fragmentation pattern information of many thousands of organic compounds that can be used to identify chemicals.

OEHHA has also researched the scientific literature and compiled a list of chemicals that may be of relevance to the study. OEHHA compared the chemicals on the list to those in the NIST Standard Reference Database Number 69 (NIST, 2015) and found a total of 92 organic compounds that are on the list but not in the NIST database. They constitute the Supplemental Chemical List (Tables below).

The Supplemental Chemical List is divided into three tiers based on the likelihood of the chemicals being found in crumb rubber and synthetic turf fields:

1) The first tier represents chemicals that were detected in: (i) air samples collected at indoor or outdoor synthetic turf fields, (ii) tire crumb rubber or whole tire leachates, (iii) biofluid or methanol extracts, or (iv) synthetic turf blade organic solvent extracts.
2) The second tier represents chemicals detected: (i) in air samples collected at automobile or truck retreading facilities, (ii) in air samples of synthetic turf emission chambers where the source of rubber granulate is not exclusively tire rubber derived, or (iii) from aggressive solvent extraction of crumb rubber.
3) The third tier represents chemicals identified in the scientific literature, they include: (i) chemical additives used in tire manufacturing, and (ii) biocides that were/are marketed to control or deter the growth of microbial organisms on synthetic turf fields. Some of this information could be outdated. For example, chemical additives were included in a review of the International Agency for Research on Cancer (IARC) that was published in 1982 (IARC, 1982).

In addition to chemical names and CASRN (Chemical Abstracts Service Registry Number), other physicochemical property information that can assist the chemical identification process are also provided in the table. The information on molecular weight, boiling point, octanol/water partition coefficient, and water solubility are obtained from the US Environmental Protection Agency Estimation Program Interface Suite (EPISuite^{TM,} v. 2012). These values are either estimated or experimentally derived as indicated.

The purpose of the Supplemental Chemical List is to provide information to LBNL to help identify chemicals. A tentative chemical identification would prompt a comparison against the corresponding chemical standard to confirm the identity of the chemical.

DRAFT --- Supplemental Chemical List

Chemicals listed in Supplemental List (Tier 1, 2, and 3) are substances not listed on the NIST Standard Reference Database Number 69 (NIST, 2015).

The NIST database is available at the online NIST Chemistry WebBook: www.webbook.nist.gov/chemistry.

Notes:

*Experimental values from EPISuite v. 4.1

** These chemicals do not represent unique substances. Their physicochemical properties are derived from the EPI Suite in accordance with the listed CASRN.

*** These chemicals may or may not be present as the stated metal salts. The respective free acid or sodium salt of the metal salts is included for this purpose.

All other physicochemical values are estimates obtained from EPISuite v 4.1(EPISuite^{TM,} v. 2012).

Chemical Name: Adopted from cited literature source. The name was corrected in accordance with the NIST Chemistry Webbook, PubChem or ChemSpider databases.

CASRN: Chemical Abstracts Registry Number. CASRN numbers were derived from the NIST Chemistry Webbook, PubChem or ChemSpider databases.

MW: Molecular Weight. Derived from EPISuite v 4.1. If the chemical was not listed on EPISuite, the molecular weight was obtained from PubChem or ChemSpider databases.

BP (C): Boiling Point in degrees Celsius. Derived from EPISuite v 4.1 - MPBPWIN v 1.43

logKow: Logarithm of the octanol water partition coefficient. Derived from EPISuite v 4.1 - KOWWIN v 1.68

H2O Solubility (mg/L): Water Solubility at 25 C. Derived from EpiSuite v 4.1 - WATERNT v 1.0.

DRAFT --- Supplemental Chemical List, Tier 1

Chemicals that were analytically detected in (i) air samples collected at indoor or outdoor synthetic turf fields (Dye et al., 2006; NYDEC, 2009; Simcox et al., 2011), (ii) Tire crumb rubber or whole tire leachates (CDEP, 2010; Nilsson et al., 2008; NYDEC, 2009; Plesser and Lund, 2004; OMEE, 1994; Cheng et al., 2014), (iii) Biofluid or methanol extracts (Kanematsu et al., 2009; Lioy and Weisel, 2011), or (iv) Synthetic turf blade organic solvent extracts (Nilsson et al., 2008).

Chemical Name	CASRN	MW	BP (C)	logKow	H2O Solubility (mg/L)	Source
Cyclopropane 1-Chloro-2-ethenyl-1-methyl	62337-93-3	116.59	92.92	3.11	267.44	Air sampling at synthetic turf field (NYDEC, 2009)
1H-Benzotriazol-5-amine, 1-methyl-	27799-83-3	148.17	309.7	0.22	211660	Air sampling at synthetic turf field (NYDEC, 2009)
2,2,7-Trimethyl-3-octyne	55402-13-6	152.28	167.22	4.84	1.573	Crumb rubber leachate (CDEP, 2010)
Ethanone, 1-[4-(1-methylethenyl)phenyl]-	5359-04-6	160.22	240.65	3.12	350.68	Crumb rubber headspace analysis, Crumb rubber leachate (Nilsson et al., 2008)
6-Acetoxy-2,2-dimethyl-m-dioxane	828-00-2	174.2	218.5	0.49	1000000 *	Tire rubber leachate (Cheng et al., 2014)
a-D-xylofuranoside, methyl 2-O-methyl	32469-86-6	178.19	292.63	0	56390	Crumb rubber leachate (CDEP, 2010)
2-Dibenzofuranamine (2-Aminobenzofuran)	3693-22-9	183.21	345.25	3.13	28.485	Air sampling at synthetic turf field (NYDEC, 2009)
4-Dibenzofuranamine (4-Aminobenzofuran)	50548-43-1	183.21	345.25	3.13	28.485	Air sampling at synthetic turf field (NYDEC, 2009)
2-Methyl-N-phenyl-aniline	1205-39-6	183.26	298.25	3.84	27.98	Tire rubber leachate (OMEE, 1994)
Heptane, 4-ethyl-2,2,6,6-tetramethyl-	62108-31-0	184.37	173.09	6.43	0.04912	Air sampling at synthetic turf field (NYDEC, 2009)
N,N-Diphenyl formamide	607-00-1	197.24	337.5 *	1.91	1063	Tire rubber leachate (OMEE, 1994)
Methane, diethoxy-cyclohexane	1453-21-0	212.34	276.56	4.34	300.22	Crumb rubber leachate (NYDEC, 2009)
Dodecane, 2,7,10-trimethyl	74645-98-0	212.42	228.48	7.49	0.004421	Air sampling at synthetic turf field (NYDEC, 2009)
Texanol B (2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate)	25265-77-4	216.32	244 *	3	1360.7	Air sampling at indoor synthetic turf field (Dye et al., 2006)
Phenol, 4-nonyl-, branched	84852-15-3	220.36	295 *	5.77	5000 *	Crumb rubber leachate, Synthetic turf blade CH2Cl2 extraction (Nilsson et al., 2008)
iso-Nonylphenol	11066-49-2	220.36	324.47	5.61 *	1.6194	Crumb rubber leachate (Plesser and Lund, 2004)

Chemical Name	CASRN	MW	BP (C)	logKow	H2O Solubility (mg/L)	Source
N-Cyclohexyl-2-benzothiazolamine	28291-75-0	232.35	365.03	4.82	99.182	PM2.5/PM10 analysis at indoor synthetic turf field (Dye et al., 2006)
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	95-33-0	264.41	398.29	3.47	819.19	PM2.5/PM10 analysis at indoor synthetic turf field (Dye et al., 2006)
2,2'-Bibenzothiazole	4271-09-4	268.35	--	--	--	Crumb rubber biofluid extraction (Lioy and Weisel, 2011)
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	94320-32-8	268.4	--	--	--	Shredded rubber mulch MeOH extraction (Kanematsu et al., 2009)
N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylendiamine	793-24-8	268.41	369.67	4.68	2.8262	Crumb rubber leachate (Nilsson et al., 2008)
7-Hydroxybenzo[f]flavone	86247-95-2	288.3	--	--	--	Shredded tire rubber mulch MeOH extraction (Kanematsu et al., 2009)
1-Iodo-2-methylundecane	73105-67-6	296.24	--	--	--	Air sampling at synthetic turf field (NYDEC, 2009)
4,4'-((p-Phenylene)diisopropylidene)diphenol	2167-51-3	346.47	--	--	--	Synthetic turf blade CH2Cl2 extraction (Nilsson et al., 2008)
Hexa(methoxymethyl)melamine	3089-11-0	390.44	448.2	1.61	1000000	Crumb rubber leachate (Nilsson et al., 2008)
22R-bishomohopane (22R,17(ALPHA)H,21(BETA)H-Bishomohopane)	67069-25-4	440.8	435.49	11.76	4.408E-07	Air sampling at synthetic turf field (Simcox et al., 2011)
22S-bishomohopane (22S,17(ALPHA)H,21(BETA)H-Bishomohopane)	67069-15-2	440.8	435.49	11.76	4.408E-07	Air sampling at synthetic turf field (Simcox et al., 2011)
Diisodecylphthalate	89-16-7	446.68	463.36	10.36	0.28 *	Crumb rubber leachate (Plesser and Lund, 2004)
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	52829-07-9	480.74	495.85	6.5	0.62794	Crumb rubber leachate (Nilsson et al., 2008)

DRAFT --- Supplemental Chemical List, Tier 2

Chemicals analytically detected (i) in air samples collected at automobile or truck retreading facilities (Cocheo et al., 1983), (ii) in air samples from synthetic turf emission chambers where the source of rubber granulate is not exclusively tire rubber derived (Moretto, 2007), or (iii) from the aggressive solvent extraction of crumb rubber (Nilsson et al., 2008).

Chemical Name	CASRN	MW	BP (C)	logKow	H2O Solubility (mg/L)	Source
2-Methyl pyridine	1333-41-1	93.13	129.3 *	1.11 *	1000000 *	Synthetic turf chamber emissions (Moretto, 2007)
Dimethylcyclopentane (isomeric mixture)	28729-52-4	98.19	99.5 *	3.52	11.166	Synthetic turf chamber emissions (Moretto, 2007)
1-Isopropoxy-2-methyl-2-propanol	3587-75-5	132.2	151.37	0.87	52380	Synthetic turf chamber emissions (Moretto, 2007)
1-Methyl-3-(1-methylethenyl)cyclohexene	499-03-6	136.24	167.66	4.83	44.388	Emissions at Automobile or Truck Tire Retreading Factory (Cocheo et al., 1983)
Cyclohexene-5-methyl-3-(1-methylvinyl)	86853-03-4	136.24	163.29	4.7	28.156	Emissions at Automobile or Truck Tire Retreading Factory (Cocheo et al., 1983)
Phenethylmethyl sulfoxide	7714-32-1	168.25	--	--	--	Crumb rubber CH2Cl2 extraction (Nilsson et al., 2008)
Dodecene	25378-22-7	168.33	213.8 *	6.1	0.1127	Synthetic turf chamber emissions (Moretto, 2007)
2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	147-47-7	173.26	260 *	3.3	117.24	PM analysis at scrap tire shredding facility (Chien et al., 2003), Synthetic turf chamber emissions (Moretto, 2007), Recycled rubber playground surface headspace analysis (Celeiro et al., 2014), Chemicals used in Automobile or Truck Tire Retreading Factory (Cocheo et al., 1983)
p-Hydroxydiisopropylbenzene	71520-03-1	178.28	253.82	3.4	225.6	Synthetic turf chamber emissions (Moretto, 2007)
2-(2H-Benzotriazol-2-yl)-5-methylphenol	4998-48-5	225.25	--	--	--	Crumb rubber CH2Cl2 extraction (Nilsson et al., 2008)
Tridecylbenzene	129813-59-8	260.47	--	--	--	Emissions at Automobile or Truck Tire Retreading Factory (Cocheo et al., 1983)
N-Cyclohexylthiophthalimide (CTP)	17796-82-6	261.34	468.3	3.66 *	27.254	Chemicals used in Automobile/Truck Tire Retreading Factory (Cocheo et al., 1983)
2-(5-Chloro-2-benzotriazolyl)-6-tert-butyl-p-cresol	3896-11-5	315.81	450.11	5.55	0.6838	Crumb rubber CH2Cl2 extraction (Nilsson et al., 2008)
Phenol, 2-(5-chloro-2H-benzotriazol-2-yl)-4,6-bis(1,1-dimethylethyl)-	3864-99-1	357.89	473.33	6.91	0.02628	Crumb rubber CH2Cl2 extraction (Nilsson et al., 2008)

DRAFT --- Supplemental Chemical List, Tier 3

Chemicals reported in scientific literature, including (i) chemical additives in tire manufacturing, and (ii) as antimicrobial biocides that were/are marketed for use on synthetic turf fields (OEHHA, 2016).

Some old chemical additives are based on a 1982 IARC report (IARC, 1982) and include chemical additives in tires, tubes, remolds and retreads, as well as byproducts found in such industries.

Chemical Name	CASRN	MW	BP (C)	logKow	H2O Solubility (mg/L)	Source
Phenol, styrenated	61788-44-1	120.15	209.22	2.41	3302	Production and use in the tire rubber industry (IARC, 1982)
Dimethyldithiocarbamic acid ***	79-45-8	121.22	181.95	0.69	259900	Free acid of metal salt: Dimethyldithiocarbamic acid, Bismuth/Potassium/Selenium/Sodium salt
Dimethyldithiocarbamic acid, sodium salt ***	128-04-1	143.2	461.59	-2.41	1000000	Production and use in the tire rubber industry (IARC, 1982)
tert-Octyl mercaptan	141-59-3	146.29	160 *	3.99	30.71	Production and use in the tire rubber industry (IARC, 1982)
Diethyldithiocarbamic acid, selenium salt ***	21559-14-8	149.27	221.57	1.67	28990	Production and use in the tire rubber industry (IARC, 1982)
Dimethylnaphthalene (isomeric mixture)	28804-88-8	156.23	265 *	4.31 *	14.85	Found as byproducts in the tire rubber industry (IARC, 1982)
Ethylnaphthalene	27138-19-8	156.23	258.6 *	4.4 *	10.7 *	Found as byproducts in the tire rubber industry (IARC, 1982)
2-Mercaptotoluimidazole	53988-10-6	164.23	348.88	2	1290	Production and use in the tire rubber industry (IARC, 1982)
2-Mercaptobenzothiazole ***	149-30-4	167.24	301.8	2.42 *	120 *	Free acid of metal salt: 2-Mercaptobenzothiazole zinc salt
Diethyldithiocarbamic acid, sodium salt ***	20624-25-3	171.25	484.8	-1.43	1000000	Sodium salt of Diethyldithiocarbamic acid, selenium salt
p-Toluenesulfonyl hydrazide	1576-35-8	186.23	332.2	0.55	17250	Production and use in the tire rubber industry (IARC, 1982)
Dimethyldithiocarbamic acid, potassium salt ***	128-03-0	187.36	484.8	-1.43	1000000	Production and use in the tire rubber industry (IARC, 1982)
tert-Dodecyl mercaptan	25103-58-6	202.4	227 *	6.07	0.2801	Production and use in the tire rubber industry (IARC, 1982)
p-Toluenesulfonyl semicarbazide	10396-10-8	229.26	413.45	-0.62	5101	Production and use in the tire rubber industry (IARC, 1982)

Chemical Name	CASRN	MW	BP (C)	logKow	H2O Solubility (mg/L)	Source
N-Oxydiethylenedithiocarbamyl-N'-oxydiethylenesulfenamide (OTOS)	13752-51-7	248.36	352.97	-0.84	1000000	Accelerators or Vulcanizing Agents (RMA, 2016), Chemicals used in tire industry (ChemRisk, 2008)
N,N-Diisopropyl-2-benzothiazole-sulfenamide	95-29-4	266.42	368.72	3.23	33.47	Production and use in the tire rubber industry (IARC, 1982)
N,N'-Dicyclohexyl-p-phenylenediamine	4175-38-6	272.44	379.45	5.24	0.5896	Production and use in the tire rubber industry (IARC, 1982)
Pentachlorothiophenol ***	133-49-3	282.4	315.71	5.91	0.1398	Free acid of metal salt: Pentachlorothiophenol, zinc salt
2-Morpholinodithiobenzothiazole (MBSS)	95-32-9	284.41	418.31	1.59	6087.9	Accelerators or Vulcanizing Agents (RMA, 2016), Chemicals used in tire industry (ChemRisk, 2008), Production and use in the tire rubber industry (IARC, 1982)
N,N'-Ditolyl-p-phenylenediamine (DTPD)	27417-40-9	288.4	421.38	5.13	0.15639	Antioxidant&Antiozonant (RMA, 2016), Chemicals used in tire industry (ChemRisk, 2008)
Caprolactam disulfide (CLD)	23847-08-7	288.43	470.37	0.98	52618	Accelerators or Vulcanizing Agents (RMA, 2016), Chemicals used in tire industry (ChemRisk, 2008)
N-(1-Methylheptyl)-N'-phenyl-p-phenylenediamine	15233-47-3	296.46	399.87	5.74	0.1627	Production and use in the tire rubber industry (IARC, 1982)
Dibutyl xanthogen disulfide	105-77-1	298.49	387.56	4.02	4.623	Production and use in the tire rubber industry (IARC, 1982)
1,1-Di-tert-butylperoxy-3,3,5-trimethylcyclohexane	6731-36-8	302.46	63 *	6.53 *	0.6 *	Production and use in the tire rubber industry (IARC, 1982)
N,N'-Bis(1,4-dimethylpentyl)phenylendiamine (77PD)	3081-14-9	304.52	364.35	6.3	0.074747	Antioxidant&Antiozonant (RMA, 2016), Chemicals used in tire industry (ChemRisk, 2008), Production and use in the tire rubber industry (IARC, 1982)
Dioctyldimethyl ammonium chloride	5538-94-3	305.98	488.29	2.69	0.0008542	Reported by OEHHA as potential turf biocide (OEHHA, 2016)
N-N'-Bis(1-ethyl-3-methylpentyl)-p-phenylenediamine	139-60-6	332.58	387.56	7.29	0.004735	Production and use in the tire rubber industry (IARC, 1982)
1,2-Dihydro-6-dodecyl-2,2,4-trimethylquinoline	89-28-1	341.59	423.11	9.25	0.00008739	Production and use in the tire rubber industry (IARC, 1982)
Dibenzoyl-p-quinone dioxime	120-52-5	346.35	440.17	4.28	1.442	Production and use in the tire rubber industry (IARC, 1982)
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	4979-32-2	346.55	200 *	4.8 *	0.0564 *	Accelerators or Vulcanizing Agents (RMA, 2016), Chemicals used in tire industry (ChemRisk, 2008), Production and use in the tire rubber industry (IARC, 1982), Chemical additives in tire rubber manufacturing (Sovereign Chemical Company, online)
Pentachlorothiophenol, zinc salt ***	117-97-5	347.79	357.42	6.07	0.04193	Production and use in the tire rubber industry (IARC, 1982)
Alcohol Ethoxylate 6	68439-45-2	350.5	414.94	1.43	20775	Reported by OEHHA as potential turf biocide (OEHHA, 2016)
Didecyl dimethyl ammonium chloride	7173-51-5	362.09	534.7	4.66	7.1879E-06	Reported by OEHHA as potential turf biocide (OEHHA, 2016)

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Chemical Name	CASRN	MW	BP (C)	logKow	H2O Solubility (mg/L)	Source
Dimethyldiphenylthiuram disulfide (MPTD)	53880-86-7	364.56	484.69	5.97	0.04052	Chemicals used in tire industry (ChemRisk, 2008)
Dipentamethylenethiuram tetrasulfide (DPTT)	120-54-7	384.67	497.36	2.8 *	10 *	Accelerators or Vulcanizing Agents (RMA, 2016), Chemicals used in tire industry (ChemRisk, 2008), Production and use in the tire rubber industry (IARC, 1982), Chemical additives in rubber manufacturing (Sovereign Chemical Company, online)
Zinc 2-mercapto-toluimidazole	61617-00-3	391.83	605.03	3.06	3.9183E-07	Production and use in the tire rubber industry (IARC, 1982)
2-Mercaptobenzothiazole zinc salt ***	155-04-4	397.86	544.4	5.02	0.3792	Chemicals used in tire industry, Impurities and byproducts of tire industry (ChemRisk, 2008), Production and use in the tire rubber industry (IARC, 1982)
4,4’-Dicumyldiphenylamine	10081-67-1	405.59	507.08	8.51	6.7774E-06	Production and use in the tire rubber industry (IARC, 1982), Chemical additives in tire rubber manufacturing (Sovereign Chemical Company, online)
Tetrabutylthiuram disulfide (TBTD)	1634-02-2	408.74	478.84	7.6	8.6463	Chemicals used in tire industry (ChemRisk, 2008)
4,4'-Methylenedicarbanilic acid, diphenyl ester	101-65-5	438.49	552.72	5.97	0.01415	Production and use in the tire rubber industry (IARC, 1982)
Di-N,N'-pentamethylenethiuram tetrasulfide	971-15-3	448.79	563.88	4.43	2.569	Production and use in the tire rubber industry (IARC, 1982)
2,2'-Dithiobisbenzanilide	135-57-9	456.58	721.15	4.59	0.1617	Production and use in the tire rubber industry (IARC, 1982)
Ethylphenyldithiocarbamic acid, zinc salt	14634-93-6	458.03	--	--	--	Production and use in the tire rubber industry (IARC, 1982)
2,2'-Methylenebis(4-methyl-6-nonylphenol)	7786-17-6	480.78	583.98	13.1	2.338E-08	Production and use in the tire rubber industry (IARC, 1982)
Tetrabenzylthiuram disulfide (TBZTD)	10591-85-2	544.81	676.21	8.53	0.0058314	Chemicals used in tire industry (ChemRisk, 2008), Chemical additives in rubber manufacturing (Sovereign Chemical Company, online)
Dimethyldithiocarbamic acid, selenium salt ***	144-34-3	559.79	618.8	-0.54	424.4	Production and use in the tire rubber industry (IARC, 1982)
Dimethyldithiocarbamic acid, bismuth salt ***	21260-46-8	569.6	471.52	-1.6 *	130 *	Production and use in the tire rubber industry (IARC, 1982)
Zinc dibenzyldithiocarbamate (ZBEC)	14726-36-4	610.197	527.81	5.41	0.04791	Accelerators or Vulcanizing Agents (RMA, 2016), Chemicals used in tire industry (ChemRisk, 2008), Production and use in the tire rubber industry (IARC, 1982), Chemical additives in rubber manufacturing (Sovereign Chemical Company, online)
Trisnonylphenyl phosphite	26523-78-4	689.02	724.14	20.05	3.112E-16	Production and use in the tire rubber industry (IARC, 1982)

Chemical Name	CASRN	MW	BP (C)	logKow	H2O Solubility (mg/L)	Source
Acetone-diphenylamine condensation products **	68412-48-6	--	--	--	--	Production and use in the tire rubber industry (IARC, 1982), Modern tire rubber addititives (RMA, 2016)
Alkyl (C12-18) dimethylbenzyl ammonium chlorides **	68391-01-5	--	--	--	--	Reported by OEHHA as potential turf biocide (OEHHA, 2016)
Alkyl (C12-18) dimethyl(ethylbenzyl) ammonium chlorides **	68956-79-6	--	--	--	--	Reported by OEHHA as potential turf biocide (OEHHA, 2016)
Di-(2-ethyl)hexylphos-phorylpolysulfide (SDT)	Not Found	--	--	--	--	Accelerators or Vulcanizing Agents (RMA, 2016)

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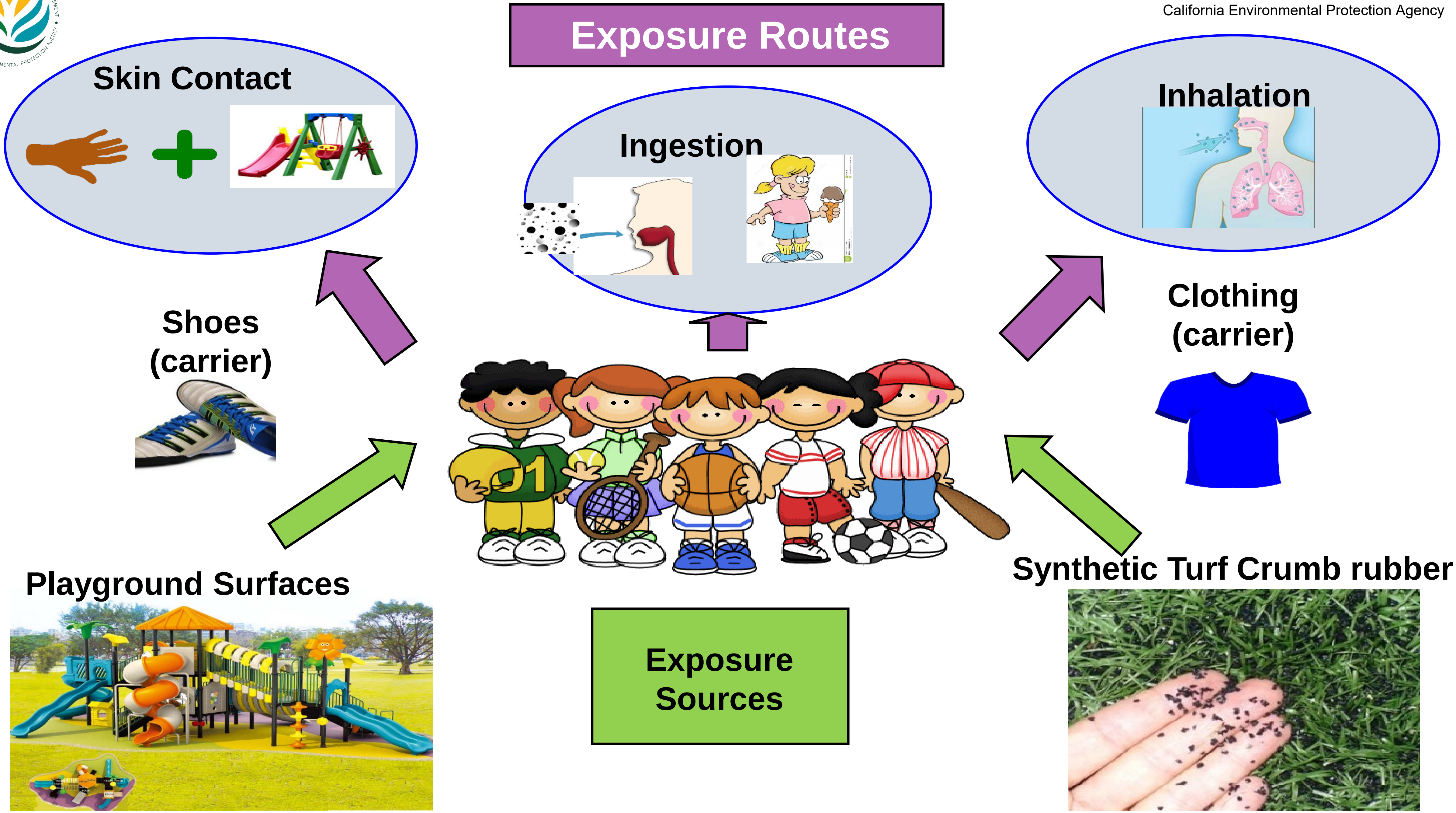
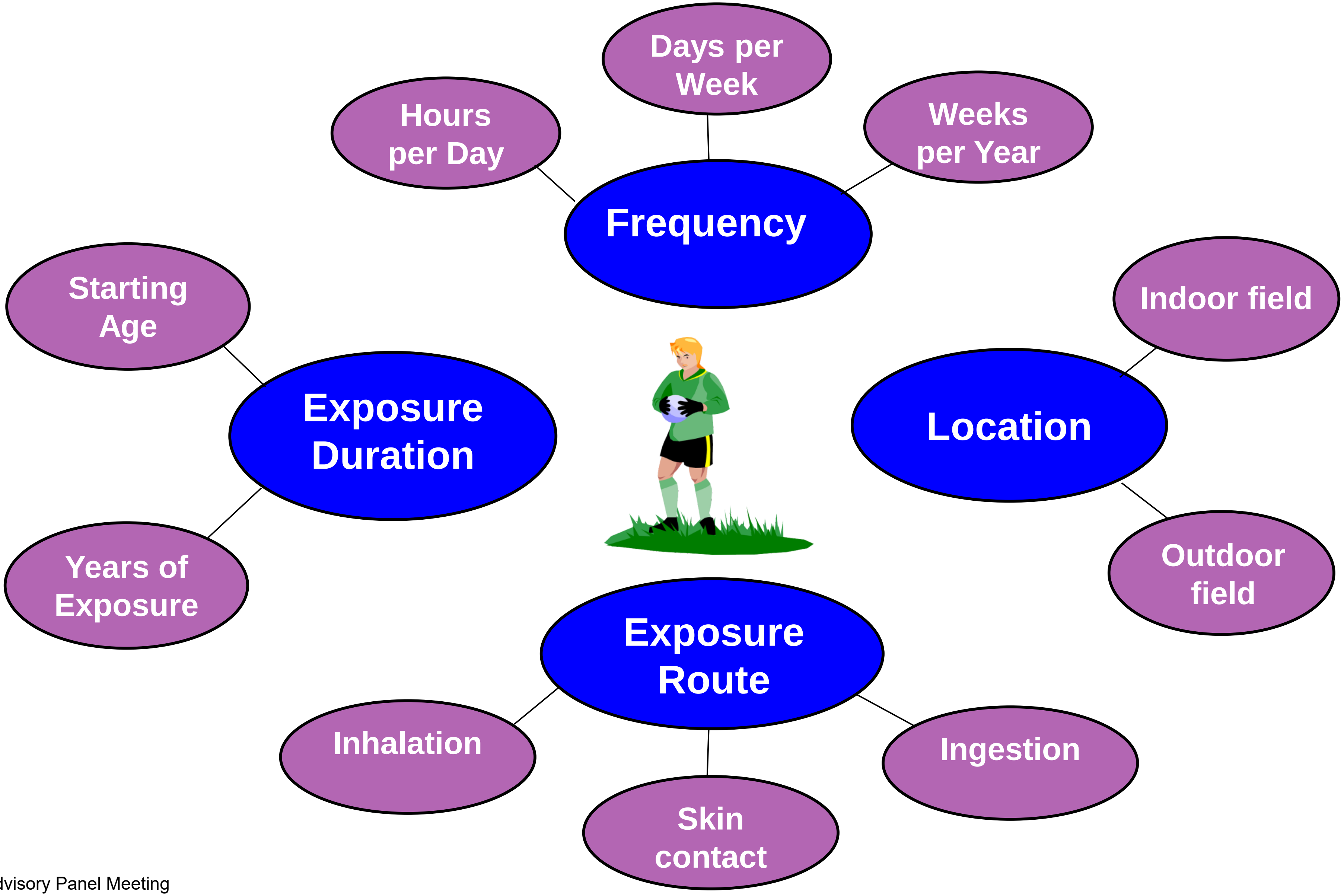
Section 2

Exposure Pathways Studies


Exposure Routes
Skin Contact
Ingestion
Inhalation
Shoes
(carrier)
Clothing
(carrier)
Playground Surfaces
Exposure
Sources
Synthetic Turf Crumb rubber

Examples of Exposure Parameter

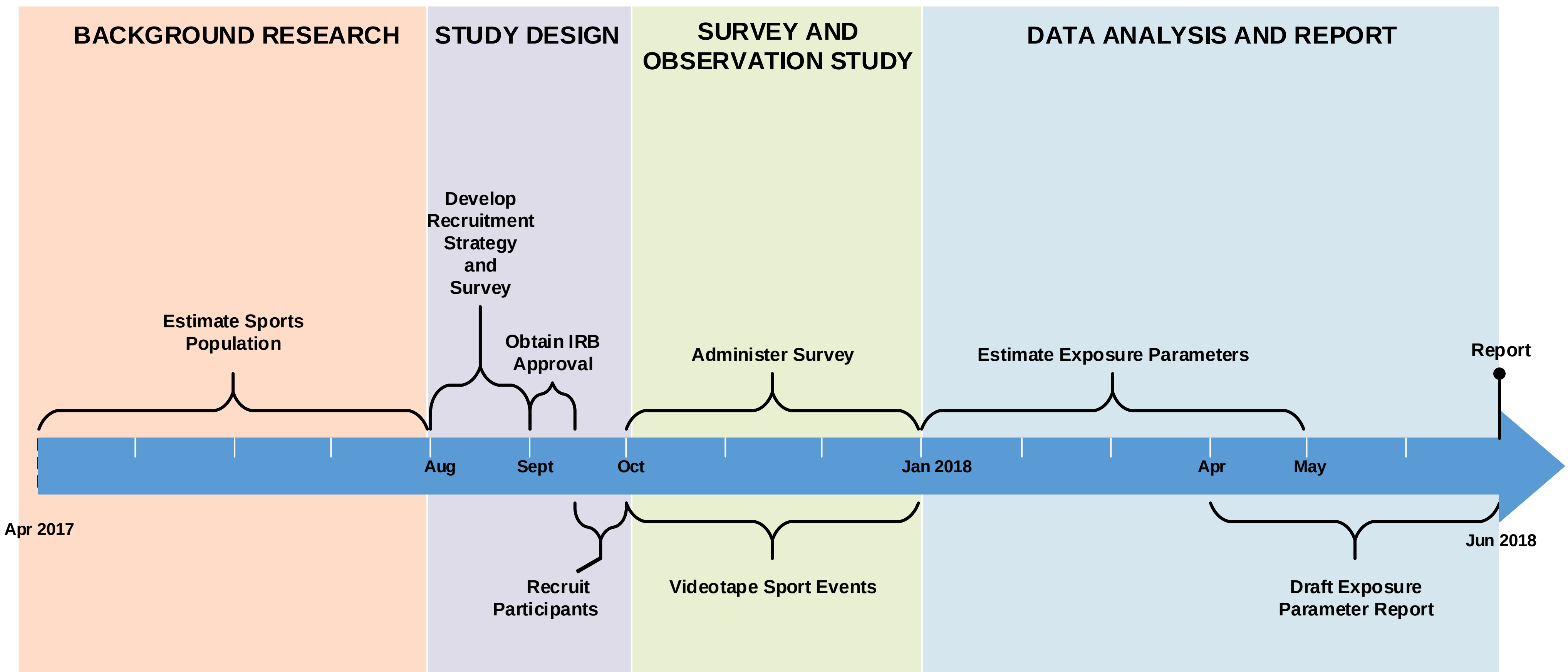


Section 2A

Time-Activity Behavior Study

Office of Environmental Health Hazard Assessment (OEHHA)
California Environmental Protection Agency

Section 2A. Task 3
Time Activity Behavior Pattern Study Timeline



Section 2B

Emission Modeling of Synthetic Turf Chemicals

Section 2B. Modeling the Environmental Fate of Organic Chemicals Released from Synthetic Turf

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Environmental fate multimedia models are commonly used to describe the fate of organic contaminants in outdoor and indoor environments. Models provide a framework to explore possible relationships between chemical and environmental factors and potential exposure outcomes for different scenarios. Two of the most common approaches for fate and transport modeling are based on the chemical activity and the fugacity of compounds of interest. In this project, we apply the concept of fugacity (Mackay, 2001) to describe the fate of organic chemicals released from crumb rubber and other synthetic turf components used in sport fields. The developed model takes as input values the physicochemical properties of the chemicals, such as the octanol-water partition coefficient (K_{OW}), the air-water partition coefficient (K_{AW}), their degradation half-lives in different media, and the properties of the environment, such as the dimensions of the sports field, temperature, wet and dry deposition, air flows etc. In the absence of available measurements for partition coefficients between crumb rubber and air (K_{CA}), we start with the chemicals' partition coefficients between soil and air (K_{SA}) and we modify the soil characteristics to represent synthetic turf components.

Laboratory experiments are being conducted in parallel with the model development to:

a. identify chemicals present in the emission stream
b. quantify chemical specific emission rates for *field panels*
c. explore changes in emissions with aging

The field panels consist of backing material, synthetic turf blades, and crumb rubber infill assembled in stainless steel trays with ultra-low sorption coating. Each tray represents a complete turf and crumb structure providing representative surface diffusion characteristics. All emission tests are conducted following California Specification 01350 (V1.1, CDPH/EHLB, 2010) in small chambers with controlled temperature and relative humidity under constant air flow (1 L/min). The initial test was conducted with panels constructed from freshly manufactured material aged continuously under standard conditions (25 ^{o}C and 50% relative humidity) for six weeks with measurement taken at the start, and again after two, four, and six weeks. These data provide a baseline aging profile. The tests will be repeated using different aging regimes including elevated ozone, temperature, and episodic "rain" events. The baseline aging study identified a number of chemicals that are used as industrial solvents, such as methylisobutylketone and trichloroethylene, and a few rubber-related substances, such as benzothiazole and naphthalenes. For most of the industrial solvents the emissions decreased substantially after two weeks but for benzothiazole the emissions remained stable.

The measured emission rates from the laboratory testing were used to calibrate our model and to explore how emissions might change due to increased action on the field (e.g., by players during practice), and due to changes in temperature and water content of the crumb. Our simulations indicate that:

a. the concentrations of the chemicals in the air are expected to increase with increasing action due to particle resuspension
b. increasing surface temperature is expected to increase the concentrations of some of the chemicals in the air
c. increased water content of the crumb is expected to slow down emissions of chemicals with high water solubility.

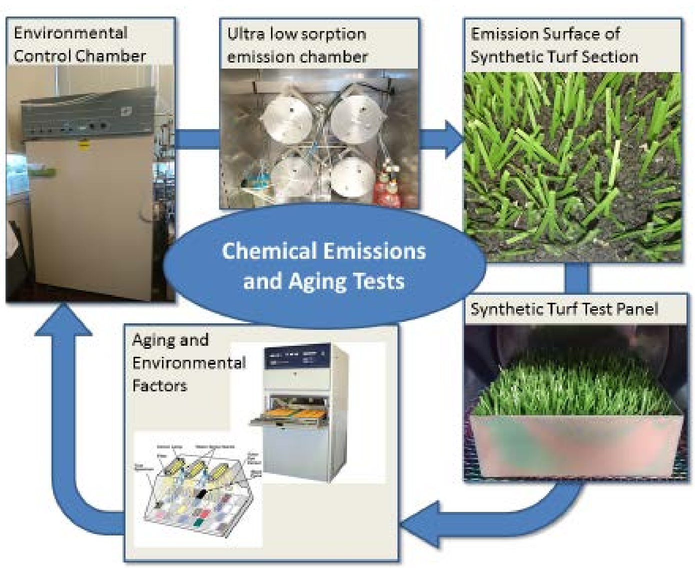

Figure 1. Chemical Emission and Aging Test Scheme

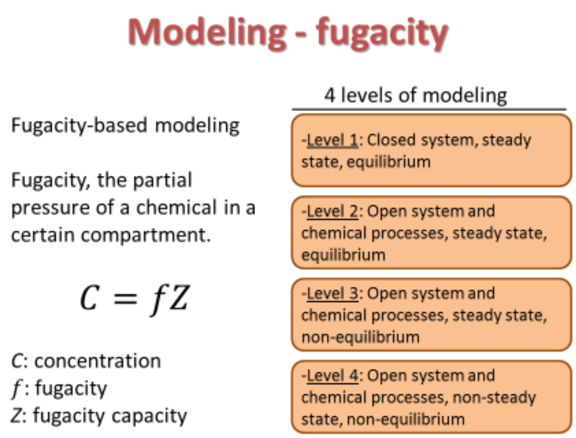

Figure 2. Fugacity Based Modeling

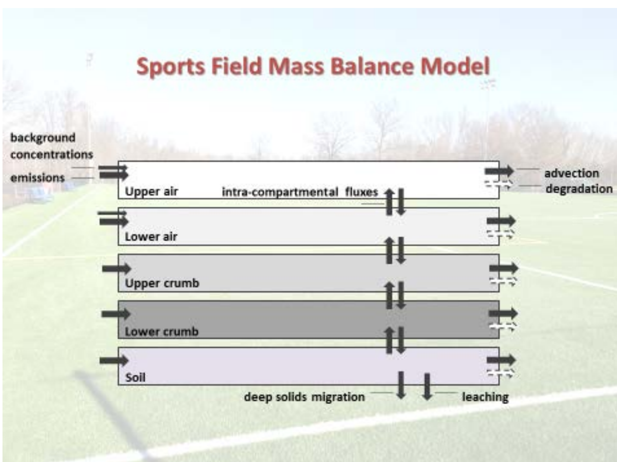

Figure 3. Mass Balance Modeling of Sports Field

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Section 3
Bioassessibility Study

Section 3A

Biofluid Compositions

Section 3A. Biofluid Compositions

Introduction

The Lawrence Berkeley National Laboratory, under contract with OEHHA, will conduct bioaccessibility studies using artificial biofluids to better assess the potential exposure to chemicals that can be released from crumb rubber. Bioaccessibility is defined as the amount of a chemical that is available to be absorbed into the human body following an exposure. In order to characterize potential human hazard following exposure to chemicals in crumb rubber, the identity of chemicals in crumb rubber will be determined, relevant exposure pathway(s) will be characterized, and the level of chemical-available absorption from the crumb rubber will be estimated.

Artificial biofuids are designed to represent the biological fluids of specific compartments in the body. OEHHA will use biofluids representing the three predominant exposure pathways through which exposure to chemicals from crumb rubber is thought to occur: oral, inhalation, and dermal. Artificial saliva, gastric fluid, and intestinal fluid will be used to study the oral exposure pathway. Artificial interstitial deep lung fluid and alveolar phagolysosomal fluid will be used to study the inhalation exposure pathway. Artificial sebum and sweat will be used to study the dermal exposure pathway. The compositions of the artificial biofluids that OEHHA plans to use are described in the following discussions. They are chosen based on the demonstrated use in available published literature and what is available commercially.

1.1. Oral Exposure—Saliva, Gastric Fluid, and Intestinal Fluid

Physiology of Gastrointestinal Tract

The main roles of the gastrointestinal (GI) tract are to take in and digest food, extract and absorb nutrients and energy needed to sustain the body, and expel all remaining waste. It is composed of many anatomic parts including the mouth, stomach, and intestine. These three components play a major role in the extraction and absorption of not only nutrients, but also contaminants that humans can be exposed to through ingestion.

Saliva is a complex fluid secreted by salivary glands into the oral cavity. Saliva is mostly water but also contains inorganic and organic components including hormones, lipids (such as fatty acids and their derivatives), glucose, proteins, amino acids, and other nitrogenous compounds (such as urea). It lubricates the oral cavity to protect from physical damage during daily activities, such as eating and speaking, and to ensure easy passage into the stomach, and to initiate the digestion of food (Edgar, 1992). The main salivary proteins are α-amylase, mucins, proline-rich proteins, and histatins, together accounting for about 90% of the total protein (Chiappin *et al.*, 2007; Edgar, 1992; Gibson and Beeley, 1994). Salivary lipids mostly consist of cholesteryl ester, cholesterol, mono/di/triglycerides, fatty acids, and phospholipids (Larsson *et al.*, 1996).

Gastric fluid is found in the stomach. A main function is to break down food in the stomach to begin the release of nutrients and other components for absorption (Dean and Ma, 2007). The main components of gastric fluid include water, electrolytes, hydrochloric acid, digestives enzymes, mucus, lipids, and very low levels of bile (Kong and Singh, 2008). Fluid composition, most notably the acidity (pH), can change depending on the amount and type of food that is ingested. In the fasted state, gastric fluid is highly acidic with a pH of 1 to 2. Once food is ingested, gastric pH can rise to approach neutral with a value of 6 to 7 (Mudie *et al.*, 2010).

Intestinal fluid is found in the small intestine. Intestinal fluid further aids in food digestion after the food leaves the stomach. The majority of nutrient absorption occurs in the small intestine (Dean and Ma, 2007). The composition of intestinal fluid is similar to gastric fluid, but levels of constituents such as bile and lipids are higher in the intestinal fluid. Similar to the gastric fluid, the composition of intestinal fluid can vary based on food ingested. In the fasted state, the average intestinal pH is approximately 6.5. In the fed state, the average intestinal pH is around 5 (Mudie *et al.*, 2010).

Bioaccessibility Studies Used to Study Bioaccessibility in the GI Tract

Artificial Saliva

In the literature, artificial saliva has been used to study the bioaccessibility of drugs (Davis *et al.*, 1971), nitrosamine release from rubber balloons (Altkofer *et al.*, 2005), the resistance to corrosion of metals used in dental implants (Rajendran *et al.*, 2009), cytokine expression in dermal cells (Malpass *et al.*, 2013), and the remineralization of lesions on enamel (Ionta *et al.*, 2014). Some of these artificial saliva compositions are purely inorganic, while other contain proteins and organic components (such as urea or uric acid). A few contain α-amylase, the most abundant protein in saliva (Chiappin *et al.*, 2007). The inclusion of lipids in an artificial saliva composition has not been studied or validated to date.

Artificial Gastric Fluid

Artificial gastric fluid has been used to study the bioaccessibility of metals in soils (Hamel *et al.*, 1998) and alloys (Hillwalker and Anderson, 2014), the absorption of lipophilic drugs (Vertzoni *et al.*, 2005), and the estimation of the types and amounts of organic and inorganic chemicals that may be extracted from crumb rubber (OEHHA, 2007). Two of these fluids are hydrochloric acid in simple inorganic buffers (Hamel *et al.*, 1998; Hillwalker and Anderson, 2014). One is a slightly more complex inorganic buffer containing pepsin (OEHHA, 2007) and the most complex fluid is an inorganic buffer containing lipids, bile salts, and pepsin (Vertzoni *et al.*, 2005), the most abundant digestive enzyme in the stomach (Dean and Ma, 2007).

Artificial Intestinal Fluid

No bioaccessibility studies using only artificial intestinal fluid were found in the scientific literature.

Combinations of Artificial Saliva and Artificial Gastric and Intestinal Fluids

Most often artificial saliva, artificial gastric fluid, and artificial intestinal fluid are used in sequence to understand the bioaccessibility of various chemicals along the GI tract. These studies have evaluated the bioaccessibility of metals in soil (Ellickson *et al.*, 2001; Ellickson *et al.*, 2002; Hamel *et al.*, 1999; Ljung *et al.*, 2007), lead in pottery flakes (Oomen *et al.*, 2003), lead in house dust (Yu *et al.*, 2006), semi-volatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs) and metals in synthetic turf materials (Lioy and Weisel, 2011; Pavilonis *et al.*, 2014; Zhang *et al.*, 2008), or mycotoxins from food (Versantvoort *et al.*, 2005). Many saliva compositions are inorganic buffers containing mucin and/or urea, while some include α-amylase. Some of the artificial gastric fluid compositions are simple three-component buffers of sodium chloride, hydrochloric acid, and pepsin. Others are more complex containing additional components such as bile salts, lipids, and/or pepsin to better mimic the physiological conditions in the stomach. Lastly, a simple sodium bicarbonate solution is the most common buffer used to mimic the intestinal fluid. Other artificial intestinal fluids composed of more complex inorganic and organic solutions containing the digestive enzymes pancreatin and lipase, lipids, and bile salts are also seen in the literature.

Artificial biofluid compositions used for dissolution studies of pharmaceuticals (Jantratid *et al.*, 2008; Marques *et al.*, 2011) are typically more complex—including the major components of gastric and intestinal fluids with both lipids and bile salts in physiologically relevant concentrations. Various compositions have been adopted to mimic the ‘fasted’ and ‘fed’ conditions in order to examine how the presence of food can affect the solubility of drugs.

Proposed Artificial Saliva, Gastric Fluid, and Intestinal Fluid for Evaluating Bioaccessibility by the Oral Route

OEHHA proposes to use the saliva buffer composition listed in Table 1 as the artificial saliva for the bioaccessibility study of chemicals in crumb rubber. This artificial saliva composition has been used to assess the bioaccessibility of mycotoxins (complex organic molecules), aflatoxin B and ochratoxin A, from food (Versantvoort *et al.*, 2005). Similar buffer compositions have also been used to study the bioaccessibility of metals in soil and dental implants (Oomen *et al.*, 2003; Rajendran *et al.*, 2009). This artificial saliva contains the major physiological components of saliva and a pH of 6.7, which is close to a human saliva pH of 6.5 as suggested in a review of approaches on oral bioaccessibility (Dean and Ma, 2007).

The ingestion of food changes the composition and pH of fluids of the GI tract and can affect the bioaccessibility of chemicals from crumb rubber. In the fed state, the relatively high contents of fats and proteins in the stomach and small intestine can facilitate the dissolution of highly lipophilic chemicals such as PAHs. OEHHA, therefore, determines that there is a need to examine the bioaccessibility of chemicals in crumb rubber under various fed conditions. Table 1 shows the proposed gastric and intestinal fluid compositions. These artificial biofluid combinations mimic the biofluid compositions at the early and late fed state in the stomach or small intestine (Jantratid *et al.*, 2008). These biofluid combinations chosen were developed to evaluate the dissolution of pharmaceuticals (Jantratid *et al.*, 2008; Marques *et al.*, 2011).

Overall, the proposed biofluid compositions in Table 1 are the most complex and physiologically relevant found in the literature. The gastric and intestinal artificial biofluids are commercially available (biorelevant.com). Milk is often included in the fed state's biofluid combinations to provide the levels of carbohydrates, fats, and proteins following a typical meal. For the current study, OEHHA plans to use powdered baby formula to mimic the nutrient content of different fed states.

Table 1.1. Artificial biofluids proposed for evaluating oral bioaccessibility

Saliva Composition	**Gastric Fluid Composition** (Jantratid *et al.*, 2008)	**Intestinal Fluid Composition** (Jantratid *et al.*, 2008)
10 ml Potassium chloride 89.6 g/L 10 ml Potassium thiocyanate 20 g/L 10 ml Sodium dihydrogen phosphate 88.8 g/L 10 ml Sodium phosphate dibasic 57 g/L 1.7 ml Sodium chloride 175.3 g/L 20 ml Sodium bicarbonate 84.7 g/L 8 ml Urea 25 g/L 290 mg α-Amylase 15 mg Uric acid 25 mg Mucin pH = 6.8 ± 0.2 Augmented to 500 ml with distilled water (Versantvoort *et al.*, 2005)	**Fasted**[1]	**Fasted**[1]
	80 µM Sodium taurocholate 20 µM Lecithin 0.1 mg/ml Pepsin 34.2 mM Sodium chloride Hydrochloric acid *q.s.*[2] pH 1.6	3.0 mM Sodium taurocholate 0.2 mM Lecithin 19.12 mM Maleic acid 34.8 mM Sodium hydroxide 68.62 mM Sodium chloride pH 6.5
	Fed	**Fed**[1]
	237.02 mM Sodium chloride 17.12 mM Acetic acid 29.75 mM Sodium acetate 1:1 Milk/buffer Hydrochloric acid/sodium hydroxide *q.s.* pH 5.0	10.0 mM Sodium taurocholate 2.0 mM Lecithin 5 mM Glycerol monooleate 0.8 mM Sodium oleate 55.02 mM Maleic acid 81.65 mM Sodium hydroxide 125.5 mM Sodium chloride pH 5.8
	Early Fed	**Early Fed**
	148 mM Sodium chloride 1:0 Milk/buffer (100% Milk) Hydrochloric acid/Sodium hydroxide *q.s* pH 6.4	10 mM Sodium taurocholate 3 mM Lecithin 6.5 mM Glyceryl monooleate 40 mM Sodium oleate 28.6 mM Maleic acid 52.5 mM Sodium hydroxide 145.2 mM Sodium chloride pH 6.5
	Late Fed	**Late Fed**
	122.6 mM Sodium chloride 5.5 mM Ortho-phosphoric acid 32 mM Sodium dihydrogen phosphate 1:3 Milk/buffer Hydrochloric acid/Sodium hydroxide *q.s* pH 3	4.5 mM Sodium taurocholate 0.5 mM Lecithin 1 mM Glyceryl mono-oleate 0.8 mM Sodium oleate 58.09 mM Maleic acid 72 mM Sodium hydroxide 51 mM Sodium chloride pH 5.4

[1] This biofluid composition is available in powder from biorelevant.com.

[2] *Quantum satis* (abbreviation *q.s.*) is a Latin term that means "the amount which is enough". The designation of *q.s.* after a biofluid component means to add as much of this component needed to achieve the desired pH.

1.2. Dermal Exposure— Bioaccessibility Measurements Using Artificial Sweat and Sebum Mixture

Physiology of Skin Surface Film Liquid System

The surface of the skin is protected by a liquid film composed of sweat and sebum. Sweat is a fluid produced by sweat glands throughout the human body primarily for thermoregulation. It is mostly water and has both organic and inorganic components consisting of electrolytes, ionic constituents, organic acids, carbohydrates, amino acids, nitrogenous substances, and vitamins (Stefaniak and Harvey, 2006). Sebum is an oily, waxy substance secreted from sebaceous glands located on the skin throughout the entire body, except for the palms of the hands and the soles of the feet. It is a lipid rich mixture containing primarily triglycerides, free fatty acids, wax esters, squalene, cholesterol esters, and free cholesterol (Picardo *et al.*, 2009; Stefaniak *et al.*, 2010). This substance helps to lubricate and waterproof the skin. Together the mixture of sweat and sebum create a skin surface film liquid (SSFL) that provides a protective epidermal barrier against the absorption of exogenous substances.

Bioaccessibility Studies Using Artificial Sweat

Many artificial sweat formulations have been used for bioaccessibility studies of metals in the literature. Most are simple and typically contain only a few inorganic, organic, and nitrogenous constituents. Many lack both amino acids and vitamins that are naturally present in sweat. Studies using simple sweat compositions have been used to investigate the bioaccessibility of metals and organics in crumb rubber (Lioy and Weisel, 2011; Pavilonis *et al.*, 2014), metals in alloy dust (Hillwalker and Anderson, 2014), non-steroidal anti-inflammatory drug (NSAID) releases from plasters (Marques *et al.*, 2011), nitrosamine releases from rubber consumer products (Altkofer *et al.*, 2005), identifying drug contamination in human hair (Cairns *et al.*, 2004), and the partitioning of volatile organic chemicals (VOCs) (Cheng *et al.*, 2005). Other more complex buffers have also been used to better reflect the physiological composition of human sweat. These complex artificial sweats have been used to study the dissolution of metal sensitizers (Stefaniak *et al.*, 2014a), silver releases from textiles (Stefaniak *et al.*, 2014b), and flame retardant releases from indoor dust (Pawar *et al.*, 2016).

Bioaccessibility Studies Using Artificial Sebum

Artificial human sebum has been used in the literature to study the bioaccessibility of beryllium materials (Stefaniak *et al.*, 2011), silver releases from textiles (Stefaniak *et al.*, 2014b), flame retardant releases from indoor house dust (Pawar *et al.*, 2016), and the secretion of persistent organic pollutants (POPs) (Diaz-Vazquez *et al.*, 2005). Most of these artificial sebum compositions are incomplete, either lacking some important constituents or using concentrations of components that are not physiologically relevant. Squalene and wax esters are especially important constituents in sebum, as the only place they are found in the body is in the sebum. These two components play a role in the structure of skin lipids and stability of the skin barrier (Pappas, 2009; Picardo *et al.*, 2009; Zouboulis, 2004). The most complete and accurate composition of human sebum, containing the known constituents at relevant levels, was developed by Stefaniak *et al.* (2010). Jojoba oil has been proposed (Wertz, 2009) as a potential substitute for wax esters (e.g., palmityl palmitate, oleyl oleate), since thin-layer chromatography analysis shows that it produces a single chromatograph spot corresponding to wax esters. Vitamin E is also present in sebum in trace amounts. It is a known inhibitor of lipid oxidation (Thiele *et al.*, 1999) and is added to ensure the stability of squalene in artificial sebum during storage and application. Previous studies (Stefaniak *et al.*, 2010; Wertz, 2009) have shown squalene rapidly oxidizes in the absence of Vitamin E at 32 °C. In the presence of 0.1% Vitamin E, squalene is chemically stable for 48 hours at 32 °C or 6 months on storage either neat or in chloroform/methanol solution at 4 C° or -20 °C.

Bioaccessibility Studies Using Artificial Mixture of Sweat and Sebum

A few studies were found that utilize a mixture of artificial sweat (Harvey *et al.*, 2010) and artificial sebum (Stefaniak *et al.*, 2010) to assess dermal exposure to chemicals. These studies evaluated the bioaccessibility of beryllium from beryllium-containing materials (Stefaniak *et al.*, 2011), silver from silver-treated textiles (Stefaniak *et al.*, 2014b), and organic flame retardants from indoor house dust (Pawar *et al.*, 2016). The compositions of the artificial sweat and artificial sebum used in these studies do not differ considerably among these three studies. The sebum and sweat formulations used to study flame retardants in indoor house dust (Pawar *et al.*, 2016) are slightly modified from those used by Stefaniak *et al.* (2011) and Stefaniak *et al.* (2014b) with some of the constituents removed, but the concentration of the other constituents is the same.

Proposed Artificial Sweat and Sebum for Evaluating Dermal Bioavailability

To best represent the environment of the skin surface, OEHHA proposes to use an artificial sweat (Pavilonis *et al.*, 2014) and artificial sebum (Stefaniak *et al.*, 2010) mixture to evaluate the bioaccessibility of chemicals in crumb rubber (Table 2).

The artificial sweat composition from Pavilonis *et al.* (2014) was used for metal and organic bioaccessibility studies in crumb rubber and is a simple formulation containing inorganic, organic, and nitrogenous constituents. Results of a recent metal release study (Midander *et al.*, 2016) suggest that a simple artificial sweat biofluid (EN 1811:2011) can provide similar inorganic extraction results compared to a more comprehensive artificial sweat biofluid containing over 60 components including electrolytes, organic acids and carbohydrates, amino acids, nitrogenous substances, and vitamins. The composition of the artificial sweat by Pavilonis *et al.* (2014) is similar to the simple sweat tested in Midander *et al.* (2016) (EN 1811 artificial sweat, pH of 6.5), except the former contains two additional known components of sweat, ammonium chloride and acetic acid, and is expected to be an effective buffer for inorganic extraction. The proposed sweat composition has a more physiologically relevant pH of 5.4. The median pH of human sweat is 5.3.

The selected artificial sebum (Stefaniak *et al.*, 2010) has the most representative composition of human sebum found in the literature. It has demonstrated success in bioaccessibility studies of inorganic and organic chemicals from various materials. This sebum composition, however, is complex and contains components that may present technical issues in the preparation and analysis of the targeted chemicals. OEHHA may consider a less complex sebum used by Pawar *et al.* (2016) as an alternate artificial sebum formulation, if technical issues become a concern. The sebum used by Pawar *et al.* (2016) contains 4 of the 10 components (see Table 2) in the sebum used by Stefaniak *et al.* 2010 and has been demonstrated to have good bioaccessibility values of 72-94% for lipophilic compounds.

Table 1.2. Artificial biofluid compositions used to simulate the dermal exposure to synthetic turf materials.

Sweat Composition	Sebum Composition[3]
340 mM Sodium Chloride	**0.5151 g/L Squalene, 99+%**
330 mM Ammonium Chloride	**0.9718 g/L Palmityl palmitate, 98%**
83 mM Urea	0.2430 g/L Oleyl Oleate, ≥99%
170 mM Lactic Acid	1.0690 g/L Tristearin
42 mM Glacial Acetic Acid	**0.5345 g/L Triolein**
pH 5.4	0.6876 g/L Stearic/Palmitic Acids, 96%
	0.6876 g/L Oleic Acid
	0.0972 g/L Cholesteryl Oleate
	0.1944 g/L Cholesterol
	0.1 % Vitamin E
(Pavilonis *et al.*, 2014)	(Stefaniak *et al.*, 2010)

[3] **Bold** constituents are the components of the simplified sebum used by Pawar *et al*. 2016.

1.3. Inhalation Exposure—Interstitial Deep Lung Fluid and Alveolar Phagolysosomal Fluid

Physiology of Respiratory Tract

The way fine particles behave in the human respiratory tract has been well studied. Based on physicochemical and physical properties, inhaled particles can be deposited in different regions of the lung. Larger particles that deposit in the upper airways are removed by mucociliary clearance mechanisms. The particles get trapped in mucus and propelled upwards out of the lung by beating cilia lining the airways and are expelled through the mouth via coughing or enter the gastrointestinal tract via swallowing. Smaller particles can reach the lower airways and pulmonary region of the lung where gas exchange occurs. These deep lung regions do not have cilia or mucus as defense mechanisms. Instead, the lower airways and deep lung are protected by phagocytic macrophages, which can engulf and remove particles, and lung fluid, which can aid in the dissolution of particles (Davies and Feddah, 2003).

Artificial interstitial deep lung fluid is designed to mimic the fluid contained in the deep lung interstitium (interstitial deep lung fluid, ILF) that surrounds and supports alveolar sacs. ILF contains inorganic components, mucus, proteins, phospholipids, and surfactant (a phospholipoprotein complex). Its main function is to protect lung cells from physical and chemical damages, pathogens, and to help with gas exchange (Akella and Deshpande, 2013). ILF typically has a pH of 7 to 7.5 (Boisa *et al.*, 2014). Small soluble particles that deposit in the deep lung may dissolve in the ILF.

Particles that do not dissolve in ILF may be removed from the lung through phagocytosis by macrophages. Inside the macrophage, phagosomes containing particles fuse with lysosomes creating phagolysosomes. These phagolysosomes have an acidic environment (pH ~4.5), and contain inorganic components, proteins, and enzymes to assist with particle digestion (Stefaniak *et al.*, 2005; Stopford *et al.*, 2003; Xu and Ren, 2015). Artificial alveolar phagolysosomal fluid is designed to mimic the fluid within phagolysosomes (alveolar phagolysosomal fluid, ALF), which particles come into contact with following phagocytosis by macrophages. Chemicals in the particles may eventually become bioaccessible.

Bioaccessibility Studies Using Artificial Interstitial Lung Fluid

In the literature, Gamble's solution (Moss, 1979) is often used as an artificial ILF. The solution contains inorganic, organic, and protein components that have been shown to be in nearly identical compositions as in the human ILF (Davies and Feddah, 2003). A few studies have used Gamble's solution to investigate the bioaccessibility of metals in alloys (Henderson *et al.*, 2014), of iron- and chromium-based particles (Hedberg *et al.*, 2010), of platinum, palladium, and rhodium released from vehicle exhaust and road dust (Colombo *et al.*, 2008), and of cobalt in cobalt compounds and alloys (Stopford *et al.*, 2003), as well as the solubility of silicon dioxide particles (Larson *et al.*, 2010). The Gamble's solution, however, lacks lipids which are crucial constituents of the pulmonary surfactant component in the lung fluid. The pulmonary surfactant is not only responsible for lung stability, but as a barrier defense (Akella and Deshpande, 2013; Glasser and Mallampalli, 2012). Dipalmitoyl phosphatidylcholine (DPPC, also known as dipalmitoyl lecithin), the major constituent of pulmonary surfactant (Akella and Deshpande, 2013), has been applied to modify the Gamble's solution. The modified Gamble's solution has been used to determine the bioaccessibility of organics and metals in crumb rubber (Lioy and Weisel, 2011; Pavilonis *et al.*, 2014). It has also been used to examine the dissolution of aerosol inhaler products (Davies and Feddah, 2003), and the bioaccessibility of metals from atmospheric particles (Julien *et al.*, 2011). Alternatively, artificial ILF of compositions different from the Gamble's solution have been used to study the bioaccessibility of lead in the PM10 fraction of soil (Boisa *et al.*, 2014) and the dissolution of mineral fibers (Thelohan and de Meringo, 1994). These fluids contain lactates, tartrate, and pyruvate whereas Gamble's solution contains acetate.

Bioaccessibility Studies Using Artificial Alveolar Phagolysosomal Fluid

Our literature search found no studies involving use of artificial ALF to measure the bioaccessibility of organic compounds, while as noted above, there are several studies that have used it to evaluate the bioavailability of metals in different contexts. Artificial ALF has also been used to measure the dissolution rate of silicon dioxide particles to determine lung residence time (Larson *et al.*, 2010), and wool fibers of varying chemical compositions (Thelohan and de Meringo, 1994). Among these studies, the artificial ALFs used were of very similar compositions. In some studies, however, formaldehyde was included in the artificial ALF. Formaldehyde is naturally produced in the human body and has a role in several biological processes such as the methylation of amino acids (Kalasz, 2003). However, formaldehyde is an oxidizer and can polymerize in the absence of a stabilizer. It may also react with nucleophilic chemicals (Feldman, 1973). For these reasons, an artificial ALF containing formaldehyde may not be an ideal lung buffer for our study.

Proposed Artificial Interstitial Lung and Alveolar Phagolysosomal Fluids for Evaluating Bioavailability from Inhalation Exposures

Table 3 presents the proposed artificial ILF. Pavilonis et al. (2014) applied this fluid to assess the nature and amounts of inorganic and organic chemicals that can be released from crumb rubber. The artificial ILF is a modified Gamble's solution containing a physiological relevant lipid—DPPC. The addition of DPPC probably will enhance the dissolution of lipophilic chemicals in crumb rubber. The fluid has a pH of (waiting for response to personal communication with Pavilonis).

Table 3 also lists the proposed artificial ALF. This fluid has a physiologically representative composition, but does not include formaldehyde. The fluid contains anionic components (citrate and tartrate) to complex with and facilitate the dissolution of metal ions, along with organic components (lactate and pyruvate) that may aid in the dissolution of some organics from the fine particles.

Table 1.3. Artificial biofluid compositions used to simulate the inhalation exposure to synthetic turf materials.

Interstitial Deep Lung Fluid (ILF) Composition	Alveolar Phagolysosomal Fluid (ALF) Composition
10 mM Magnesium chloride	0.050 g/L Magnesium chloride
150 mM Sodium chloride	3.21 g/L Sodium chloride
4 mM Potassium chloride	0.071 g/L Disodium hydrogen phosphate
1 mM Disodium phosphate	0.039 g/L Sodium sulphate
5 mM Sodium sulfate	0.128 g/L Calcium chloride
25 mM Calcium chloride	0.077 g/L Sodium citrate dihydrate
7 mM Sodium acetate	6.00 g/L Sodium hydroxide
34 mM Sodium bicarbonate	20.8 g/L Citric acid
3 mM Sodium citrate	0.059 g/L Glycine
0.20% (w/v) Dipalmitoyl lecithin (aka DPPC)	0.090 g/L Sodium tartrate dihydrate
	0.085 g/L Sodium lactate
	0.086 g/L Sodium pyruvate
	pH 4.5
(Pavilonis *et al.*, 2014)	(Colombo *et al.*, 2008)

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Section 3B

Bioassessibility Study Setup

Section 3B. Bioaccessibility of Chemicals in Crumb Rubber

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Bioaccessibility is the amount of a chemical in an environmental medium that can potentially cross a biological membrane (lung, gut, skin) during exposure. Bioaccessibility is important for understanding exposure in terms of absorbed dose and health risk. Traditional methods used to measure bioaccessibility involve incubating a sample in an artificial biofluid held at physiologically relevant temperature and agitated for a number of hours. As compounds are "extracted" from the test substance into the biofluid simulant, the concentration in the receiving phase increases. This can lead to a reduction in the concentration gradient between the test material and biofluid, which in turn can slow the rate of mass transfer reducing the apparent bioaccessibility of the compound. In a living organism, cell membranes will actively remove chemicals from biofluid and into the blood stream using various transport and metabolic functions available in epithelial cells. To better mimic this process, we have adapted a solid phase extraction system, called stir bar sorptive extraction (SBSE) to simulate the natural extraction processes. In SBSE, a solid sorption phase is coated on a stir bar. The stir bar is placed in a biological fluid simulant along with the test material and used continuously to agitate the mixture and to provide a simulated biological reservoir. The process is conducted at a physiologically relevant temperature and timeframe. Chemicals released from the test substance into the biofluid are transferred into the solid phase of the stir bar. By continuously removing the chemicals from the biofluid, the extraction process remains in a state of dynamic equilibrium allowing more chemicals to be removed from the crumb rubber sample over a physiologically relevant time period. Three protocols with different fluid compositions and mixing times will be used to represent the different routes of exposure: dermal, oral and inhalation. Initial results show significant presence of the chemical signature of crumb rubber and also aromatics, polycyclic aromatic hydrocarbons (PAHs) and some halogenated chemicals. The bioaccessible concentration will be compared to the total concentration measured in paired samples using aggressive solvent extraction and used to estimate the bioaccessible fraction of contaminants in the exposure media.

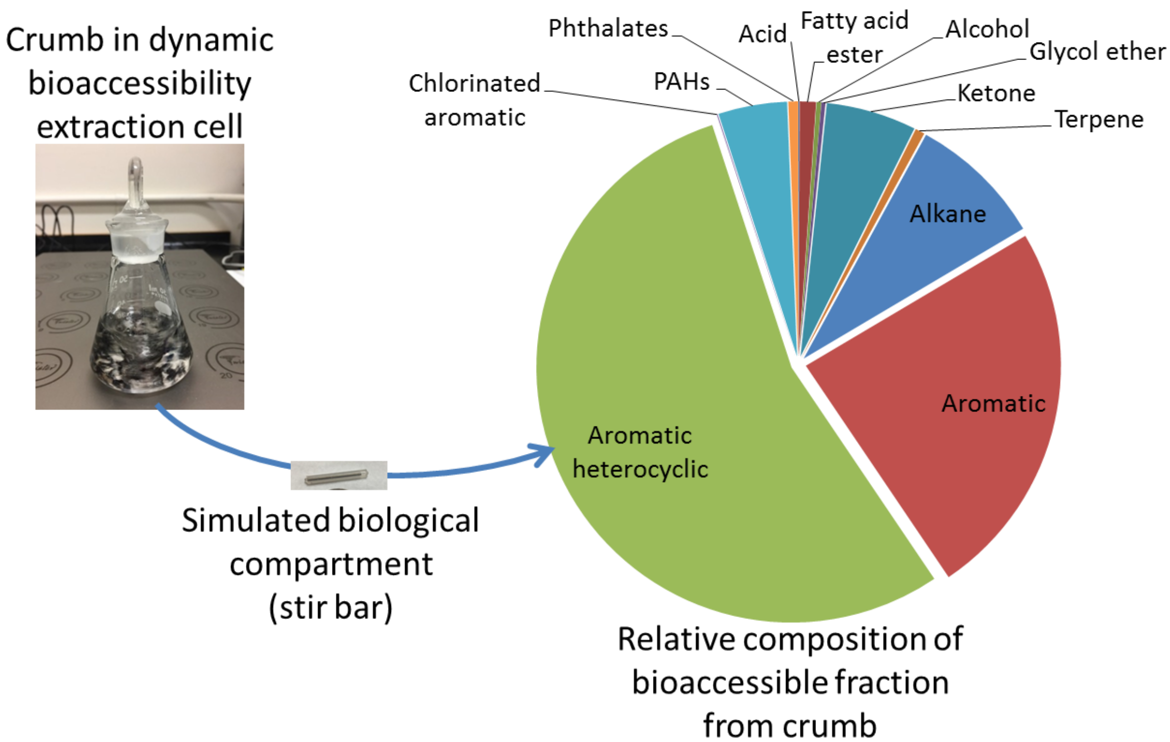


Figure 1. Results from initial range finding experiment using dynamic bioaccessibility measurement protocol in aqueous solution.

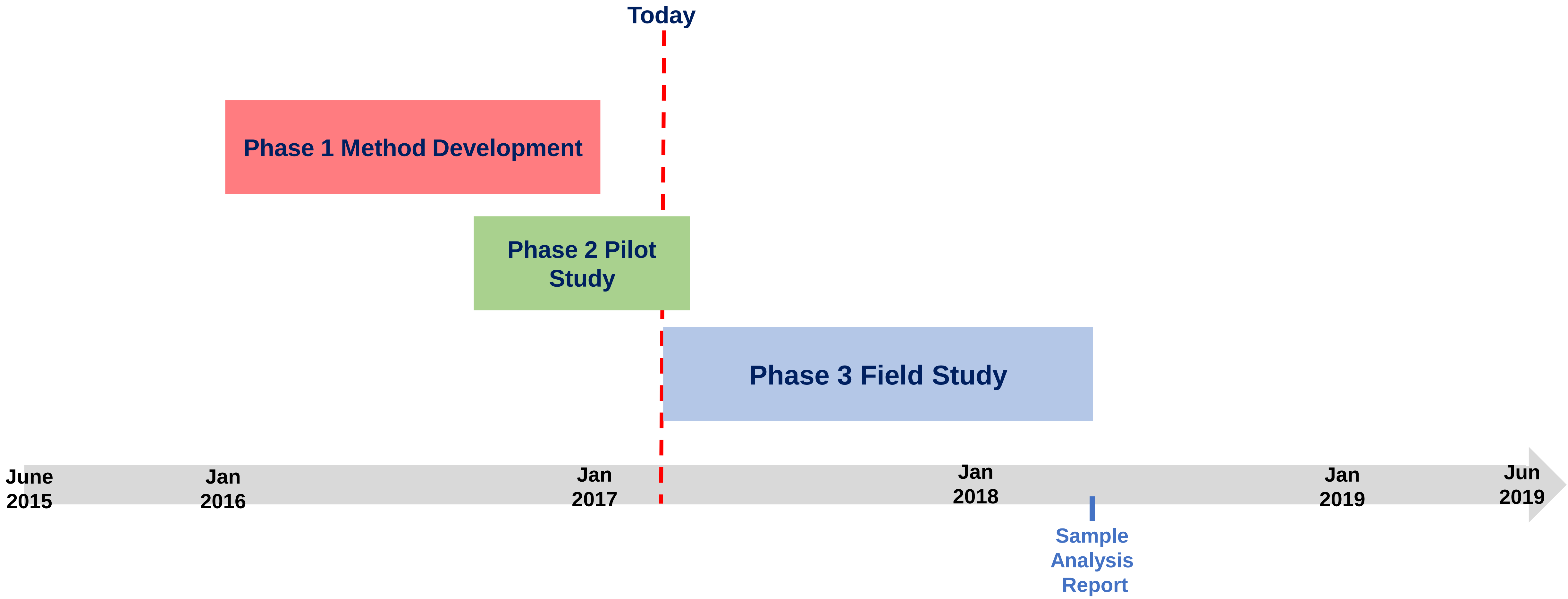
Section 4

Field Study

Section 4. Field Study – A Stepwise Approach

Study Phase	Phase 1	Phase 2	Phase 3
Goal	Provide field crumb rubber samples for SOP development	Validate and modify field sampling protocol	Collect field samples for the study
Number of Fields	Total of 4	Total of 2	20+
Location	2 each Northern and Southern CA	Northern and Southern CA	Throughout CA
Field Age	1 New (0-5 Years) and 1 Old (10+ Years) pair in Northern and Southern CA	1 New (0-5 Years) in Northern CA and 1 Old (10+ Years) in Southern CA	Young (0-8 Years) and Old (9+ Years)
Sample Type	Crumb rubber	Crumb rubber, chemical vapor, airborne particles	Crumb rubber, chemical vapor, airborne particles
Activity on Field	No Activity	Limited field surface agitation near sampling locations	Scripted human activity to create surface agitation

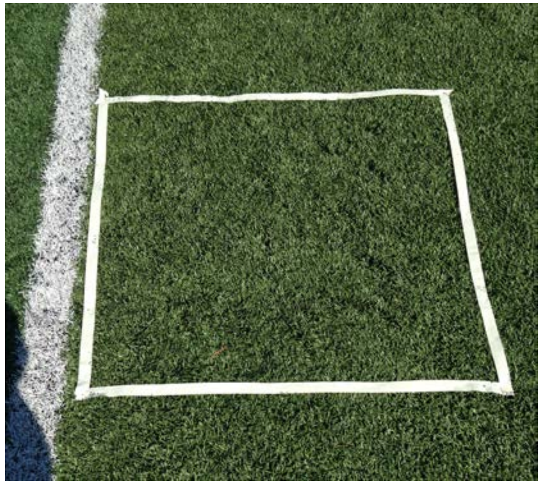
Task 4
Field Study Timeline

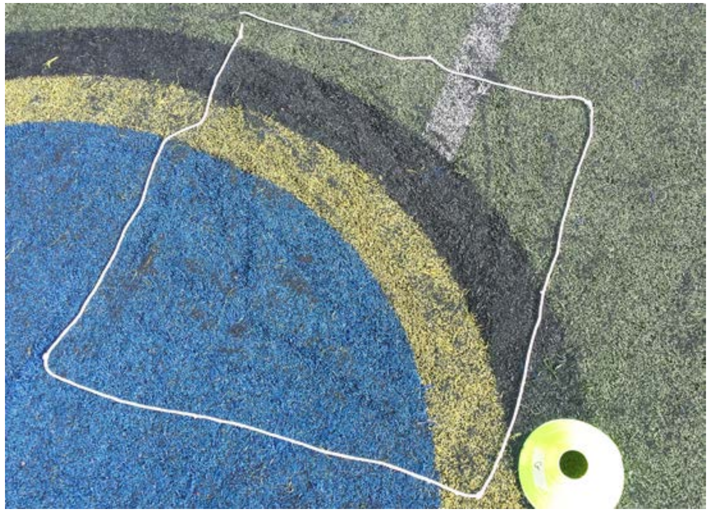


Section 4A

Phase 1 Field Study

Section 4A. Phase 1 Field Study
Sampling Field Set-up





Section 4B

Phase 2 Field Study

Section 4B. Phase 2 Field Study

Validate and modify field sampling protocol

Primary Experimental Unit (PEU)

PEU built around a soccer goal with ball repeatedly bounced into net and with instrumented carts logging continuously at each side and behind net

Instrumented Carts for Field Testing

- 3-D anemometer
- Semi-volatile Compounds
- Volatile Compounds
- Total Particle Mass
- PM2.5 Particle Mass
- PM10 Particle Mass
- Size resolved particle number concentrations
- Ultrafine particle number concentration
- Aerodynamic particle size number concentration
- IR-Surface Temperature

Section 4C

Phase 3 Field Study

Section 4C. Phase 3 Field Study

Selection of Synthetic Turf Fields to Sample

There are 905[1] synthetic turf fields in California. These fields are of various ages and are located throughout California, where they are subjected to different environmental conditions (e.g., ozone, climate). OEHHA has categorized these fields by common characteristics into subgroups, and proposes to randomly sample from the different subgroups to ensure each are represented. This stratified random sampling approach has the advantages over simple random sampling in that all subgroups identified for sampling will be represented.

One of the primary goals of the field sampling is to identify the chemicals present and their concentrations in different media (air, biofluids simulations) associated with the use of synthetic turf fields in California. There are several factors that may impact the integrity of crumb rubber in synthetic turf fields, which in turn may affect the identities and amounts of chemicals available for human exposure. OEHHA has identified the following factors as potentially important and has categorized the 905 fields in California into groups based on these factors, to guide the field selection process:

a) Climate
b) Age of field
c) Ambient ozone level

a. Climate

Weathering of crumb rubber can impact the availability of chemicals for exposure on the synthetic turf fields. Weathering is a function of climate (e.g., rainfall, temperature range). OEHHA used the 16 climate zones created by the California Energy Commission (CEC, 2015; PGE, 2006) to characterize the climate in our field selection process. Figure 1 shows the 16 climate zones, and Table 1 lists the California counties covered by each of these climate zones. Some counties fall within multiple climate zones.

[1] OEHHA synthetic turf field database based on 2016 data from CalRecycle, Does not include fields on military bases.

Figure 1. A California map showing the 16 Climate Zones (source: California Energy Commission (CEC), 2015)

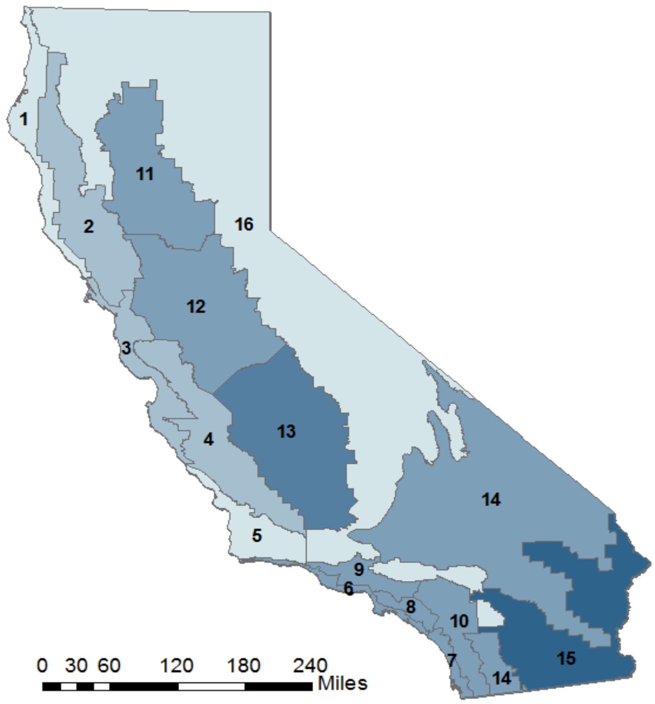


Table 1. Counties in each Climate Zone

Climate Zone	Counties Covered by Climate Zone*
1	Del Norte, Humboldt, Menodocino
2	Humboldt, Lake, Marin, Mendocino, Napa, Sonoma, Trinity
3	Contra Costa, Marin, Monterey, Mendocino, Santa Cruz, San Francisco, San Mateo, Solano, Sonoma
4	Monterey, San Benito, San Luis Obispo, Santa Barbara, Santa Clara
5	San Luis Obispo, Santa Barbara
6	Los Angeles, Orange, Santa Barbara, Ventura
7	San Diego
8	Los Angeles, Orange
9	Los Angeles, Ventura
10	Riverside, San Bernardino, San Diego
11	Butte, Colusa, Glenn, Nevada, Placer, Shasta, Sutter, Tehama, Trinity, Yuba
12	Alameda, Amador, Calaveras, Contra Costa, El Dorado, Mariposa, Merced, Sacramento, San Joaquin, Solano, Stanislaus, Tuolumne, Yolo
13	Fresno, Kern, Kings, Madera, Tulare
14	Imperial, Kern, Los Angeles, Riverside, San Diego, San Bernardino
15	Imperial, Inyo, Riverside, San Diego, San Bernardino
16	Alpine, Amador, Butte, Calaveras, Del Norte, El Dorado, Fresno, Glenn, Inyo, Kern, Lassen, Los Angeles, Madera, Mariposa, Mendocino, Modoc, Mono, Nevada, Placer, Riverside, San Bernardino, Shasta, Sierra, Plumas, Siskiyou, Tehama, Trinity, Tulare, Tuolumne, Ventura, Yuba

*Some counties are covered by multiple climate zones

Based on the mean temperature data in warm season (May to October, 2011-5; Weather Underground, https://www.wunderground.com) and other climate considerations, we consolidated the 16 climate zones into five climate regions (shown in Figure 2):

i. Region 1: Southern Coastal Areas (Climate Zones 6 to 9). This region consists of the Southern California coast. The warm ocean water keeps the climate mild throughout the year. Rain mostly occurs in winter. During the warm seasons in 2011-5, the mean average temperature ranged from 69 to 72°F and the mean maximum temperature ranged from 84 to 89°F.

ii. Region 2: Northern and Central Coastal Areas (Climate Zones 1 to 5). This region is situated along the Northern and Central California coast. Weather is greatly influenced by the Pacific Ocean. Generally, summers are cool and winters are mild and wet. Strong wind and fog are common. In 2011-5 during the warm seasons (May to October), the mean average temperature ranged from 57 to 67°F and the mean maximum temperature ranges from 64 to 80°F.

iii. Region 3: Southern California Interior valleys (Climate Zone 10) and Northern California Central Valley (Climate Zones 11 to 13). These valleys receive little influence from the ocean. Summers are dry and hot, while winters are wet and can be relatively cold. During the warm season in 2011-5, the mean average temperature ranged from 72 to 78°F and the mean maximum temperature ranged from 88 to 93°F.

iv. Region 4: Southern California high and low deserts (Climate Zones 14 and 15). This region is characterized by the extreme hot and dry summers and moderately cold winters. During the warm season in 2011-5, the mean average temperature ranged from 82 to 86°F and mean maximum temperature ranged from 97 to 102°F.

v. Region 5: Mountainous Area (Climate Zone 16). This region contains California's high-altitude, mountainous areas. Climate in the region is mild in summers and cold and snowy in winters. The mean average temperature was 69°F and mean maximum temperature was 85°F in the warm seasons in 2011-5

The Figure 2 map of California displays these five climate regions and Table 2 gives the number of synthetic turf fields in each of the regions. As shown in Table 2, some climate regions have many more fields than others. The fields are more concentrated in metropolitan areas.

Figure 2. A California map illustrating the five climate regions and the location of synthetic turf fields

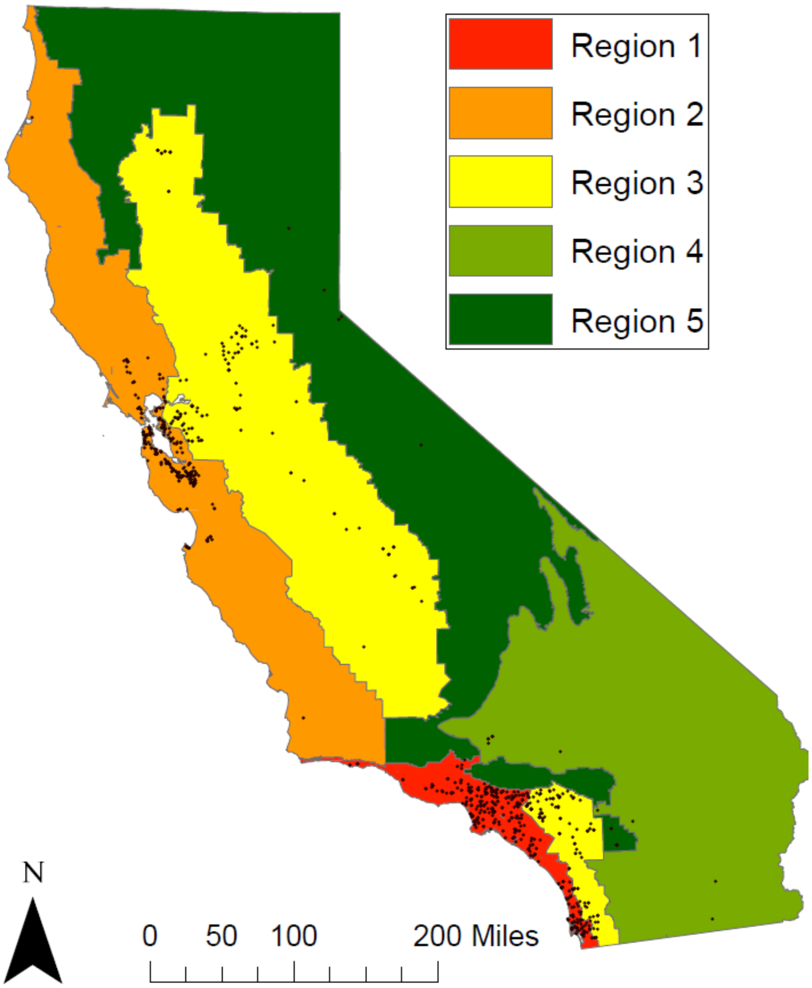


Table 2. Climate Regions

Climate Region	Climate Zones Covered	No. of Fields
1	6 -9: southern coastal areas	376
2	1 - 5: northern and central coastal areas	272
3	10 – 13: southern interior valleys and northern Central Valley	233
4	14 -15: southern high and low deserts	14
5	16: mountainous area	10

b. Age of Field

Aging of the crumb rubber in the synthetic turf fields is another factor that can affect the chemicals and tire particles available for exposure. Based on information from some field owners, warranties for synthetic turf fields are usually eight years. Figure 3 shows the age distribution of fields in California as a whole and Figure 4 shows the age distribution of fields in each region.

In California, 52 percent of the fields are at or below nine years of age (Figure 3b). For field selection, we divided fields in each climate region into two age groups: 0-8 years and 9+ years (Table 3). With few fields overall, Regions 4 and 5 have small numbers of fields in each of the two field age groups.

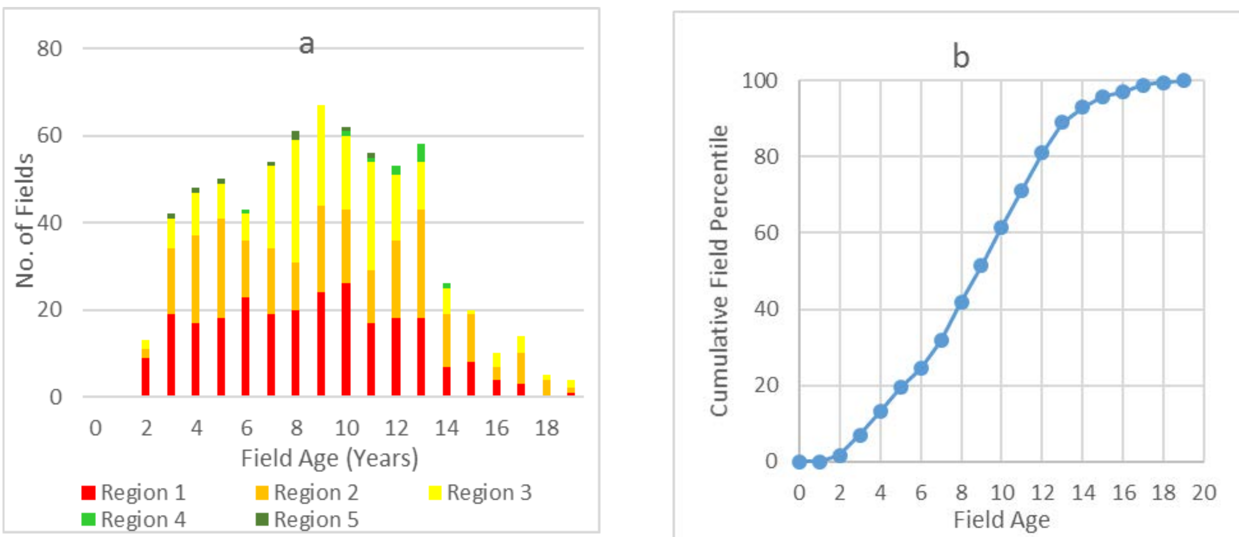


Figure 3. (a) Age Distribution of Fields in California; (b) Cumulative Distribution of Field Age in California.

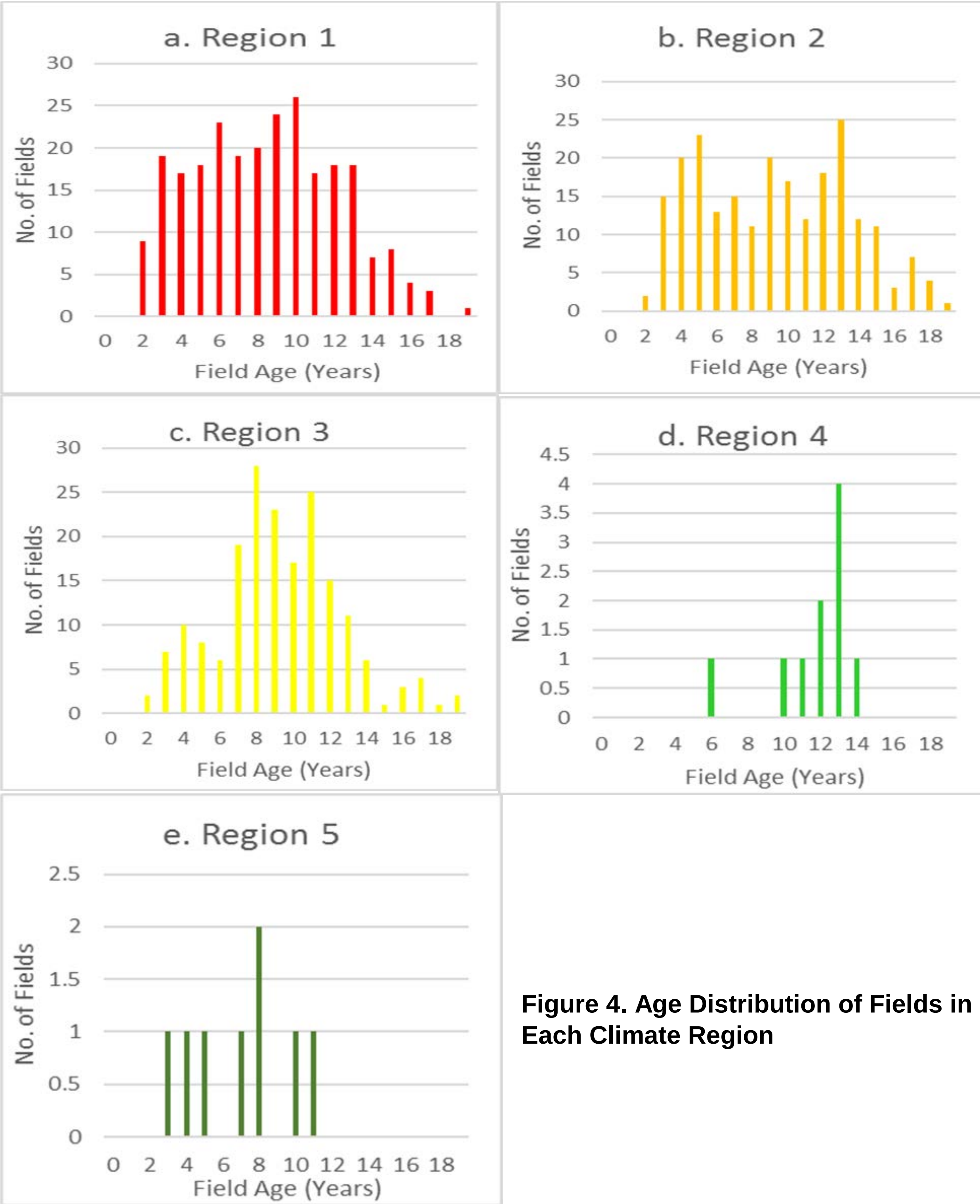


Figure 4. Age Distribution of Fields in Each Climate Region

c. Atmospheric Ozone Level

High ozone levels can accelerate the deterioration of the crumb rubber in the synthetic turf fields and affect the chemicals and tire particles available for exposure. Accordingly, we further characterized the fields into high and low ozone subgroups. Ozone data are obtained from the CalEnviroScreen database (OEHHA, 2014). Areas of the state with ozone levels at or below 50th percentile were categorized as low ozone areas, while areas with ozone levels above the 50th percentile were categorized as high ozone areas. For some regions and field ages, some ozone subgroups have very small number of fields or no fields, as shown in the next section (Tables 3a-e).

d. Field Selection

Applying the categorization scheme described above, the 905 fields are sorted into 20 subgroups: 5 climate regions × 2 age groups × 2 ozone subgroups. Tables 3a-e show the numbers of the fields in the different climate regions falling into the different age and ozone level subgroups. In climate regions 1-3, each region has a much greater number of fields compared to climate regions 4 and 5 which cover mountainous and desert areas of the state.

Resources permit the sampling and characterization of approximately 20-25 fields. We propose to randomly select two fields per each subcategory in each of the climate regions with a relatively large number of fields (in Regions 1 to 3) and one field per each subcategory in the regions with few fields (Regions 4 and 5). We also propose to exclude those subcategories with only one field. Since some of the subcategories do not contain any fields, the number of fields selected under this approach would be 23 (Table 4).

Table 3. Stratification of Fields in Each Region by the Age of Field and Ozone Exposure Levels

Table 3a. Climate Region 1			
Field Age (Years)	No. of Field		
	Low Ozone	High Ozone	Total
0-8	71	54	125
9+	62	65	127
Unknown*	60	64	124
Total No. of Fields	193	183	376

Sample size: 8

*Fields of unknown age will be contacted to verify age

Table 3b. Climate Region 2			
Field Age (Years)	No. of Field		
	Low Ozone	High Ozone	Total
0-8	99	0	99
9+	130	0	130
Unknown*	43	0	43
Total No. of Fields	272	0	272

Sample size: 4

*Fields of unknown age will be contacted to verify age

Table 3c. Climate Region 3			
Field Age (Years)	No. of Field		
	Low Ozone	High Ozone	Total
0-8	43	37	80
9+	60	48	108
Unknown*	36	9	45
Total No. of Fields	139	94	233

Sample size: 8

*Fields of unknown age will be contacted to verify age

Table 3d. Climate Region 4			
Field Age (Years)	No. of Field		
	Low Ozone	High Ozone	Total
0-8	1	0	1
9+	2	7	9
Unknown*	0	4	4
Total No. of Fields	3	11	14

Sample size: 2

*Fields of unknown age will be contacted to verify age

Table 3e. Climate Region 5			
Field Age (Years)	**No. of Field**		
	Low Ozone	**High Ozone**	**Total**
0-8	**1**	**5**	**6**
9+	**1**	**1**	**2**
Unknown*	**0**	**2**	**2**
Total No. of Fields	**3**	**8**	**10**

Sample size: 1
*Fields of unknown age will be contacted to verify age

To select specific fields for sampling, the following procedure is proposed. First, fields in each subcategory will be randomly sorted. Field owners will then be contacted in the order of the sorted lists until the designated number of fields is recruited and sampled in each subcategory. OEHHA will conduct this stratified random sampling to select 23 fields from the 905 fields in California, thus sampling 2.5% of the fields. This will result in field sampling for chemical analysis that reflect the exposure conditions and field age of the synthetic turf fields in California.

Table 4. Total Number of Synthetic Turf Fields to be Sampled in Each Region

Climate Region		No. of Fields	No. of Fields Sampled
1	Southern coastal areas	376	8
2	Northern and central coastal areas	272	4
3	Interior valleys	233	8
4	Southern high and low deserts	14	2
5	Mountainous areas	10	1

References

CEC (2015). California Building Climate Zone Areas. California Energy Commission (http://www.energy.ca.gov/maps/renewable/building_climate_zones.html)

OEHHA (2014). California Communities Environmental Health Screening Tool: CalEnviroScreen Version 2.0. Office of Environmental Health Hazard Assessment (https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-version-20)

PGE (2006). The Pacific Energy Center's Guide to: California Climate Zone and Bioclimatic Design. Pacific Gas and Electric Company. (http://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zones_01-16.pdf)

Appendix A

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 B

University of California Davis Report "Design Considerations for a Study on Environmental Health Effects of Synthetic Turf on Children"

UC DAVIS EXTENSION
COLLABORATION CENTER

Design Considerations for a Study on Environmental Health Effects of Synthetic Turf on Children

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Submitted by
UC Davis Extension Collaboration Center
May 31, 2016

1333 Research Park Drive, Davis, CA 95618 (530) 757-8965 collaboration@ucdavis.edu extension.ucdavis.edu

Table of Contents

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Acknowledgements: Claire Meunier and Wallis Lapsley were hardworking and reliable research assistants on this project. The report was prepared as part of CalRecycle contract number DRR14150, Total Contract Amount $2,858,000, pursuant to Government Code Section 7550.

Report Overview: Purpose and Methods

This report was commissioned by the Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, to prepare for a large, comprehensive study to assess the health effects of synthetic turf and crumb rubber on children. Specifically, this report is intended to meet the following goals.

1. Estimate the number of hours that children playing soccer or football spend on synthetic turf through age 30.
2. Calculate high and low exposure scenarios for youth soccer and football players.
3. Present recommendations for study designs based on published research on the environmental health effects of synthetic turf.

Interviews and Internet searches were used to estimate the number of children who play soccer and football and the number hours children spend on synthetic turf. Approximately six hours of interviews were conducted with one college-level Division I soccer play, one college-level Division I football player, and one youth football coach. These expert informants provided annual practice and game schedules; insight into the differences in practice hours and length of season for recreational versus competitive leagues; and, estimates of additional informal practice hours, not supervised by coaches, that highly motivated athletes engage in. They also identified or confirmed the names of youth sports associations which regulate the number of hours of practice and games and which also could be contacts for future surveys of coaches and/or parents. Web searches provided the estimated number of children who play these sports in California, access to regulations on practice and game hours (e.g., the American Youth Soccer Organization for recreational soccer for children 4-18, the California Interscholastic Federation for high school sports), and annual practice and game schedules for a single school or club for youth and high school soccer and football teams. Annual schedules and personal practice estimates were used to estimate high and low exposure scenarios. These schedules reflect only one school or club, and so may not be representative of hours spent in practice and games throughout California.

Recommendations for future studies were based in part on a meeting with OEHHA scientists and the background information they provided: notes from public hearings on synthetic turf that OEHHA hosted in fall, 2015; a report from CalRecycle on health hazards of synthetic turf[1]; and, a summary of the goals of the larger planned study on synthetic turf. To complement this information, a literature search identified 40 peer-reviewed articles using a PubMed, specifying articles published since 2005 with title words “synthetic turf”, “artificial turf”, “crumb rubber,” and the bibliographies of these studies. Due to the short time frame for this report, I did not review government studies on artificial turf, but they may be of interest in future study planning efforts. For a list of government reports, see the references in the review article by Cheng et al.[2] The background information and peer-reviewed literature was used to create three study aims with research objectives for each aim and, where possible, tested protocols to collect and analyze relevant data.

Soccer: Range of Hours Spent on Soccer Fields by California Youth

Soccer is among the most popular sports for boys and girls in California. As of 2014-15, approximately 100,000 girls and boys played soccer for their high school team [3] and an estimated 300,000 youth played in recreational leagues.[4] Children can begin playing on a soccer team at the age of four in a recreational league[5]; play on a recreational or competitive league through high school while also playing on their high school team; and, potentially, continue playing all the way through college until 22 or 23 years old. The length of the season, and the number of hours spent in coach-supervised practice and games, and the number of hours spent in informal practice away from coaches, increases with age and level of competition.

Playing season and heat. Appendix 2 includes sample game and practice schedules by month and shows that youth play organized soccer for at least one month of the summer. Recreational leagues often begin in August, and competitive leagues host tournaments throughout the summer. For college players, their nine-month season is intense during August and September which are among the two hottest months in California.

Does player position expose some players to artificial turn and crumb rubber more than others? There are no studies available to answer this question. In a related field, injury epidemiology studies focus on traumatic soccer injuries resulting in lost days of play (e.g., ACL tears) rather than skin abrasions which often don't require a missed day or medical attention; furthermore, these studies rarely analyze injury data by position of players.[6] There are several exceptions. For instance, an extensive review found two studies conducted in Europe reporting that the rate of skin abrasions among soccer players in general is high, but not significantly higher among goalies compared to midfielders or defenders.[6] Also, a five year cohort study of American women collegiate soccer players found no significant difference in all types of injuries across defensive positions, including goalies. [7]

Challenges in estimating time on synthetic turf vs. natural grass. The vast majority of soccer practice time is spent on the field on drills and games (versus off the field in the weight room or other locations). However, the proportion of time spent on synthetic turf versus natural grass is difficult to estimate. It depends in part upon whether the home team field, where practice and half of the games occur, is made of synthetic turf. Second, the same team may change fields based on the season of the year: summer games could occur on grass whereas in rainy seasons practice could shift to turf fields, either outdoor or indoor. Finally, the distribution of turf fields varies widely, with a higher proportion of synthetic turf fields in the Los Angeles and San Francisco Bay area, and so youth players in these regions may spend more, or all, of their time on synthetic turf.

Estimates of time spent on the field. One criticism of exposure estimates to synthetic turf fields is that they assume lifetime exposure, when in fact children spend a limited number of hours on soccer fields. Appendix 2 includes sample annual game and practice schedules for teams at different playing levels and ages. Tables 1 and 2 summarize this information by providing estimates of the number of hours spent on soccer fields for one year and cumulatively from ages 4 through 30.

Table 1 shows that over one year competitive players spend many more hours on the field compared to recreational players: for ten year olds, competitive players spend about four times the number of hours on the field, while 20 year old competitive players could spend as much as 33 times the number of hours on the field compared to recreational players. Table 2 shows that a competitive player, over 26 years of cumulative playing time, could spend seven times more hours on soccer fields compared to a recreational player (6627 versus 947 hours). As explained above, actual exposure to synthetic turf will vary based on the proportion of time the player spends on synthetic turf or natural grass.

Table 1. Number of Hours Spent on Soccer Fields: One Year Estimates for a 10 and a 20 Year Old*

Age & Level of Competition	# Hours: Team Practice & Games	# Hours: Informal Practice *	Total Hours on Field
10 year old			
Recreational League	81	0	81
Competitive League	242	96	338
20 year old			
Recreational League	20	0	20
Division I College Team	340	336	340-676

*Information on calculations used for these estimates is included in Appendix 1.

Table 2. Low and High Exposure Scenarios for Time on Soccer Fields: Estimates for Ages 4-30*

Scenario	Ages 4-10	Ages 11-18	Ages 19-22	Ages 23-30	Total Hours
Low Exposure					
Playing Level	Recreational League	Recreational League	Intramural or Parks & Recreation League	Recreational league or Parks & Recreation League	
# Hours*	403	324	80	140	947
High Exposure					
Playing Level	Recreational League	Competitive League & High School Team	College Division I or II	Competitive Adult League	
# Hours**	403	3040	2704	480	6627

* Information on calculations used for these estimates is included in Appendix 1.

Football: Range of Hours Spent on Football Fields by California Youth

About 103,000 boys in California played football on a high school team in 2015, about twice as many players as the second most popular sport for boys (track and field). [3] Approximately 230 girls played high school football in 2015, but will not be mentioned in this section on football since their participation is very low. Boys can play tackle football from ages 5-15 in youth football clubs sponsored by national organizations such as Pop Warner or American Youth Football.[8] As with soccer, the number of hours of practice and length of the game increases with age. At age 16 there are no organized tackle football leagues for boys, and so a player has several options: stop playing football, play flag football through a club or the local parks and recreation department, or play for a high school and then possibly a college team. The primary opportunity for adults to be involved in football is in flag football leagues offered by intramural sports on college campuses, parks and recreation departments, or by non-profit sports leagues such as national organizations like WAKA or local organizations like Top Gun Flag Football which serves the Los Angeles area. This report will not assess time on the field for flag football because there is no tackling and so contact with the turf and crumb rubber is limited.

Compared to soccer, several factors limit the number of hours players spend on the football field between the ages of 5-30. First, unlike soccer, there does not seem to be a distinction between recreational and competitive youth players; the difference is in the time spent in summer camps where "entry level" or "elite" training is provided based on age and ability (see, for instance, Stanford Football Camps). Second, informal practice may be limited to conditioning off the field, such as running intervals to increase speed and weight training to increase strength. Further interviews should confirm how football players spend their time in informal practice. Third, the opportunities to play tackle football are very limited after age 15, and so it is likely that many youth football players shift to flag football or a different sport when they turn 16.

Playing season and heat. Appendix 3 includes sample game and practice schedules by month and shows that youth play tackle football for at least two months of the summer: the season begins in July, with intensive training in August. Youth football training camps may be offered in June and July. For high school and college players, August also requires intensive practice hours to prepare for the start of the season in September. Football has a shorter season than soccer, but may require more hours on the field during the hottest months in California.

Does player position expose some players to artificial turf and crumb rubber more than others? There are no studies available to answer this question, but injury epidemiology studies of football sometimes touch on this subject. For example, a study of 400 high school football games played on grass or turf showed higher incidence of skin abrasions on turf, regardless of player position.[9] This may indicate more contact with artificial turf and crumb rubber among football players who play on artificial turf. Studies reporting differences in injuries by player position are mixed. For instance, a study of high school football players in California found that player position and time played during the game were predictors of higher injury rates of any type: specifically, offensive and defensive backfielders had about a 20% increased rate of injury compared with linemen, and starters had a 60% higher injury rate than for nonstarters.[10] In contrast, a study comparing injury rates among high school student football players on natural grass versus artificial turf found no difference in injury rates by player position except for special teams players who were twice as likely to suffer any type of injury on artificial turf compared to natural grass.[9]

Challenges in estimating time on synthetic turf vs. natural grass. As with soccer, the proportion of time youth football players spend on synthetic turf versus natural grass is difficult to estimate. It depends in part upon whether the home team field is made of synthetic turf and whether the player lives in an area of California with a high proportion of synthetic turf football fields. Therefore, exposure estimates are of time spent on a field in general, and do not distinguish between natural grass and artificial turf fields.

Estimates of time spent on the field. One criticism of exposure estimates to synthetic turf fields is that they assume lifetime exposure, when in fact children spend a limited number of hours on football fields. Appendix 3 includes sample schedules for teams at different ages as well as training camp schedules. Tables 3 and 4 summarize this information by providing estimates of the number of hours spent on football fields for one year and cumulatively from ages 5 through 30.

Table 3 shows that over one year, a 20 year old football player would spend about twice as many hours on the field compared to a 10 year old (284 hours vs. 146 hours). Table 4 scenarios are based on the assumption that few players will continue to play tackle football after college, and so cumulative exposure to a football field is likely limited to ages 5-23, compared to ages 4-30 for soccer. It also shows that college players could spend 2.4 times as many hours on the field compared to players who do not go on to join a high school football team. As with soccer estimates, actual exposure to synthetic turf will vary based on the proportion of time the player spends on synthetic turf or natural grass.

Table 3. Number of Hours Spent on Football Fields: One Year Estimates for a 10 and a 20 Year Old*

Age & Level of Competition	# Hours: Team Practice & Games	# Hours: Summer Training and Camps	Total Hours on Field
10 year old, Club Football	126	20	146
20 year old, Division I College Team	284	n/a	284

* Information on calculations used for these estimates is included in Appendix 1.

Table 4. Low and High Exposure Scenarios for Time on Football Fields: Estimates for Ages 4-30*

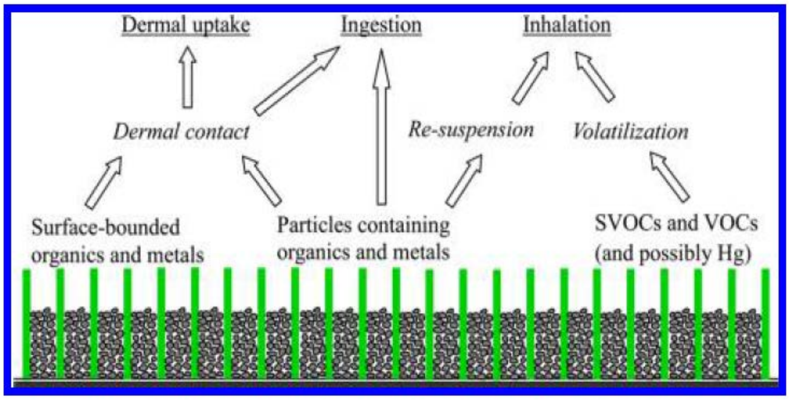
Scenario	Ages 5-14	Ages 15-18	Ages 19-22	Ages 23-30	Total Hours
Low Exposure					
Playing Level	Club Football	Club Football			
# Hours	1314	146	0	0	1460
High Exposure					
Playing Level	Club Football	High School Team	College Division I or II	n/a	
# Hours	1314	1096	1136	0	3546

* Information on calculations used for these estimates is included in Appendix 1.

Study Design Considerations

Cheng and colleagues published the most recent review of research on artificial turf in 2014, covering both the environmental and health effects.[2] As with other studies, they identify three possible exposure pathways: dermal, ingestion, and inhalation (Figure 1).

Figure 1. Major Exposure Pathways for Athletes and Occasional Users to Hazardous Substances in Artificial Turf Fields



Source: Cheng, Hu, and Reinhard, 2014.

Cheng et al.'s review concluded that most peer-reviewed and government studies have found that toxic compounds in synthetic turf and crumb rubber are present in levels that are below limits for human health. Nevertheless, fewer than 20 studies on human health effects of synthetic turf have been published, and there are a number of limitations.

- Most studies have used laboratory techniques to assess exposure, with no human involvement.
- Key questions remain about differences in toxicity by age of field and indoor versus outdoor fields.
- Of the handful of studies that have used biomonitoring with humans, the number of study participants is small, and most studies focus on the inhalation pathway. Little is known about dermal or ingestion pathways.
- None of the studies has examined children's exposure to synthetic turf, nor their siblings or family members.

Therefore a number of different studies could be conducted to fill in gaps in knowledge on the health effects of synthetic turf. The next section outlines three different study aims and associated research methods to close some of the gaps in knowledge.

Aim 1: Characterize chemicals that can be released from synthetic turf in different settings and ages of fields.

Objective 1: Determine whether indoor synthetic turf fields have higher levels of VOCs and SVOCs than outdoor fields.

Objective 2: Assess differences in chemical composition of turf and crumb rubber in new versus older fields.

Overview: Samples should be collected in August or September during hottest months when children are likely to be using the fields. Recommendations for the number of fields, age of fields, sample collection and analysis methods are based on a handful of studies conducted on this topic. There are clear protocols and validated analysis methods to follow.

Table 5. Recommended Sampling and Analysis Procedures for Chemical Characterization

Source of Materials	Number of Fields & Locations	Protocol for Sample Collection & Analysis
New crumb rubber samples	N/A: Samples provided by CalRecyle & major manufacturers	**Crumb rubber sample collection following the method of Menicchi et al., 2011[11]:** About 50 g of granulate were collected from the center of each of 12 sectors on the playing field. The 12 samples were pooled to obtain one composite sample per field. **Crumb rubber analysis following the method of Kim et al., 2012[12]** (see also Zhang et al.[13])**:** Analyze small vs. large granules (more or less than 250 um) separately based on evidence that smaller particles are likely to be ingested unconsciously. Use digestive fluid solution elution concentration to estimate ingestion of heavy metals and other compounds in crumb rubber. **Air sample collection and analysis following methods of Simcox et al., 2011[14]** (see also: Li et al., 2010[15]): Stationary air samplers at 6" & 3' above ground for one hour & recording of date, time, surface temperature, and wind speed at each sampling location. Researchers describe methods of sample collection and analysis to detect VOCs, SVOCs, PAHs, etc.
Outdoor fields	15 fields each in Los Angeles County, the SF Bay Area, and the Central Valley consisting of: 5-8 fields < 1 year old 5-8 fields 1-5 years old 5-8 fields > 5 years old 45-72 fields total	
Indoor fields	15 fields in one location: 5-8 fields < 1 year old 5-8 fields 1-5 years old 5-8 fields > 5 years old	
Comparison: Natural grass field[14] or highly populated location[11] near synthetic turf fields in study	At least one field/location in Los Angeles County, the SF Bay Area, and the Central Valley	Same method as air sample collection and analysis by Simcox.

Aim 2: Use biomonitoring and personal monitoring to assess uptake of chemicals present in synthetic turf.

Objective 1: Use tested strategies to measure exposure from inhalation, ingestion, and dermal exposure pathways.

Overview: Less than a handful of studies have been conducted on humans to assess their exposure to toxins associated with crumb rubber and synthetic turf. Protocols for biomonitoring inhalation are well documented, but less so for ingestion and dermal exposure pathways. Note that biomonitoring can require surveys or other means to assess alternative sources of toxins of interest (see, for instance, van Rooig et al. [16]). Table 6 summarizes a variety biomonitoring options and presents key references; the full study by OEHHA will likely select one or two of these options based on available resources and toxins of interest (e.g., PAHs, metals, etc.).

Table 6. Biomonitoring Options to Assess Youth Exposures from Playing on Synthetic Turf

Exposure pathway	Measurement Strategy	Study participants & comparison groups:	Protocol for Sample Collection & Analysis
Inhalation	Personal air samplers	Soccer teams playing on synthetic turf, including a mix of recreational and competitive teams at different age levels (eg. 6-8 year olds, 12 year olds, high school and college level). Comparison group: matched teams playing on grass fields.	**Air sample collection and analysis following methods of Simcox et al., 2011[14]** (see also: Li et al., 2010[15]): Use personal air samplers during a practice or practice game for 1-2 hours with breaks for water and adjustment of air sampling equipment. Researchers describe methods of sample collection and analysis to detect VOCs, SVOCs, PAHs, etc.
Dermal	Hand wipes, tape striping.	A subset of players recruited for studies listed above. Collect samples before and after a soccer game.	**Both hand wipes and tape stripping have been used to assess dermal exposure to PAHs.[17,18]** These methods should be assessed for other toxins of interest such as zinc.[13]
All pathways	Urine test; blood test; non-invasive measures such as hair or fingernails.	Same as above. Consider adding younger siblings of youth players.	**Urine sample collection and analysis following methods of van Rooig, 2010[16]:** Collect urine samples and surveys to assess other sources of PAHs before and after practice begins; explore the utility of urine tests to measure other toxins in crumb rubber. **Blood tests** are a traditional means to assess zinc and lead,[19] and **non-invasive biomonitoring [20]** for metals have used hair and finger/toenail samples.

Aim 3: Improve exposure assessment scenario development to better estimate exposures, including high and low exposure scenarios, for 1) different player positions in soccer and/or football; and, 2) siblings of young soccer/football players.

Objective 1: Use biomonitoring data to 1) explore differences by player position; and, 2) differences among younger siblings who play on synthetic turf vs. natural grass while watching games and practices.

Objective 2: Use an observational method to better understand younger siblings' interaction with crumb rubber.

Studies on skin abrasions in sports provide some insight into the ways that young athletes come into contact with synthetic turf. But virtually nothing is known about their younger siblings who may play with and ingest crumb rubber as they watch practices and games. OEHHA may decide to make use of the biomonitoring data they plan to collect to address these gaps in knowledge. In addition, an observational study could shed light on younger sibling interaction with synthetic turf. Table 7 lists some considerations and references to address these two study objectives.

Table 7. Using Novel Methods to Better Describe Interaction with Synthetic Turf among Athletes and their Younger Siblings.

Objective	Study Issues to Consider
1. Use biomonitoring data	If biomonitoring data will be collected, consider consulting a statistician to determine what sample size would be necessary to detect a significant difference between comparison groups (i.e., player positions, siblings who play on turf vs. grass). This could increase study costs, but go far to allay parents' concerns if no significant difference is found.
2. Use an observational method to collect objective data on contact with synthetic turf and crumb rubber.	A validated method has been established for young children by Stanford University's Exposure Research Group (ERG). The ERG conducted its first pilot study to collect micro-level activity time series (MLATS) data for young children in 1994, and has updated the method since then.[21,22] Less is known about how well this method could be used with older children playing soccer, but the literature on physical activity measurement may provide some models to adapt.

Additional Considerations for the Full Study

1. **Revise the Exposure Scenarios Presented in this Report to Include a Representative Sample of Schools and Clubs.** The short timeframe for this report limited the exposure scenarios to information from only one school or club. Selecting 10-15 schools and clubs from each age group and level of play, and averaging the number of practice and game hours across the schools and clubs, would provide a more representative estimate of the number of hours that youth spend on the field. Verifying the typical number of informal practice hours could be accomplished through surveys or interviews with players and parents.

2. **Limit the Full Study to Soccer.** The cost and time involved to thoroughly study more than one sport may be beyond the resources available for the full study. Peer-reviewed research focusses on one sport, and on one level (e.g., amateur adult clubs or NCAA players or professionals), for this very reason. About 100,000 California high school students play soccer and 100,000 play football for their school teams,[3] and these sports have similar interaction with crumb rubber through sliding, diving, and tackling. Other popular high school sports do not have the same interaction with the field and exposure to crumb rubber (e.g., track, tennis), or they have significant interaction with crumb rubber but have low participation rates (e.g., lacrosse, rugby[3]) and so affect fewer California youth. In choosing between soccer and football, the full study should consider focusing on soccer because of high public concern about this particular sport, as evidenced in the public hearings and press reports. Results from exposure assessment estimates may be generalizable to football; alternatively, a sub-study could be conducted to confirm that football players spend about the same amount of time on the field and interact with the field in the same way as soccer players. A description of a sub-study is beyond the scope of this report.

3. **Recommendations for Recruitment of Study Participants.** Press coverage of possible health issues with synthetic turf and OEHHA's public hearings in fall 2015 demonstrate a high level of anxiety among parents with children who use synthetic turf fields. This may make it easier to recruit families into the study because the topic is of great interest to them. But extra effort should be invested to develop trust and to improve recruitment and retention. Some suggestions include:
   - Begin recruitment early with education of soccer/football organizations about the study. Provide reasonable financial incentives to the organizations and teams for study participation.
   - Create a study advisory board including representatives from parents, coaches, and players. Their roles could include input on keeping study participants engaged (e.g., through a regular newsletter or other means of communication); the best strategies to share study results with participants; and recommendations on recruitment strategies. Define their roles at the outset to avoid misunderstandings and confusion.
   - Develop a short, informative handout for parents and coaches summarizing the health research on synthetic turf. Parents appear to be poorly or partially informed on the available research. They also appear to overestimate the number of hours their children spend on the field.
   - Provide individual biomonitoring results to each study participant in a timely manner, along with clear, low literacy instructions on how to interpret the results.

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Appendix 1: Assumptions and calculations for low and high exposure scenarios for soccer and football

Table 1. Number of Hours Spent on Soccer Fields: One Year Estimates for a 10 and a 20 Year Old
Informal practice is voluntary time spent by players without coaches present, either engaged in drills or playing unofficial games on the field. Based on an interview with a college soccer player, hours spent in informal practice is estimated for 10 year olds at 2 hours/week for 48 weeks, and for 20 year olds at 7 hours/week x 48 weeks.

10 year old:

- Recreational League: 81 hours of games and practice with no informal practice. Follows the schedule of the Davis, CA, AYSO team in Appendix 2.
- Competitive League: 242 hours of games and practice, with 96 hours of informal practice. Based on reports by a current Division I soccer player.

20 year old:

- Recreational League: one 10-week season annually, with 20 hours for games and zero hours for formal or informal practice. Follows the Davis, CA, Department of Parks and Recreation schedule and the UC Davis Intramural Sports schedule of 10 games/season.
- Division I College Team: annual game and practice schedule plus 7 hours/week of informal practice= 676 hours. See Appendix 2 for details.

Table 2. Low and High Exposure Scenarios for Time on Soccer Fields: Estimates for Ages 4-30

<u>Low Exposure</u>

Ages 4-10:	4-7 recreational soccer league: 40 hours/year x 4 years= 160 hours 8-10 recreational soccer league: 81 hours/year x 3 years= 243 hours
Ages 11-18	11-14 recreational soccer league: 81 hours/year x 4 years= 324 hours 15-18: no soccer participation, as AYSO teams decline significantly for teenagers.
Ages 19-22	intramural or parks and recreation league: 10 2-hour games per season annually with no practice, or 20 hours/year x 4 years = 80 hours
Ages 23-30	intramural or parks and recreation league: 10 2-hour games per season annually with no practice, or 20 hours x 7 years = 140 hours

<u>High Exposure</u>

Ages 4-10:	4-7 recreational soccer league: 40 hours/year x 4 years= 160 hours 8-10 recreational soccer league: 81 hours/year x 3 years= 243 hours
Ages 11-18	11-18 competitive soccer league: 338 hours/year x 7 years= 2366 hours 15-18 high school soccer team: 84 hours/year x 4 years = 336 hours
Ages 19-22	Division I College soccer team: 676 hours x 4 years= 2704 hours

Ages 23-30	3 seasons per year of adult leagues, games only (no practice, formal or informal) at 2 hours/game and 30 games/year: 60 hours/year x 8 years = 480.

Table 3. Number of Hours Spent on Football Fields: One Year Estimates for a 10 and a 20 Year Old
See Appendix 3 for sample annual schedules of games and practices.

10 year old, club football: 126 hours of games and practice plus 20 hours of summer football camp.

20 year old, Division I college football: 284 hours of games and practice.

Table 4. Low and High Exposure Scenarios for Time on Football Fields: Estimates for Ages 5-30

Low Exposure assumptions: a boy plays club football ages 5-15, then stops. Includes 126 hours games and practices plus 20 hours of summer training camp each year.

Ages 5-15: 146 hours/year x 10 years=1460 hours

High Exposure assumptions: a boy plays club football ages 5-14, high school football from ages 15-18, college football from 19-22, then stops playing tackle football.

Ages 5-14 club football: 146 hours/year x 9 years=1314 hours
Ages 15-18 high school football: 274 hours/year x 4 years=1096
Ages 19-22 college football: 284 hours/year x 4 years=1136
Ages 23-30 no tackle football=0 hours

Appendix 2: Soccer

Sample Soccer Practice and Game Schedule: College Men's Team, Division I, 2015-2016 Source: Interview with College Soccer Player		
August	September	October
Artificial Turf Hours: **4** Grass Hours: **58** Total Hours: **62**	Artificial Turf Hours: **0** Grass Hours: **52** Total Hours: **52**	Artificial Turf Hours: **2** Grass Hours: **52** Total Hours: **54**
Week 1 Wednesday August 12th-Saturday August 15th Practice Times: 9-11am and 3-5pm Artificial Turf Hours: **0** Grass Hours: **16** **Week 2** Sunday August 16th- Saturday August 22nd Practice Times: 9-11am and 3-5pm Game on August 22nd: 5-7pm Artificial Turf Hours: **0** Grass Hours: **22** **Week 3** Sunday August 23rd- Monday August 31st Aug 23rd-26th Practice Times: 9-11am and 3-5pm Aug 27th Travel to Seattle Practice 5pm-7pm **Turf** Aug 28th Game 7pm-9pm Aug 29th Practice 9-11am **Turf** Aug 30th Game 7:30-9:30pm Aug 31st- Travel day Artificial Turf hours: **4** Grass Hours: **20**	**Week 1** Tuesday September 1st- Sunday September 6th Practice Times 12-2pm Friday Sep 4th Game 5-7pm Sunday Sep 6th Game 5-7pm Artificial Turf Hours: **0** Grass Hours: **14** **Week 2** Monday September 7th- Sunday September 13th Sep 7th: Day Off Practice Times 12-2pm Game Sep 11th 4:30-6:30pm Artificial Turf Hours: **0** Grass Hours: **12** **Week 3** Monday September 14th-Sunday Sep 20th Sep 14th: Off Practice Times: 12-2pm Game Sep 20th: 5-7pm Artificial Turf Hours: **0** Grass Hours**: 12** **Week 4** Monday September 21st- Wednesday Sep. 30 Sep 21st: Off Practice Times: 12-2pm Game Sep 24th: 4-6pm Game Sep 27th: 1-3pm Sep 28th: Off Sep 30th: Travel Artificial Turf Hours: **0** Grass Hours: **14**	**Week 1** Thursday October 1st-Sunday October 4th Practice Times: 12-2pm Games Oct 1: 7-9pm **Turf** Oct 3: 7-9pm Oct. 4th: Off Artificial Turf Hours: **2** Grass Hours: **4** **Week 2** Monday October 5th-Sunday October 11th Practice Times: 12-2pm Games Oct 8: 4-6pm Oct 10: 1-3pm Oct. 11th Day Off Artificial Turf Hours: **0** Grass Hours: **12** **Week 3** Monday October 12th- Sunday October 18th Practice Times: 12-2pm Games October 14th 3-5pm Oct 17th 3-5pm Oct 18th: Day Off Artificial Turf Hours: **0** Grass Hours: **12** **Week 4** Monday October 19th-Sunday October 25th Practice Times: 12-2pm Games Oct. 21 7-9pm and Oct. 24 3-5pm Oct 25: Day Off Artificial Turf Hours: **0** Grass Hours: **12** **Week 5** Monday October 26th- Sunday Nov 1st Practice Times: 12-2pm Games Oct 28 7-9pm and Oct 31 2-4pm Nov 1st: Day off Artificial Turf Hours: **0** Grass Hours: **12**

November	January	February
Artificial Turf Hours: **0** Grass Hours: **18** Total: **18**	Artificial Turf Hours: **16** Grass Hours: **8** Track Hours: **6** Total: **30**	Artificial Turf Hours: **16** Grass Hours: **8** Track Hours: **6** Total: **30**
Week 1 Monday November 2nd-Sunday Nov. 8 Practice Times: 12-2pm Game Saturday Nov 7 7-9pm Sunday Nov. 8: Travel/Day Off Artificial Turf Hours: **0** Grass Hours: **12** **Week 2** Monday November 9th – Wednesday Nov. 11th Practice Times: 12-2pm Game Nov 11th 7-9pm Artificial Turf Hours: **0** Grass Hours: **6** **Weeks 3 and 4** Weight Lifting 2-3 times a week, no outside practices **Rest of the winter Quarter off for Academics**	**Week 1** January 4th – January 10th Monday-Thursday Practice 12-2pm Friday Off Turf Hours: **4** Track Hours: **2** Grass Hours: **2** **Week 2** January 11th- January 17th Monday-Thursday Practice 12-2pm Friday Off Turf Hours: **4** Track Hours: **2** Grass Hours: **2** **Week 3** January 18th- January 24th Jan 18th : Holiday Off Monday-Thursday Practice 12-2pm Friday Off Turf Hours: **4** Track Hours: **0** Grass Hours: **2** **Week 4** January 25th- January 31st Monday-Thursday Practice 12-2pm Friday Off Turf Hours: **4** Track Hours: **2** Grass Hours: **2**	**Week 1** Monday February 1st- Sunday February 7th Monday-Thursday Practice 12-2pm Friday Off Turf Hours: **4** Track Hours: **2** Grass Hours: **2** **Week 2** Monday February 8th-Sunday February 14th Monday-Thursday Practice 12-2pm Friday Off Turf Hours: **4** Track Hours: **2** Grass Hours: **2** **Week 3** Monday February 15th-February 21st Monday-Thursday Practice 12-2pm February 15th: Holiday Off Friday Off Turf Hours: **4** Track Hours: **0** Grass Hours: **2** **Week 4** Monday February 22nd- Sunday February 28th Monday-Thursday Practice 12-2pm Friday Off Turf Hours: **4** Track Hours: **2** Grass Hours: **2**

March	April	May
Artificial Turf Hours:**14** Grass Hours: **2** Track Hours: **2** Total: **18**	Artificial Turf Hours: **0** Grass Hours: **58** Total Hours: **58**	Artificial Turf Hours: **0** Grass Hours: **22** Total Hours: **22**
Week 1 Monday February 29th-Sunday March 6th Monday-Thursday Practice 12-2pm Friday Off Artificial Turf Hours: **4** Track Hours: **2** Grass Hours: **2** **Week 2** Monday March 7th- Sunday March 13th Monday- Friday Practice 12-2pm Turf Hours: **10** Track Hours: Grass Hours: **Week 3** Off from Practice for Finals	**Week 1** Monday March 28th – Sunday April 3rd Monday- Friday practice 12-2pm Game April 2nd: 4-6pm Sunday: Off Artificial Turf Hours: **0** Grass Hours: **12** **Week 2** Monday April 4th- Sunday April 10th Monday- Friday practice 12-2pm Games April 9th: 10-12pm and 5-	**Week 1** Monday May 2nd-Sunday May 8th Practice Monday-Thursday 12-2pm Friday May 6th Game 7-9pm Saturday and Sunday Off Artificial Turf Hours: **0** Grass Hours: **10** **Week 2** Monday May 9th- Saturday May 14th Practice Monday-Friday 12-2pm Saturday May 14th Game 3-5pm Artificial Turf Hours: **0** Grass Hours: **12** **End of scheduled team activities for the**

	7pm Sunday Off Artificial Turf Hours: **0** Grass Hours: **14** **Week 3** Monday April 11th- April 17th Monday- Friday practice 12-2pm Game April 16th 12-2pm Sunday Off Artificial Turf Hours: **0** Grass Hours: **12** **Week 4** April 18th- April 24th Monday- Friday practice 12-2pm Friday, Saturday and Sunday Off Artificial Turf Hours: **0** Grass Hours: **8** **Week 5** April 25th- May 1st Monday- Friday practice 12-2pm Game April 30th 1-3pm Sunday Off Artificial Turf Hours: **0** Grass Hours: **12**	**2015-2016 year**

Example High School Boys Soccer Practice and Game Schedule, 2015-16 Varsity
Source: https://www.cathedralcatholic.org/athletics/winter-sports

November	December	January
Artificial Turf Hours: **3** Grass Hours: **0** Total Hours: **3**	Artificial Turf Hours: **28** Grass Hours: **1.5** Total Hours: **29.5**	Artificial Turf Hours: **22.5** Grass Hours: **0** Total Hours: **22.5**
Week 1 November 18th-November 20th Practice Times: 6:45pm-8:15pm 6:00pm-7:30pm & 2:45pm-4:15pm Artificial Turf Hours: **3** Grass Hours: **1.5**	**Week 1** November 30th- December 3rd Practice Times 1:45pm-3:15pm, 5:30pm-7:00pm, 2:30pm-4:00pm, 5:45-7:00pm Artificial Turf Hours: **6** Grass Hours: **0** **Week 2** December 8th-December 11th Game December 8th 7-8:30pm **Turf** Practice Times 2:30-3:30, 2:45-4:15 Artificial Turf Hours: **2.5** Grass Hours: **1.5** **Week 3** December 14th- December 18th Practice Times: 1:45pm-3:15pm, 11:30am-1pm , 10-11:30am Game 12/16 7-8:30 **Turf** Artificial Turf Hours: **7.5** Grass Hours: **0** **Week 4** December 21st-December 26th December 25th: off Practice Times: 8:30-10am Artificial Turf Hours: **7.5** Grass Hours: **0** **Week 5** Games: 2 on the 28th and 1 on the 29th **4.5 Hours on Artificial Turf**	**Week 1** January 4th-January 8th Game 01/04 6:30-8:30 pm **Turf** Game 01/08 3:30-5:00pm **Turf** Artificial Turf Hours: **6** Grass Hours: **Week 2** January 11th-January 14th Practice Times: 1:30-3pm, 2:30-3:30pm Games Jan 13 and 14: 6:45-8:15pm **Turf** Artificial Turf Hours: **6** Grass Hours: **0** **Week 3** January 20th- January 29th Practice Times: 3:30-5:00pm, 1:30-3:15pm 2:30-3:45pm Games Jan 20,22,27 and 29th **Turf** Artificial Turf Hours: 1**0.5** Grass Hours: **0**

February	March
Artificial Turf Hours: **16.5** Grass Hours: **7.5** Total Hours: **24**	Artificial Turf Hours: **4** Grass Hours: **1.25** Total Hours: **5.25**
Week 1 February 1-February 5 Practice Times: 1:45-3:30pm, 2:30-3:45pm Games: Feb. 3 and Feb 5 6-7:30pm **Turf** Artificial Turf Hours: **6** Grass: **0** **Week 2** February 8th-February 12 Practice Times: 1:30-3pm, 2:30-4pm Games: Feb 10 and Feb 12 6-7:30pm **Turf** Artificial Turf Hours: **6** Grass: **0** **Week 3** February 16th- February 24th Practice Times: 2:30-4pm Games Feb 17,19 and 24 at 5:00-6:30pm **Turf** Artificial Turf: **4.5** Grass: **3**	**Week 1:** March 2nd- March 4th Games: March 2nd and 4th at 5-7pm **Turf** Practice: 2:45-4pm Artificial Turf Hours: **4** Grass Hours: **1.25**

Sample Annual Practice and Game Schedule: 10 year old Competitive Player

Source: Interview with Division I College Player about his past playing competitive soccer

September	October	November
Hours: 24	Hours: 24	Hours: 30
Week 1 Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **Week 3** Practice 2 times a week Game on the weekend Total hours: 6 **Week 4** Practice 2 times a week Game on the weekend Total hours: 6	**Week 1** Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **Week 3** Practice 2 times a week Game on the weekend Total hours: 6 **Week 4** Practice 2 times a week Game on the weekend Total hours: 6	**Week 1** Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **Week 3** Practice 2 times a week Game on the weekend Total hours: 6 **Thanksgiving tournament** **4-6 games, 1 practice, 12 hours**

December	January	February
Hours: 12	Hours: 28	Hours: 24
Week 1 Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 1.5 week of Holiday Break	End of December/Week 1 **Holiday Tournament** **3-5 Games 10 hours** **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **Week 3** Practice 2 times a week Game on the weekend Total hours: 6 **Week 4** Practice 2 times a week Game on the weekend Total hours: 6	**Week 1** Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **Week 3** Practice 2 times a week Game on the weekend Total hours: 6 **Week 4** Practice 2 times a week Game on the weekend Total hours: 6

March	April	May
Hours: 24	Hours: 24	Hours: 26
Week 1 Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **Week 3** Practice 2 times a week Game on the weekend Total hours: 6 **Week 4** Practice 2 times a week Game on the weekend Total hours: 6	**Week 1** Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **Week 3** Practice 2 times a week Game on the weekend Total hours: 6 **Week 4** Practice 2 times a week Game on the weekend Total hours: 6	**Week 1** Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **State Cup Tournament through the end of May 6-8 games 14 Hours**

June	July	August
Hours: 30	Hours: 6	Hours 18
Week 1 Practice 2 times a week Game on the weekend Total hours: 6 **Week 2** Practice 2 times a week Game on the weekend Total hours: 6 **Week 3** Practice 2 times a week Game on the weekend Total hours: 6 **Summer Tournament 1** **12 hours**	3 Weeks of Vacation **Week 4** Practice 2 times a week Game on the weekend Total hours: 6	**Week 1** Practice 2 times a week Game on the weekend Total hours: 6 **Summer Tournament 2** **12 hours**

Sample Annual Practice and Game Schedule: 10 year old Playing Recreational Soccer, 2015

Source: http://www.davisayso.org

August	September	October
Hours: 6	Hours: 16.5	Hours: 22.5
Week 1 – August 17th-23rd 2 practices for 1.5 hours Total hours: 3 **Week 2- August 24th-30th** 2 practices for 1.5 hours Total hours: 3	**Week 1 Aug 31st-September 6th** 2 practices for 1.5 hours Total hours: 3 **Week 2 September 7th-13th** 2 practices for 1.5 hours Game on Sep 5th for 1.5 hours Total hours: 4.5 **Week 3 September 14th-20th** 2 practices for 1.5 hours Game on Sep 19th for 1.5 hours Total hours: 4.5 **Week 4 September 21st-27th** 2 practices for 1.5 hours Game on Sep 26th for 1.5 hours Total hours: 4.5	**Week 1 Sep 28th- October 4th** 2 practices for 1.5 hours Game on Oct 3rd for 1.5 hours Total hours: 4.5 **Week 2 October 5th-11th** 2 practices for 1.5 hours Game on Oct 10th for 1.5 hours Total hours: 4.5 **Week 3 October 12th-18th** 2 practices for 1.5 hours Game on Oct 17th for 1.5 hours Total hours: 4.5 **Week 4 October 19th-25th** 2 practices for 1.5 hours Game on Oct 24th for 1.5 hours Total hours: 4.5 **Week 5 October 26th- Sep 1st** 2 practices for 1.5 hours Game on Sep 31st for 1.5 hours Total hours: 4.5

November	April	May
Hours: 4.5	Hours: 18	Hours: 13.5
Week 1 November 2nd-8th 2 practices for 1.5 hours Game on Nov 7th for 1.5 hours Total hours: 4.5 **End of Fall Season**	**Start of Spring Season** **Week 1 April 4th-10th** 2 practices for 1.5 hours Game on Apr 9th for 1.5 hours Total hours: 4.5 **Week 2 April 11th-17th** 2 practices for 1.5 hours Game on Apr 16th for 1.5 hours Total hours: 4.5 **Week 3 April 18th-24th** 2 practices for 1.5 hours Game on Sep 23rd for 1.5 hours Total hours: 4.5 **Week 4 April 25th-May 1st** 2 practices for 1.5 hours Game on Apr 30th for 1.5 hours Total hours: 4.5	**Week 1 May 2nd-8th** 2 practices for 1.5 hours Game on May 7th for 1.5 hours Total hours: 4.5 **Week 2 May 9th-15th** 2 practices for 1.5 hours Game on Sep 19th for 1.5 hours Total hours: 4.5 **Week 3 May 16th-22nd** 2 practices for 1.5 hours Game on Sep 21st for 1.5 hours Total hours: 4.5 **End of Spring Season**

Appendix 3: Football

Sample Football Practice and Game Schedule: College Men's Team, Division I, 2015-2016
Source: Interview with College Football Player

Month	Season	Hours on field a day	Hours on field a month	Description
August (1st Tuesday of full week)	Preseason training	Practice T-F: 3-5hrs depending on day (8-11am or 8-10/11am, 1-2 hours in the afternoon)	Min: 48 Max: ?	The number of double days and time varied, there was no exact number for the amount of double days.
September (1st full week)	Season	Games (4): 3-4hrs Practice T-R: 2hrs (8:30-10:30am) Practice F: 1-2hrs (8:30-9:30/10:30am)	Min: 40 Max: 48	The hours vary
October	Season	Games (4): 3-4hrs Practice T-R: 2hrs (8:30-10:30am) Practice F: 1-2hrs (8:30-9:30/10:30am)	Min: 40 Max: 48	Hours vary
November (ends the 2nd/3rd week)	Season	Games (3): 3-4hrs Practice T-R: 2hrs (8:30-10:30am) Practice F: 1-2hrs (8:30-9:30/10:30am)	Min: 30 Max: 36	Hours vary. The hours were calculated for this season, which went 3 weeks in.
December	Out-of-season	0	0	No practice or field work
January	Off-season	Practice T, R: 2hrs (6-8am)	16	
February	Off-season	Practice T,R: 2hrs (6-8am)	16	

March	Off-season	Practice T,R: 2hrs (6-8am)	8	Finals and spring break lowered the hours
April (1st full week)	Spring Season	Practice T, R, F: 2.5hrs (8:30-11 am) Practice S: 2hrs (11-1)	38	
May	Off-season	Practice T, R, F: 2.5-3hrs (8-9:30/10am).	Min: 30 Max: 36	Hours vary
June (starts the 2nd T after finals)	Summer Training	Practice T, R, F 1-2hrs (8-9/10am)	Min: 6 Max: 12	Hours vary, conditioning on field
July	Summer Training	Practice T, R, F: 1-2hrs (8-9/10am)	Min: 12 Max:24	Hours vary, Conditioning on field
Total hours on field (minimum)			284 hours	

Example High School Boys Football Practice and Game Schedule, 2015-16 Varsity
Source: https://www.cathedralcatholic.org/athletics/fall-sports

Month	Season	Hours on field a day	Hours on field a month	Description
August	Season	Practice M-F: 2hrs	40hrs	Can practice 2hrs a day before first game.
September	Season	Games (4): 2hrs Practice M-R: 2hrs	40hrs	Games are on Friday, Freshman play games on Thursday and practice on Friday.
October	Season	Games (4): 2hrs Practice M-R: 2hrs	40hrs	
November	Season	Games (2): 2hrs Practice M-R: 2hrs	20hrs	Season ends during the first few weeks of November, Teams can continue on if they make playoffs
December	Out-of-season	0	0	No practice or field work unless playoffs
January	Off-season	0	0	
February	Off-season	0	0	
March	Off-season	0	0	
April	Off-season	0	0	
May	Limited Season	Practice M-F: 2hrs	40	
June	Summer Training/Passing League	Game (1): 2hrs Practice M-F: 3hrs	62hrs	One Saturday is a 7 on 7 against another school. Made up of 3-4 30min scrimmages
July	Summer Training/Passing League	Game (1): 2hrs Practice M-F: 3hrs	32hrs	Training season ends mid July
Total			274hrs	

Sample American Youth Football (Tackle) Schedule, 2015-16

Sources: Interview with a former AYF coach, and
http://www.hometeamsonline.com/teams/?u=NJN&s=football

Month	Season	Hours on field a day	Hours on field a month	Description
July	Season	Practice M-F: 2hrs	10hrs	Practice starts the last week of July
August	Season	Games (1): 2hrs Practice (first 3 weeks) M-F: 2hrs Practice (last week) T-R: 2hrs	38hrs	Practice 5 days a week until Jamboree. Jamboree: play multiple 20 min games for 2 hrs.
September	Season	Games (4): 2hrs Practice T-R:	32hrs	
October	Season	Games (4): 2hrs Practice T-R: 2hrs	32hrs	Season ends during the first few weeks of November, Teams can continue on if they make playoffs
November	Season	Games (1): 2hrs Practice T-R: 2hrs	14hrs	Season ends first few weeks of November
December	Off-Season	0	0	No practice unless in playoffs
January	Off-Season	0	0	
February	Off-Season	0	0	
March	Off-Season	0	0	
April	Off-Season	0	0	
May	Off-Season	0	0	
June	Off-Season	0	0	
Total			126hrs	

Example Summer Football Camps for Youth Players

Sources: Interview with a youth football coach and camp websites

- http://sacyouthfootball.com/Originals/2016/2016%20SYF%20Rules%20160515.pdf
- http://www.ussportscamps.com/football/usscfootball/contact-football-camp-stanislaus-state-university/
- http://www.uclabruins.com/ViewArticle.dbml?ATCLID=208268004
- http://www.stanfordfootballcamps.com/2016_Camps.htm

Coaches expect youth football players to participate in summer football camps, which are hosted at high and college campuses around the state (and country). These camps run from 1-5 days for four hours each day. We assume summer participation in camp is 20 hours.

Appendix C

OEHHA Synthetic Turf Study Sampling Protocol

Appendix C. SYNTHETIC TURF FIELD SAMPLING PROTOCOL – Phase 2, PILOT STUDY (February 10, 2017)

1. FIELD SAMPLING

1.1. Background

The California Office of Environmental Health Hazard Assessment (OEHHA) is conducting a study of the potential health effects associated with the use of synthetic turf containing crumb rubber infill made from recycled waste tires. OEHHA plans to collect crumb rubber samples and environmental samples from outdoor and indoor synthetic turf fields and characterize the chemicals that can be released from these fields. This information will be used to assess the multi-route exposure to the chemicals by those who use or visit the fields. Lawrence Berkeley National Laboratory (LBNL) is, under contract with OEHHA, providing technical expertise and equipment to support the field sampling.

Field sampling will be carried out in three phases to serve the specific purposes of the study:

1. Laboratory Method Development: Field crumb rubber will be collected from four synthetic turf fields for chemical analysis development and the identification of chemicals of potential concern (COPCs)

2. Pilot Field Study: Field samples (crumb rubber and environmental matrices) will be collected from two synthetic turf fields to fine tune field-sampling protocols

3. Full Field Study: Field samples (crumb rubber and environmental matrices) will be collected from indoor and outdoor synthetic turf fields and playgrounds in the study. The samples will be analyzed to characterize and quantify the chemicals that may be released from these materials.

This document describes OEHHA/LBNL's plan to collect and store crumb rubber samples and environmental samples. Using information and experience gathered in Phase 1, we modified and improved the field sampling plan as needed and use it for Phase 2. This sampling plan will be further modified for the use of Phase 3.

1.2. Field Sampling

OEHHA/LBNL plans to collect crumb rubber and environmental samples at selected synthetic turf fields in California for each phase of the study.

1.3. Environmental Survey

1.3.1. *Pre-Visit Online Survey.* Before the field visit, the OEHHA field lead will conduct a pre-visit environmental survey (Appendix A) using field information available online. The internet search should include these activities:

- Review of the field surroundings within a 1-mile radius using google maps (e.g., satellite maps)
- Document the presence and location of nearby freeways, industrial facilities, or other potential sources of chemical emissions that may impact the field samples
- Document local precipitation history for the week prior to the field visit
- A check of the weather forecast for the day before and day of sampling, and considering the prior week's precipitation history, determine if the sampling schedule needed to be adjusted.

1.3.2 *Onsite Survey.* On the day of field sampling, OEHHA staff will conduct an onsite survey (Appendix B) before and during field sample collection to gather information on weather at the time of sampling (e.g., temperature, field surface temperature, relative humidity, wind direction, and wind speed), surrounding environment of the field (e.g., confirm locations of nearby freeway and industrial facilities identified in the Pre-Visit Online Survey), and visible conditions on the field (e.g., standing water from sprinklers, previous rain, or overnight condensation). The staff will also note the level of automobile traffic, and any other relevant information that may affect potential chemical emissions or exposure.

The OEHHA field lead will visually inspect the field and document (photograph, if possible) the dampness of the crumb rubber and turf blades at the time of collection. Crumb rubber samples will not be collected when either the turf blades or crumb rubber on the fields are perceptibly moist or wet. Shaded areas on the field will also be noted on the environmental survey especially in areas near or at the proposed sampling locations. If there is an unforeseen field condition, the OEHHA field lead shall immediately call the OEHHA project lead and discuss if field sampling activity need to be adjusted or rescheduled.

1.3.2. *Post-Visit Survey:* After the field visit, the OEHHA field lead will conduct a post-visit survey (Appendix C) using the internet to document the local temperature, relative humidity, wind speed, and wind direction at the time of sample collection.

1.4. Sampling Map (Field Diagram)

Before the field sampling day, the OEHHA and LBNL field leads will work together to develop a field-specific sampling diagram (Appendix D) illustrating field shape and orientation (compass showing North direction) and sampling details (including preliminary sampling locations, types and number of samples collected at each location). Appendix D shows example onsite sampling diagrams for each type of field (i.e. soccer, football) to be sampled. The diagram will be used during the field sampling to guide the sample collection. The OEHHA field lead will document any deviations from the plan on the sampling map and in the field sampling diary (Appendix E).

1.5. Crumb Rubber Collection

At a location outside the field, the OEHHA and LBNL field leads will set up a staging area to set up all the sampling supplies and a trash bag, and then brief the OEHHA/LBNL field staff (sampling team) on the sampling activity of the day and assign members of the sampling team with specific sampling tasks. The leads will distribute all sampling tools and the sampling map. The OEHHA field staff will collect crumb rubber samples at the pre-selected locations detailed on the sampling map. At each sampling location, the OEHHA field staff will use commercially available pre-cleaned metal or plastic sampling scoops provided by LBNL to collect crumb rubber from the field surface. The protocol for crumb rubber collection is as follows:

a) Identify and mark each on-field sample location using area indicator (a measured rope) to identify approximately a 1 square meter surface area (the sample collection area) to collect the sample from.

b) Put on a pair of fresh nitrile gloves.

c) Identify the 120 ml wide-mouth amber glass and 120 cc Polyethylene (PE) bottle with the affixed label corresponding to the first sampling location.

d) Carry supplies from the staging area to the sample location and place them on the ground within the marked area.

e) Press the side of the sampling scoop (metal scoop to be used with glass bottle, plastic scoop to be used with PE bottle) down onto the turf at an approximately 45º angle and move back and forth on the turf surface to collect crumb rubber within the sample collection area.

f) Scoop the crumb rubber into the sampling bottle.

g) Repeat the sample collection as needed at the same location or move to a different location within the designated sample collection area until both the glass and plastic bottles are full.

h) When bottles are full, insure that lids are tightly sealed, gather supplies and return to the staging area.

i) Record the date, time, and initials of sample collectors on sampling bottle label and into Chain-of-Custody (Appendix F).

j) Place sample in ice chest chilled with blue ice.

k) Before going to next sample location, change to a new pair of nitrile gloves, get a set of clean scoops and clean sampling bottles.

l) Repeat steps c-k until all samples are collected.

m) When done with all sample locations, return all field tools to the staging area. Ensure that nothing is left on the field.

1.6. Environmental Sample Collection

Upon arrival at the site, the field lead for environmental sample collection will review the initial selection of primary and secondary environmental sample locations and make final adjustments for the location and orientation of environmental sampling area based on current field and meteorological conditions. The rationale for the final selection of location and orientation will be documented in the field log.

Before entering the field, the OEHHA and LBNL field leads will brief the sampling team on the sampling activity of the day and assign staff with specific setup and sampling tasks. The environmental sampling will be centered around a pre-determined location on the field selected to provide cross field air flow of the predominant wind into the sampling location. The sampling area will be based around a soccer goal net with the opening of the net facing into the predominant wind with sampling packages set up to the left and right of the goal frame and behind the net. To simulate an activity field condition, surface agitation in the sampling zone will be created by launching soccer balls repeatedly into the area using a soccer ball kicking machine.

The sampling carts will be instrumented as detailed in the Table 1 at the lab prior to transport to the field. After the soccer goal net is placed in a pre-determined orientation and location, the sample carts will be placed as noted in Table 1 and the devices launched. Integrated samples will be run on re-programmed pumps.

Table 1: Instrument package

Target Metric	Instrument method or device	Sample type	Cart S = left and right of the goal frame B = back of net
wind speed direction & T/RH	3-D anemometer logged to onboard laptop	Continuous	S & B
Surface Temp	IR surface temperature probe logged to onboard laptop	Continuous	S & B
Local T/RH	HOBO U10 or equivalent logged internally	Continuous	S & B
VOCs	EPA method TO17 or equivalent using thermal desorption sorbent tubes	Integrated	S & B
Aldehydes	EPA method TO11 or equivalent using DNPH cartridge	Integrated	S & B
PAHs/ SVOCs	EPA method TO13 or equivalent using polyurethane foam + XAD2 sample train	Integrated	S & B
TSP PM	Particle mass collected on 47 mm HI-Q FP47 filter in line with SVOC sample	Integrated	S & B
PM2.5	DustTrak II 8530 particle mass analyzer logged internally	Continuous	S & B
PM (TSP)	DustTrak II 8530 particle mass analyzer logged internally	Continuous	S & B
Size Resolved Particle Number Conc.	MetOne 637 five size fractions logged to onboard laptop	Continuous	S
Total Particle Number Conc.	TSI 3781 condensation particle counter (~7 nm to 2.5 microns)	Continuous	B
Size resolved particle number conc.	TSI 3321 aerodynamic particle sizer resolved from ~ 300 nm (0.3 microns) to 20 microns	Continuous	B

The field protocol for environmental sample collection is as follows:

a) Confirm location on field for sampling area.

b) If necessary, move goal net frame into place with the opening of the net facing into the predominant wind

c) Starting from back of net, uncoil main power cable with three-way plug at the net end stretching away from the sampling area

d) Place generator at end of power cable, and install fume exhaust system with ducting running away from the sampling area. Set up any caution flags/cones and end of anchor duct in place. Start the generator.

One-hour inactive phase of testing:

e) Move three carts into position with all carts placed side-by-side at back of net and plug in power supply for carts

f) Install and orient the 3-D anemometers and align the IR probe pointing to the general area near the sampling area

g) Place pre-programmed SVOC pump on ground behind cart and connect vacuum line to SVOC sample head

h) Place pre-programmed VOC/ALD sample pumps on the carts

i) Place soccer ball kicking machine to the front of the net 18 – 20 yards from the front of the goal and install battery pack

j) Load VOC and Aldehyde tubes/cartridges in preprogrammed sampling boxes and launch all devices

k) Prior to start of SVOC sample collection, assemble sample train with sorbent cartridges and filters (this is only for the three hours active sampling period at the Pilot#1)

l) After sampling period begins, record all sample flows (VOC, ALD and SVOC) at least once per hour

Three-hour active phase of testing:

m) To start the active phase of testing, load and start the soccer ball kicking machine and program appropriate kicking cycle/speed (note that machine will need to be monitored continuously during testing)

n) Collect samples at the pre-determined locations for 3 hours

o) Move all carts to back of net and place side-by-side. Collect samples for another hour under with soccer ball launching from the ball kicking machine

The basic sampling playbook for the first pilot field will be to co-locate the sampling carts for the first hour without activity, then move the carts into position (one to each side and one at back of goal net) for a three hour test with activity, then finally return the carts to the side-by-side positon behind the net and continue the active period for an additional hour.

At the end of the sampling period, all digital data are saved on the device or laptop associated with the specific sampling cart and the data will be backed up on an external hard drive specific to the project. All integrated samples will be removed from the sampling boxes, labeled and returned to shipping/handling containers for transport back to lab.

1.7. Sample Handling and Shipping

Environmental samples and crumb samples will be packaged and transported/shipped in separate containers. The sample handling, transportation and/or shipping will follow the chain-of-custody (COC) and QA/QC protocol specified in the sampling plan (Section 3). A COC form is provided in Appendix F. Details specific to the crumb samples and environmental samples are provided below.

1.7.1 Crumb Samples

Once a bottle is filled, the date and time of collection, and initials of the sample collector will be clearly entered onto the label of each sampling bottle (Figure 1-2). The OEHHA field lead will account for all the sampling bottles after the completion of field sampling. Each sampling bottle will be placed into an individual Ziploc bag, sealed, wrapped, and placed into an insulated container (Styrofoam box or cooler) containing blue ice (4 °C). Each box of samples will contain the COC for the specific samples within the box. The boxes will be shipped via FedEx overnight or delivered on the same day to the laboratory.

Figure 1-1. Label for crumb rubber samples

Field ID: ______________
Sample No.: ______________________
Date & Time: ___________________________
Collector Initials:________

1.7.2 Environmental Samples

Environmental samples include both digital information logged on instruments or devices and physical samples collected on sampling media to be processed within a laboratory setting.

All digital data files will be assigned a unique descriptive name, saved on the instrument/device/computer associated with the sample and backed up on an external project specific hard drive as part of the shutdown procedure each day (or at each location if more than one location is tested on a given day).

1.8. Deviations from the Sampling Protocol

The OEHHA field lead will immediately contact (by phone or text) and seek approval from the OEHHA project lead for deviations from the sampling protocol that are deemed to be necessary due to variances in field conditions. The OEHHA field lead will document all the deviations in the COC records (Section 2.4) and the field sampling diary (Section 2.5).

2. Health and Safety

At least a day before the field visit, the OEHHA lead will identity and print out the contact information and full address of the nearest local emergency facility or hospital.

Before entering the field, the LBNL and OEHHA field leads will hold a tailgate meeting to go over the safety protocol. OEHHA field lead will present the emergency facility information and discuss potential physical (e.g., trips and falls, slip hazards, heat exhaustion and heat stress, dehydration, proper lifting techniques, use of personal protective equipment including eye protection, potential exposure hazards from chemicals applied to or that are on the turf, hygiene techniques and first aid) and biological hazards (e.g. bug bites). The LBNL field lead will describe detailed procedure on proper handling of mechanical, electrical, and electronic equipment. OEHHA and LBNL staff shall immediately report to the LBNL or OEHHA lead the following health and safety concerns:

- Changes in field/weather conditions that may impact the health safety of the team or individuals
- Signs of heat stress noticed on individuals
- Safety concerns observed on the field or individuals

The OEHHA and LBNL field leads will assess the conditions, report immediately to the OEHHA and LBNL project leads, contact OEHHA's industrial hygienist, and seek further assistance from the appropriate authorities (e.g., contact the local hospital), if warranted.

3. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PROCEDURES

The QA/QC procedures will be employed at the field and in the laboratory. The QA/QC samples collected in the field sampling events include field blanks and trip blanks. Field QA/QC procedures will be implemented at the fields and consist of the following measures:

- A Chain-of-Custody (COC) form will accompany all samples collected from a particular field during transportation. They will be used to ensure the integrity of the samples collected.
- A field sample log will be kept by OEHHA to record type and total number of samples collected from a particular field. It also includes sampling details, crumb rubber field locations, field ID, sampling date and times (begin and end), and sample identification numbers. Pages will be numbered, dated, and signed by the OEHHA and LBNL field staff performing sampling and data logging.
- A field sampling diary will be maintained to document all deviations from the sampling protocol and justifications for the changes. Communications between the OEHHA and LBNL field staff and the OEHHA and LBNL project leads for approval of protocol modifications onsite will be also summarized.
- One field QA/QC sample and one trip blank of each sampling bottle type will be collected at each synthetic turf field (i.e., a total of four blanks per field) and submitted for analysis along with the crumb rubber field samples.

3.1. Field Blanks Preparation

A field blank is a quality control measure used to identify potential contamination that may have occurred during crumb rubber sampling at the field and during the sample shipment to the analytical laboratory. A field blank is prepared by opening and closing a sample container at the field. OEHHA plans to prepare two field blanks (one for plastic bottle and for glass bottle) for each field. The field blanks will be preserved, packaged, and sealed in the same manner described for crumb rubber samples. For identification, a unique sample number will be assigned to each blank.

3.2. Trip Blanks Preparation

A trip blank is a quality control measure used to evaluate any potential contamination (e.g., migration of volatile organic chemicals) as a result of shipping and handling of samples. A trip blank is prepared by taking a sealed, clean sampling container and carrying it to the field. The blank container will not be opened and will accompany the sampling containers during the sampling and in the shipment to the laboratory. OEHHA plans to prepare a glass bottle and a plastic bottle trip blank for each field. The trip blanks will be handled under the same protocol for the crumb rubber samples, as described in this sampling plan. The trip blanks will be preserved, packaged, and sealed in the same manner described for crumb rubber samples. For identification, a unique sample number will be assigned to each blank.

3.3. Chain-of-Custody Records

Chain-of-Custody (COC) records are used to document sample collection and will accompany all sample shipments to the laboratory. The COC record will identify the contents of each shipment and maintain the custodial integrity of the samples. COC forms will be completed and signed by sample collectors and sample handlers and sent with the samples for each shipment. If multiple coolers are sent to a single laboratory on a single day, COC forms will be completed and sent with the samples for each cooler. Generally, a sample is considered to be in a person's custody, if it is either in the person's physical possession, in the person's view, locked up, or kept in a secured area that is restricted to authorized personnel. Until receipt by the laboratory, the custody of the samples will be the responsibility of OEHHA staff.

3.4. Field Sampling Diary

The field sampling diary shall include the location of sample collection, the name of the lead and the names of field staff who participated in the sample collection at each field. All deviations from the sampling protocol described in section 1.5 and 1.6 shall be noted including the reason for deviation and its justification. The OEHHA field lead shall immediately contact (by phone or text), discuss options with, and seek approval from the OEHHA project lead for the needs to deviate from the sample protocol before acting. The discussion and approval shall be summarized in the field sampling diary.

APPENDICES

Appendix A. Pre-Visit Environmental Survey

FIELD ENVIRONMENTAL SURVEY – PRE-VISIT

Field ID: ____________________

Sampling Date: ____________________

No. Samples Taken: ____________________

Sampling Time: Start: ____________ End: ____________

Weather Forecast for day of field sampling:

Precipitation: _____________

Temperature (High): _________________________________

Nearest Weather Station

(Weather Underground)*: ______________________

	At Start	At End
Air Temperature*:		
Relative Humidity*:		
Field Surface Temperature:		
Wind Speed and Direction*:		

Nearby and surrounding areas (within 1 miles):

- □ Freeway/Highway: __________________________________
- □ Industrial facilities: ____
- □ Athletic fields: ____
- □ Airport: ____
- □ Other potential sources of chemical emissions:

____

Traffic intensity: □ Light □ Moderate □ Heavy

Precipitation History (previous week):

Date	Precipitation

Pictures:

Picture #	Description

Other comments:

Name and Signature of Surveyor: ___________________________

Date: _______________

Google Maps image of synthetic turf field (1-mile radius)

Appendix B. Onsite Environmental Survey

FIELD ENVIRONMENTAL SURVEY – ONSITE

Field ID: ____________________

Sampling Date: ____________________

No. Samples Taken: ____________________

Sampling Time: Start: ____________ End: ____________

Meteorological Data Collected on the Field:

Precipitation: ________________________________

	At Start	At End
Air Temperature:		
Relative Humidity:		
Field Surface Temperature:		
Wind Speed and Direction:		

Nearby and surrounding areas (within 1 miles):

- ☐ Freeway/Highway: ____
- ☐ Industrial facilities: ____
- ☐ Athletic fields: ____
- ☐ Airport: ____
- ☐ Other potential sources of chemical emissions:

  ____

Traffic intensity: ☐ Light ☐ Moderate ☐ Heavy

Precipitation History (previous week):

Date	Precipitation

Pictures:

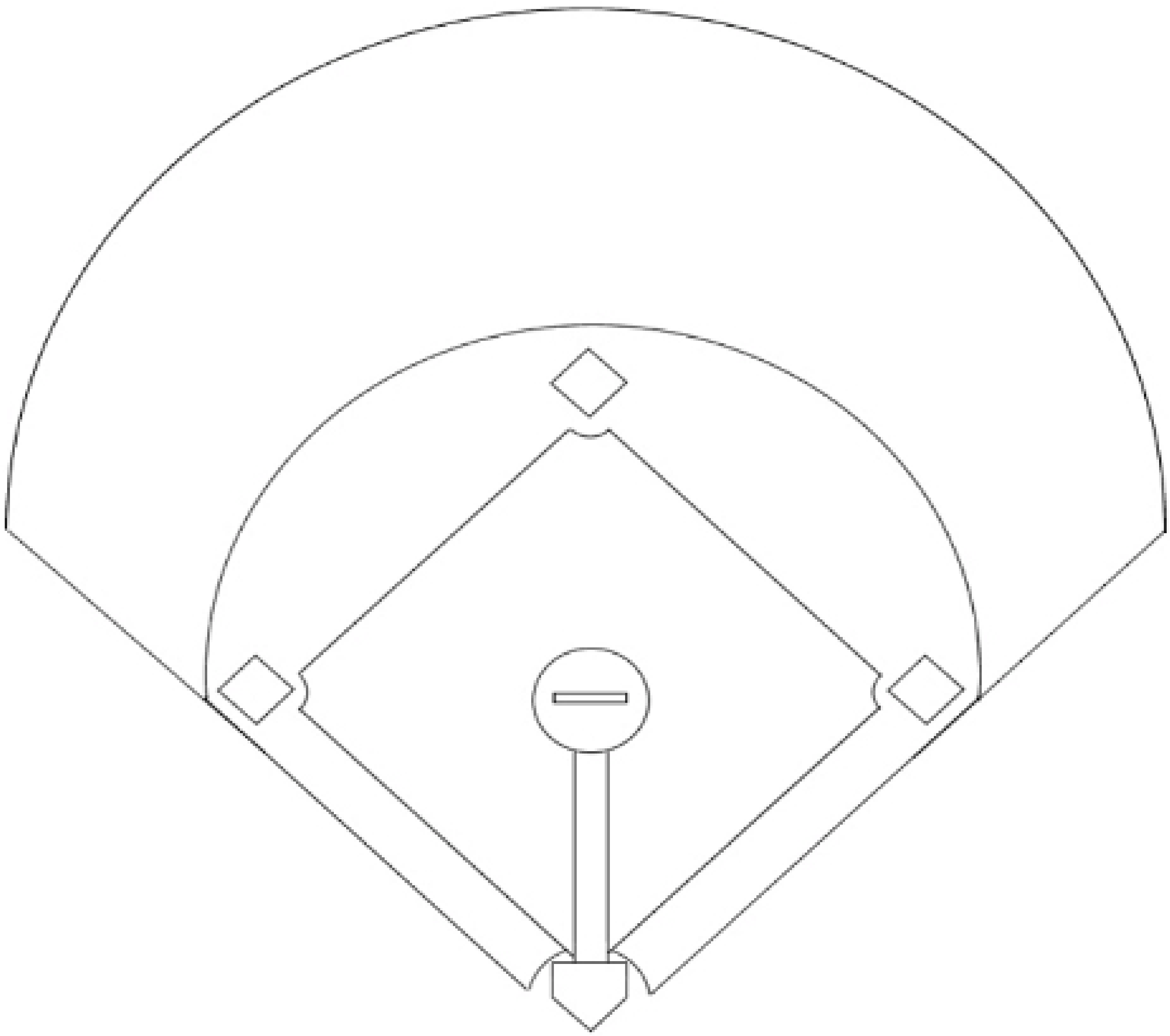
Picture #	Description

Other comments:

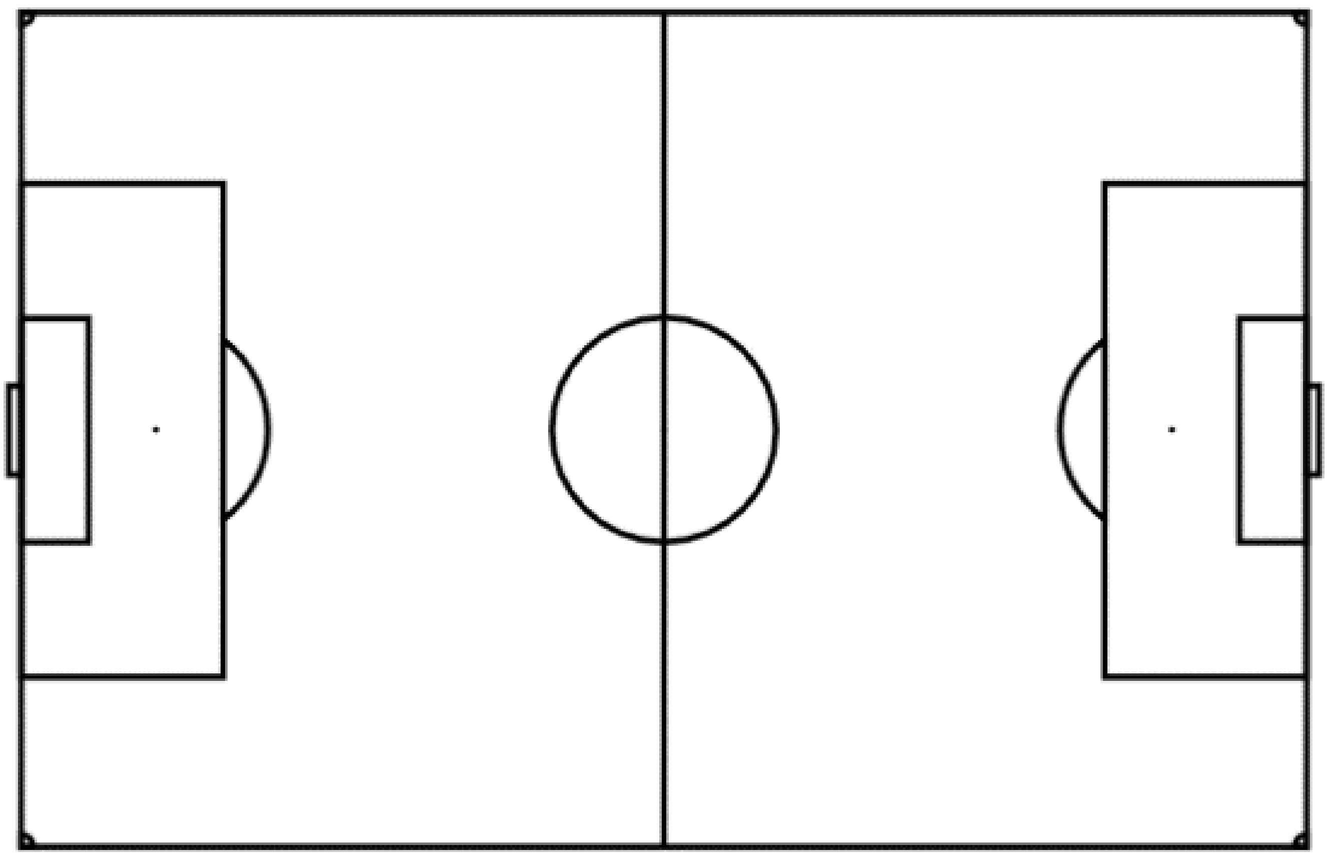
Name and Signature of Surveyor: ____

Date: ________________________________

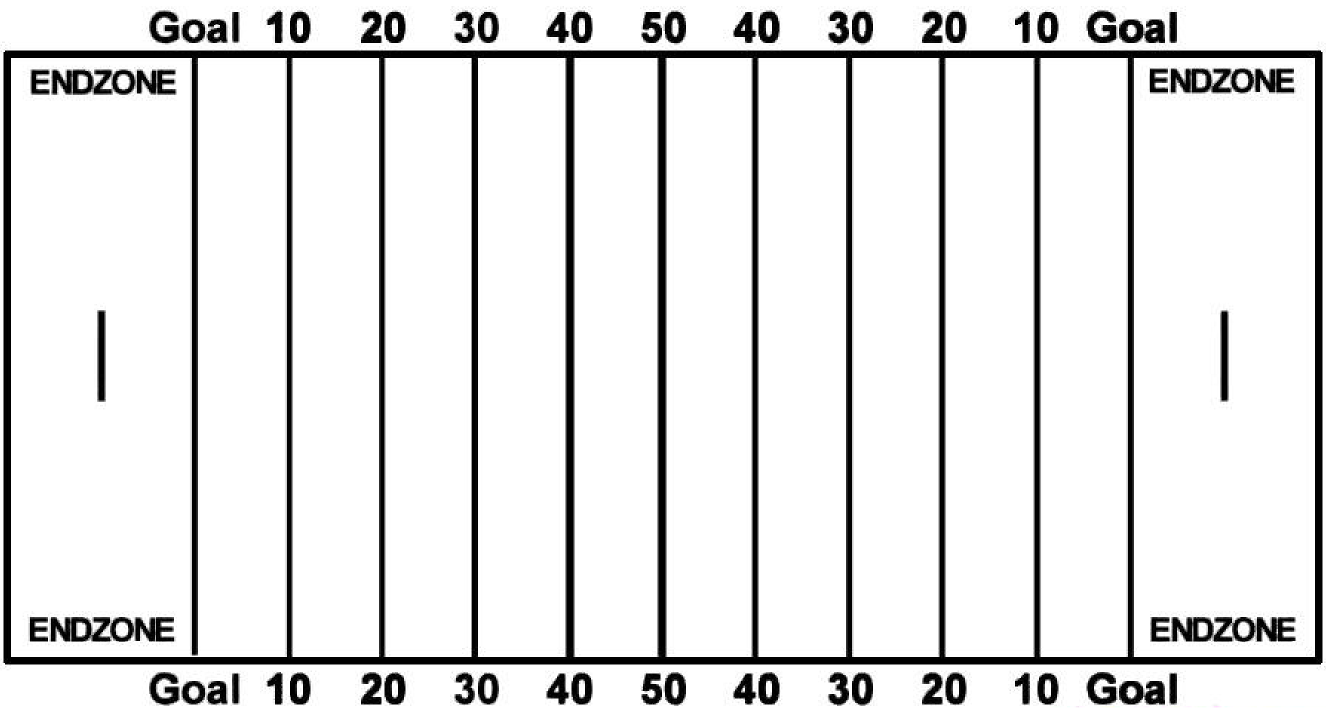
Field Diagram (Sketch field characteristics including trees, shaded areas, indicate synthetic turf, sand, gravel, grass, asphalt, concrete, etc.):



Field Diagram (Sketch field characteristics including trees, shaded areas, indicate synthetic turf, sand, gravel, grass, asphalt, concrete, etc.):



Field Diagram (Sketch field characteristics including trees, shaded areas, indicate synthetic turf, sand, gravel, grass, asphalt, concrete, etc.):



Appendix C. Post-Visit Environmental Survey

FIELD ENVIRONMENTAL SURVEY – POST-VISIT

Field ID: ____________________

Sampling Date: ____________________

No. Samples Taken: ____________________

Sampling Time: Start: ____________ End: ____________

Weather Record for the day of field sampling:

Precipitation: ________________________________

Temperature High: ________________________________

Nearest Weather Station

(Weather Underground): _________________________________

	At Start	At End
Air Temperature:		
Relative Humidity:		
Field Surface Temperature:		
Wind Speed and Direction:		

Nearby and surrounding areas (within 1 miles):

- ☐ Freeway/Highway: ____
- ☐ Industrial facilities: ____
- ☐ Athletic fields: ____
- ☐ Airport: ____
- ☐ Other potential sources of chemical emissions:

____

Traffic intensity: ☐ Light ☐ Moderate ☐ Heavy

Precipitation History (previous week):

Date	Precipitation

Pictures:

Picture #	Description

Other comments:

Name and Signature of Surveyor: ____

Date: ________________________________

Appendix D. On-site sampling map (Field Diagrams)

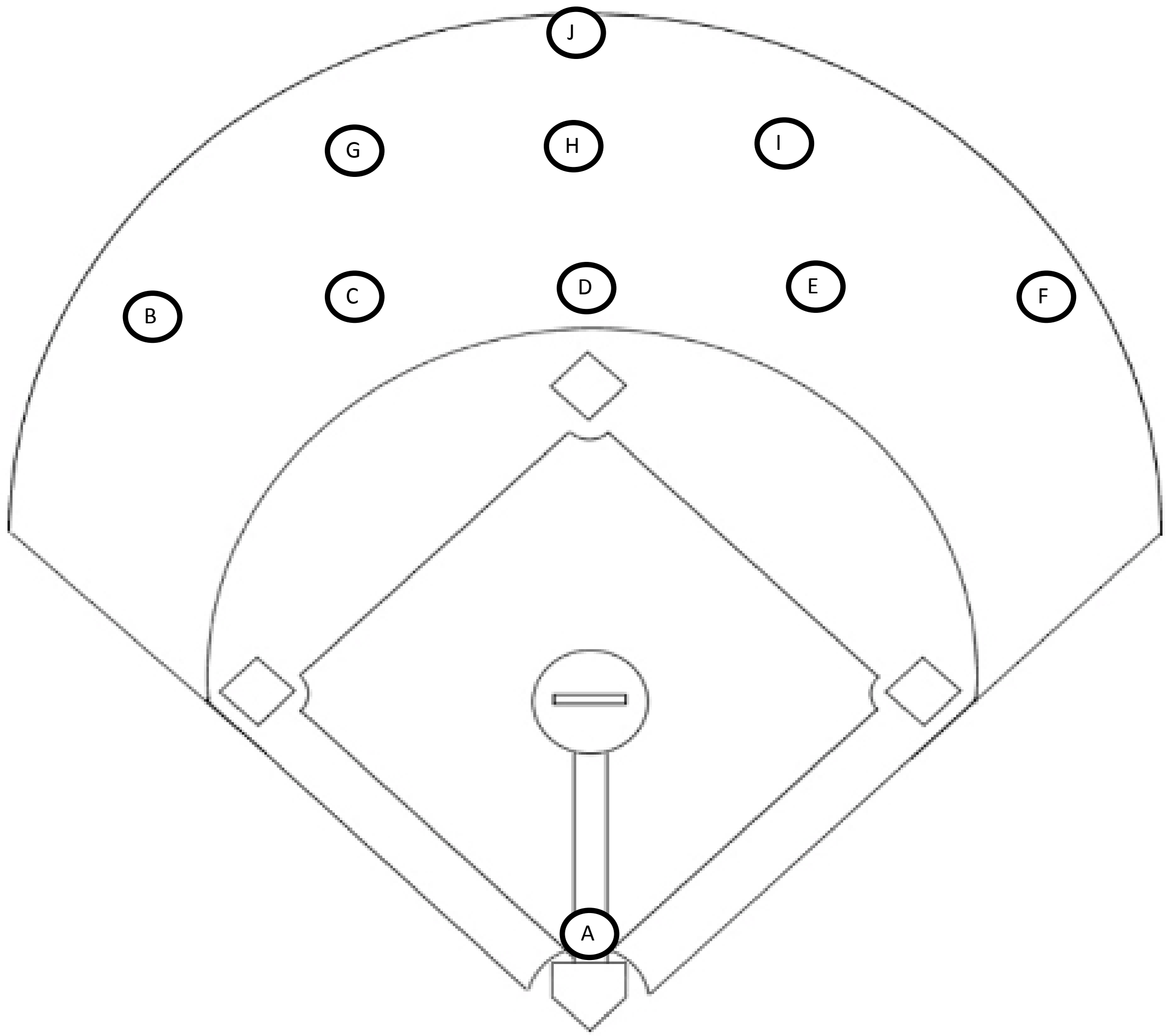


Figure D.1. An example of onsite sampling map to indicate the ten pre-selected sampling locations on a baseball field identified by the circles on the map.

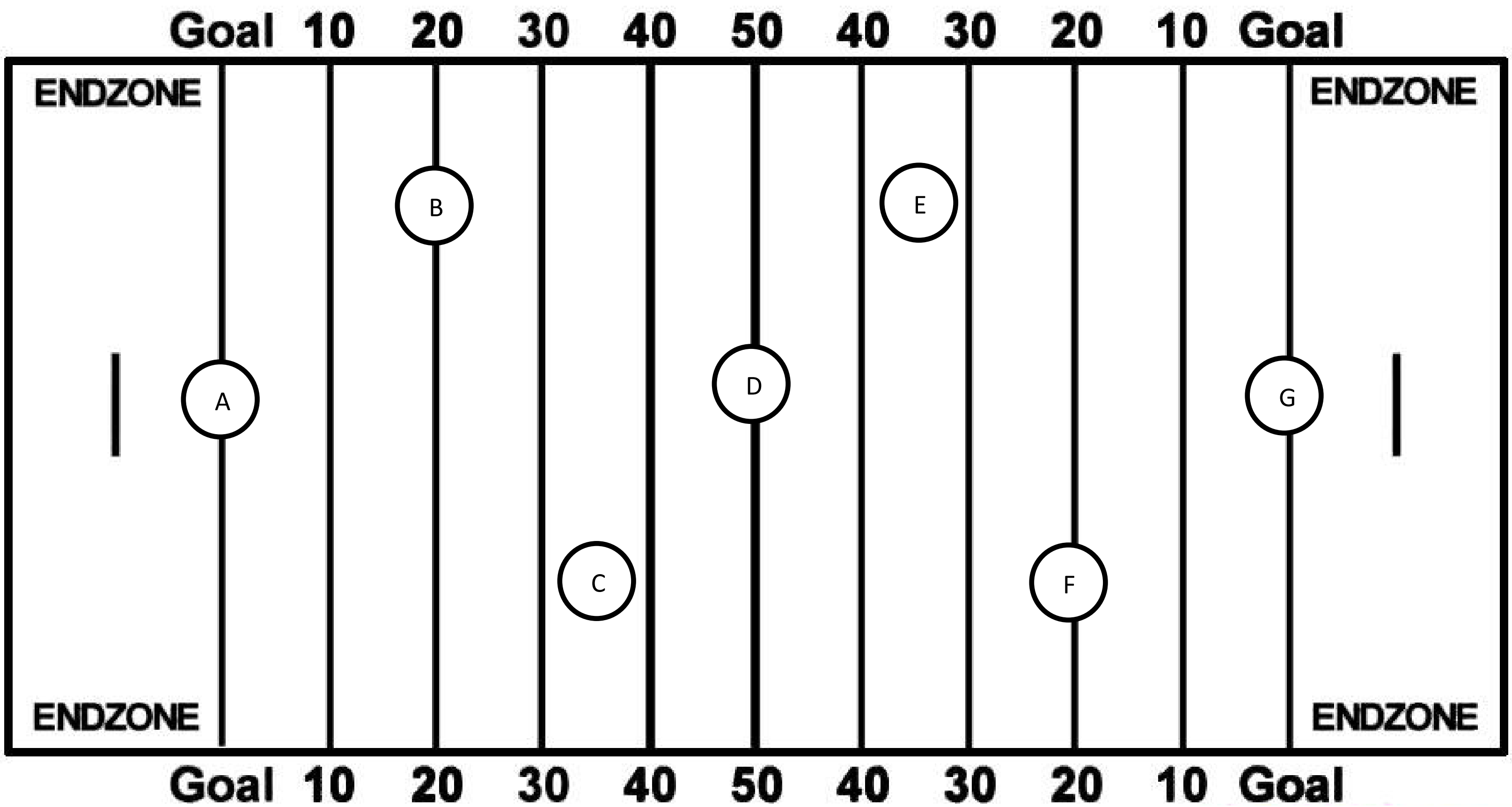


Figure D.2. An example of on-site sampling map to indicate the seven pre-selected sampling locations on a football field at identified by the circles on the map.

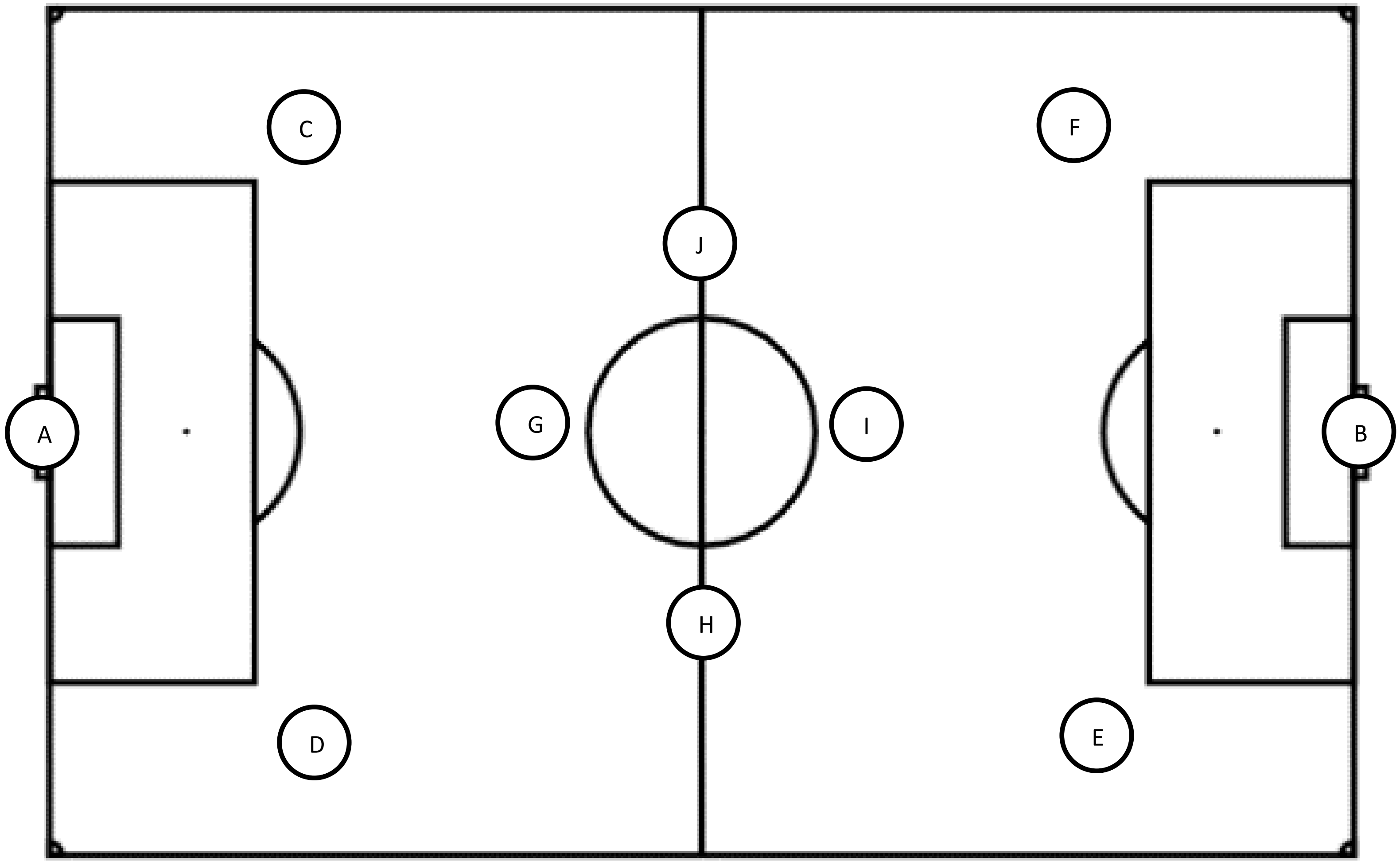


Figure D.3. An example of on-site sampling map to indicate the ten pre-selected sampling locations on a soccer field identified by the circles on the map.

Appendix E. Field Sampling Diary Template

Sampling Date: ____________________ Log Completed By: __________

Field ID: __________________

Field Name: ____________________________________

Filed Location: ____

Field Contact: ____

Collection Time: ________________________

Samples Collected (indicate # of samples, the amount, type, and sample IDs):

____

____

____

Sample Collector's Initials: ___________

Observations:

Comments:

Appendix F. Chain of Custody Form

Field ID: ……………

Recorder Signature:……………………….……………. Date: ………………………….…….

Sample ID	Collection Date	Collection Time	Collector Initials	Date Relinquished	Relinquished to	Receiver by and Initials*

Table B.1. Chain-of-Custody Record

***Please write your name and initial to maintain COC record**

Appendix D

A Handy Guide to

The Bagley-Keene Act 2004

(http://ag.ca.gov/publications/bagleykeene2004_ada.pdf)