California Environmental Protection Agency

Office of Environmental Health Hazard Assessment

Synthetic Turf Study

Synthetic Turf
Scientific Advisory Panel Meeting

May 25, 2018

MEETING MATERIALS

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Agenda

Synthetic Turf Scientific Advisory Panel Meeting

May 25, 2018, 9:30 a.m. – 4:00 p.m.
1001 I Street, CalEPA Headquarters Building, Sacramento
Sierra Hearing Room

The agenda for this meeting is given below. The order of items on the agenda is provided for general reference only. The order in which items are taken up by the Panel is subject to change.

1. Welcome and Opening Remarks
2. Synthetic Turf and Playground Studies Overview
3. Study Components

    3.1. Field Characterization Study of Synthetic Turf Fields
        3.1.1. Field Selection and Sample Collection
        3.1.3.* Weather and Surface/Subsurface Temperature
        3.1.2.* Particles in Air
        3.1.4. Preliminary Metal Data of Crumb Rubber
        3.1.5. Volatile Organic Compounds in Air
    3.2. Exposure Scenarios of Synthetic Turf Fields
        3.2.1. Pathways of Exposures
        3.2.2. Time-Activity Behavior Study
    3.3. Playground Characterization Study
        3.3.1. Draft Playground Sampling Protocols
        3.3.2. Preliminary Children Hand-To-Mouth Activity Data

4. Public Comments:
   For members of the public attending in-person: Comments will be limited to three 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 read aloud, up to three minutes each, by staff of OEHHA during the public comment period, as time allows.
5. Further Panel Discussion and Closing Remarks
6. Wrap Up and Adjournment

* Agenda items match with section numbers in the meeting materials.

Section 2
Synthetic Turf and Playground Studies Overview

SYNTHETIC TURF AND PLAYGROUND STUDIES OVERVIEW

MAY 2018 UPDATE

Background

The California Office of Environmental Health Hazard Assessment (OEHHA) is conducting a multi-year study of the potential health effects associated with use of synthetic turf fields that contain crumb rubber infill and playground mats that were made with crumb rubber. This work is being performed in collaboration with researchers at the Lawrence Berkeley National Laboratory, University of California (UC) at Berkeley and University of Arizona.

Crumb rubber is made from ground-up waste tires, which have a complex physical structure and chemical composition. The following are tasks of the synthetic turf study:

Task 1. Expert, public and interagency consultation and input
Task 2. Hazard Identification
Task 3. Exposure Scenario Development (*Section 3.2. Exposure Scenarios of Synthetic Turf Fields*)
Task 4. Characterization of chemicals that can be released from synthetic turf and playground mats and determination of human exposure potentials (*Section 3.1. Field Characterization Study of Synthetic Turf Fields* and *Section 3.3. Playground Characterization Study*)
Task 5. Biomonitoring and personal monitoring protocol development
Task 6. Reporting
Task 7. Health assessment from play on synthetic turf and playground mats

The project is scheduled to be completed in mid-2019. The sections below briefly describe the main project tasks and current status.

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 input to the study. Meetings were held February 8, 2016 and March 10, 2017, and a meeting is being convened in Sacramento on May 25, 2018.

OEHHA has consulted with several federal agencies as well as other academic research institutions in the United States and overseas. In response to a request from OEHHA, the National Toxicology Program is performing toxicology studies. OEHHA also met with the Rubber Manufacturers Association and the Carbon Black Association and with industry representatives.

These consultations were discussed at 2016 and 2017 SAP meetings.

Synthetic Turf Study

Task 2: Hazard Identification

Work related to this task includes conducting literature reviews to identify chemicals of potential concern and to characterize the toxicity of chemicals found in the study. In carrying out this task, OEHHA:

- Has conducted a thorough review on available tire-related research and studies to identify and compile a preliminary list of chemicals to guide the chemical analyses of field samples. The approach to chemical identification from field sample and monitoring samples was discussed in detail during the March 2017 Scientific Advisory Panel Meeting.
- Will update the chemical list based on additional chemicals identified during analysis of field samples—mass spectra matching with NIST database.
- Is performing a scientific literature review to gather the physicochemical properties, health effects and toxicity criteria of the chemicals of potential concern—information will be used in exposure and risk assessments of chemicals found in the study.

Task 3: Exposure Scenario Development

The goals of this task are to:

- identify and evaluate potential exposure pathways to synthetic turf chemicals and particulate matter. This involves evaluating the activities and behaviors of athletes, coaches, and bystanders while performing sport- or non-sport-related activities on synthetic turf fields and conducting a time-activity behavior study of California soccer players. At the May 2018 SAP meeting presentations on this work will be given by OEHHA and UC Berkeley. For background see subsections 3.2.1 (*Pathways of Exposures*) and 3.2.2 (*Time-Activity Behavior Study*) of the meeting materials.
- estimate values of exposure parameters:
    - based on measurements and data from the time-activity study: questionnaires, surveys, and video footage are providing information about the types, frequency and duration of activities that occur on and off the field, how often players play on synthetic turf fields (as opposed to natural turf fields), players' history in playing soccer, and micro-level activity information about players' interactions with the field itself, such as how often players slide or dive onto the field during practices and games
    - literature values: review research and studies on parameters and factors that are not measured in the time-activity study, e.g., breathing rates during different levels of exertion

- develop exposure scenarios: aggregate exposure data to develop synthetic turf specific scenarios for typical uses of synthetic turf fields

Data collected in the exposure study will contribute to characterization of exposures and the calculation of oral, dermal, and inhalation doses for exposure and risk assessment.

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

To achieve the ultimate goal of understanding the chemical and physical characteristics of exposures on synthetic turf fields, multiple activities have taken place or are in progress. These include:

- Sampling of pre-installed crumb rubber from manufacturers for developing analytical protocols for chemical analysis and bioavailability evaluation. This work was described at the previous SAP meetings.
- Protocol development for sample analysis and bioavailability assessment. This work was described and received SAP input at the previous SAP meetings.
- Random selection and entering into agreements for sampling 35 fields of various ages from four climate regions across California. This work has been completed and will be discussed at the May 2018 SAP meeting. For background see subsection 3.1.1 (*Field Characterization Study of Synthetic Turf Fields: Field Selection and Sample Collection*) of the meeting materials.
- Collection of crumb rubber and airborne particle samples - for analysis and characterization of the chemicals present and their bioaccessibility for uptake into a human body following exposure. Sample collection is complete and will be discussed at the May 2018 SAP meeting. For background see subsections 3.1.1 (*Field Characterization Study of Synthetic Turf Fields: Field Selection and Sample Collection*) and 3.1.2 (*Particles in Air*) of the meeting materials.
- Conducting analyses of classes of chemicals including volatile organic compounds (VOCs), aldehydes and ketones, semi-volatile organic compounds (sVOCs), polycyclic aromatic hydrocarbons (PAHs), non-volatile organics, and metals. This work is ongoing. Preliminary results of metals and VOCs will be discussed at the May 2018 SAP meeting. For background see subsections 3.1.4 (*Preliminary Metal Data in Crumb Rubber*) and 3.1.5 (*Volatile Organic Compounds in Air*) of the meeting materials.
- Collection and characterization of samples and data related to physical stressors and field conditions: Number count and mass concentration of fine particulate matter and particles of various sizes in the ambient air, sun exposure (insolation), temperature on and just below field surface, wind speed and direction, relative humidity, and ozone levels in the ambient air. Sample and data collection has been completed and will be discussed at the May 2018 SAP meeting. For

background see subsections 3.1.2 (*Particles in* Air) and 3.1.3 (*Weather and Surface/Subsurface* Temperature) of the meeting materials.

The chemical concentration data resulting from the sample analyses are key inputs for the characterization of inhalation, dermal and oral exposures for the risk assessment. The physical stressor data will also be discussed in the risk assessment.

Task 5: Biomonitoring and Personal Monitoring Protocol Development

The objective of this task is to develop a study plan for Institutional Review Board approval. OEHHA has contracted with UC Berkeley to develop these protocols, which are considering the following information:

- physicochemical data, pharmacokinetics (absorption, distribution, metabolism, and elimination) and toxicity of the chemicals of potential concern provided by the Hazard Identification (Task 2)
- exposure data in Task 3 and chemical data in Task 4

Task 7: Human Health Risk Assessment

The results from Tasks 2-4 will be integrated to assess the potential human health risks associated with the use of synthetic turf fields. This will include:

- The hazard identification and toxicity characterizations (Task 2) of chemicals released from synthetic fields (Task 4).
- The air concentrations of chemicals and particulate matter resulting from the sampling of synthetic turf fields (Task 4)
- Data on chemical and physical stressors (Task 4)
- The results of the bioaccessibility studies of chemicals in crumb rubber samples (Task 4)
- The exposure parameters resulting from the characterization of activities and behaviors of players, by-standers and coaches using synthetic turf fields (Task 3)

Playground Study

OEHHA is conducting a risk assessment of children playing on outdoor playground mats made of crumb rubber. This will rely on samples collected on surfaces of and in the environment at outdoor playgrounds. These samples will be used to characterize the chemicals that may be released from playground mats. Lawrence Berkeley National Laboratory (LBNL) will perform the following activities:

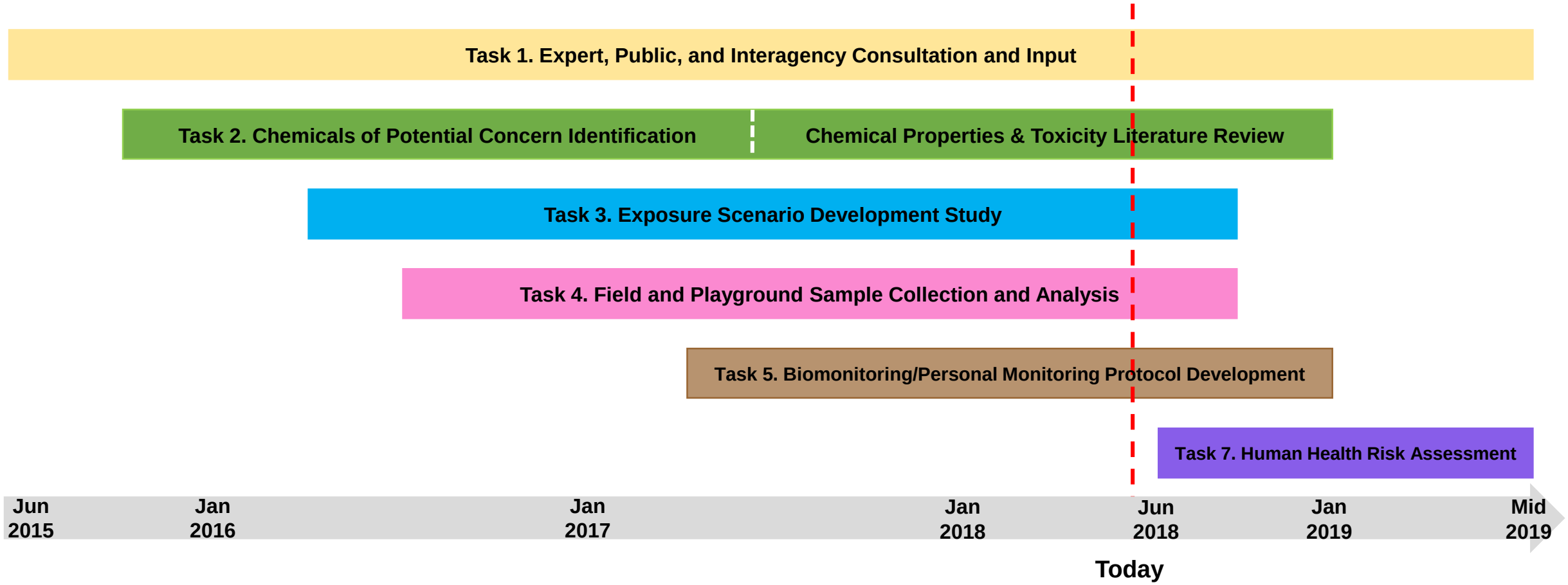
- draft sampling protocols for the study
- collect and analyze surface samples from and conduct environmental measurements on a few playgrounds at selected locations in California

UC Berkeley and University of Arizona are collaborating to:

- collect micro-level activity data from archived studies on young children playing on turf and playgrounds in California
- characterize exposure parameters based on activity patterns of children playing in the outdoor environment.

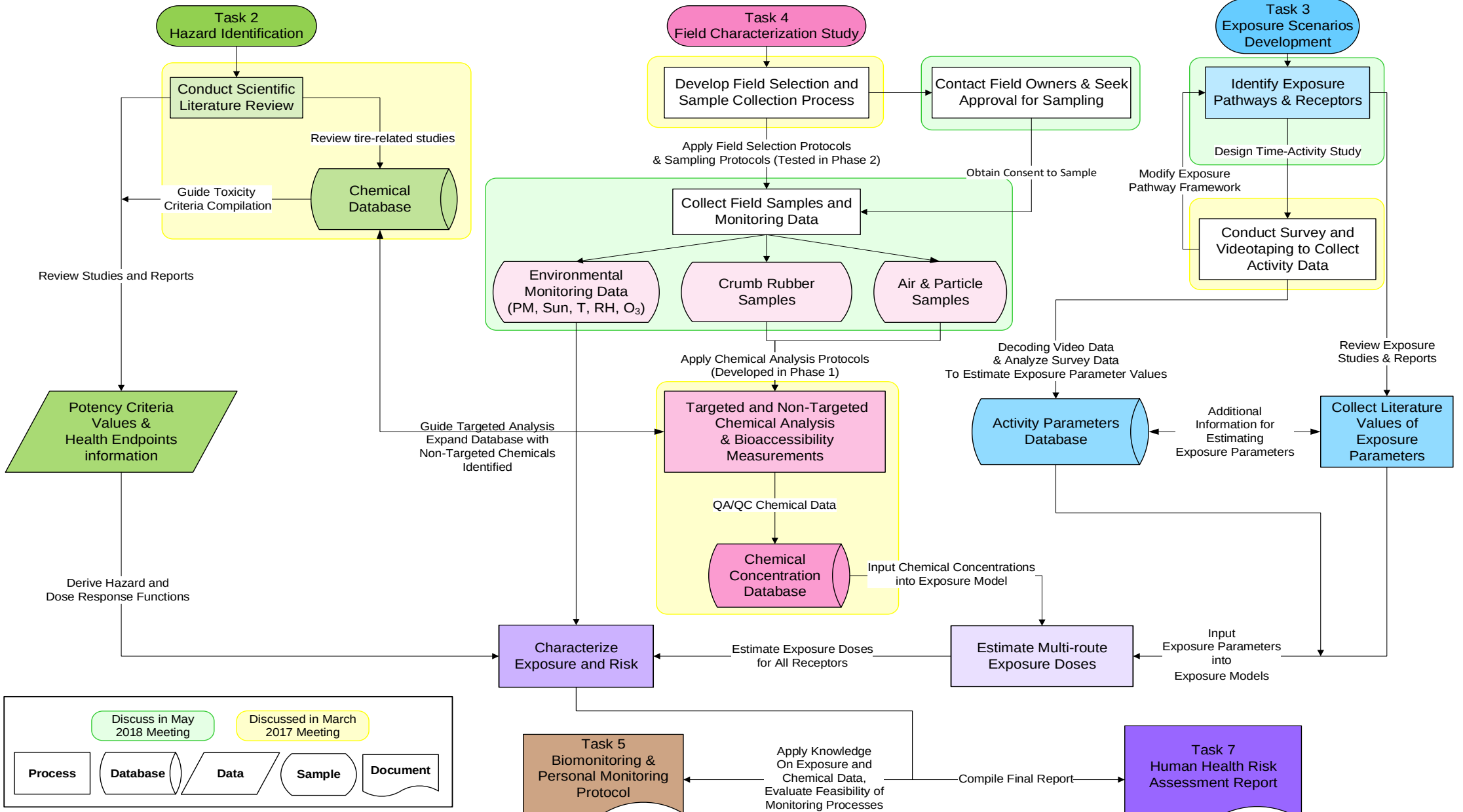
In addition, micro-level activity data collected by the University of Arizona will be used to model exposures of young children. These results will be used to assess the multi-route exposure by young children who play on the playground mats. Draft sampling protocols and preliminary micro-level activities data will be discussed at the May 25, 2018 SAP meeting. For background see *Section 3.3. (Playground Characterization Study*) of the meeting materials.

Synthetic Turf Study Overview



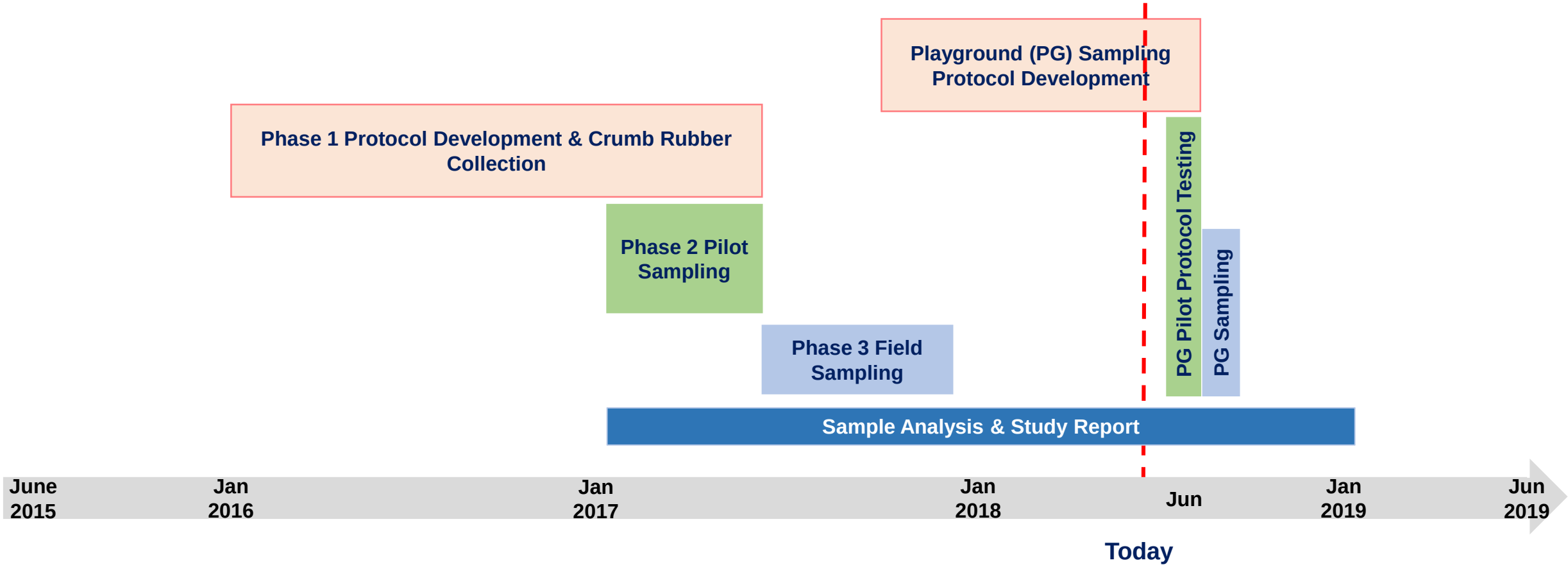
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

Synthetic Turf Study Roadmap



Section 3.1
Field Characterization Study of Synthetic Turf Fields

Task 4.
Field & Playground Sample Collection & Analysis Timeline



Section 3.1.1
Field Selection and Sample Collection

This section describes the results of the field selection in the *Field Selection and Sample Collection* document. Appendices A-D are attached to provide background information. Attachment 1 illustrates the appearance of the field surface and crumb rubber.

FIELD CHARACTERIZATION STUDY OF SYNTHETIC TURF FIELDS:

FIELD SELECTION AND SAMPLE COLLECTION

1. Background

In California, there are over 900 public or private synthetic turf sport fields with crumb rubber infill[1]. These fields are of various ages (0 to 19 years old) and are located throughout California, where they are subjected to diverse environmental conditions (e.g., smog, heat, rain). Recently, concerns of health hazards to the players using these synthetic turf fields have been raised by both academics and the public.

In 2017, the Office of Environmental Health Hazard Assessment (OEHHA) collected crumb rubber and environmental samples from 35 outdoor synthetic turf fields across California. OEHHA contracted with the Lawrence Berkeley National Laboratory (LBNL) to provide technical assistance in this effort. The work involved developing field study protocols, monitoring and sampling field conditions and the environment (air) under conditions of simulated play, and collecting crumb rubber samples. We are now in the process of characterizing the chemicals that may be released from these fields. LBNL is conducting chemical analyses of the samples taken, and is engaged in quality control and assurance of the field data. Results of the field characterization study will include the identification of chemicals released from the fields and measurements of the concentrations of these chemicals in air and simulated biological fluids. These will be used to assess the chemical exposures of players and other users of the synthetic turf fields through multiple pathways. This document describes the methods used to select fields for sampling and the selection and recruitment of fields for sampling and environmental monitoring. Other presentations describe the samples taken and some of the environmental monitoring results. A separate document on Exposure Assessment describes how player activity information will be used to translate the measured chemical concentrations into exposure estimates.

[1] OEHHA's synthetic turf field database (last updated March 2017) was compiled with data collected by CalRecycle. The database does not include sports fields on federal facilities, fields not reported to CalRecycle by installers, or fields that did not receive funding from CalRecycle.

2. Field Study – Phases 1 and 2

Collection of field samples and measurement of environmental conditions of the fields were carried out in three phases. The first two phases – sampling to support laboratory method development and pilot testing field sampling protocols – are necessary preliminary steps to the third phase - the statewide field sample collection.

2.1. *Phase 1 – Sampling to Support Development of Analytical Method*

Pre-installation crumb rubber samples were collected from tire recyclers that manufacture crumb rubber and in-field crumb rubber samples were collected from synthetic turf fields across California. OEHHA collected samples from crumb rubber facilities located in California. Additionally, we sampled in-field crumb rubber of different ages from four fields aged 3-7 years and two fields aged 10-13 years, half of the fields were in Northern California and half were in Southern California. These samples are being used for analytical method development and the identification of chemicals of potential concern (COPCs) for risk assessment purposes.

2.2. *Phase 2 - Pilot Testing of Field Sampling Protocols*

Following the development of the preliminary field study protocols for monitoring of field conditions and collection of crumb rubber and environmental samples, pilot field studies were conducted on two synthetic turf fields in Northern California to test these protocols. Crumb rubber and environmental samples were collected for chemical analyses, and field conditions were monitored from the two fields. Information gathered was applied to fine-tune the sampling procedures and develop the final field sampling protocols for the use in Phase 3 – the main field data collection study. Appendix A describes OEHHA/LBNL's final sampling plan—to collect and store crumb rubber samples, collect environmental samples, and monitor field conditions for use in Phase 3.

3. Phase 3 – Data Collection from Fields Statewide

3.1. *Study Goals*

The purposes of the Phase 3 Study are to collect samples (crumb rubber and environmental matrices) from outdoor synthetic turf fields across California and monitor the field conditions during the sampling event. These samples are being used to characterize and quantify the chemicals that may be released from crumb rubber or present in the environmental matrices.

3.2. *Stratified Random Sampling Method*

OEHHA categorized fields with certain characteristics into subgroups, and randomly sampled fields in each subgroup. This stratified random sampling approach has the advantage over a simple random sampling in that data are collected from each subgroup and represent the field conditions across California.

One of the primary goals of the field sampling is to collect samples for analysis to identify the chemicals and their concentrations in various environmental media (e.g., ambient air, airborne particles, and crumb rubber) that players and users can be exposed to during the use of synthetic turf fields. There are several factors (e.g., climate, age of a field, ambient ozone level) that may impact the integrity of crumb rubber in synthetic turf fields, which in turn may affect the nature and amounts of chemicals available for human exposure. After considering the impacts of these factors and discussing options with the Scientific Advisory Panel (SAP) at the March 10, 2017 meeting, OEHHA determined that climate and age of the field are potentially the two most important factors. Ozone, a factor initially considered for stratification, was instead addressed through monitoring the on-field and nearby off-field background ozone levels in each location sampled. Accordingly, we categorized the 905 California synthetic turf fields in the OEHHA database by climate zone and age of field and divided them into 10 subgroups in order to facilitate the field-selection process.

3.3. *Stratification Factors*

Climate. Weathering of crumb rubber can impact the release of chemicals from the synthetic turf fields. The local climate (e.g., rainfall, temperature range, and solar insolation) at the fields governs the weathering or aging of crumb rubber. California has the most diverse climate among all the states in the US (CEC, 1995). The California Energy Commission (CEC) divides California into 16 distinct climate zones based on the mean temperatures in summer and winter (CEC, 1995 & 2015). 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.

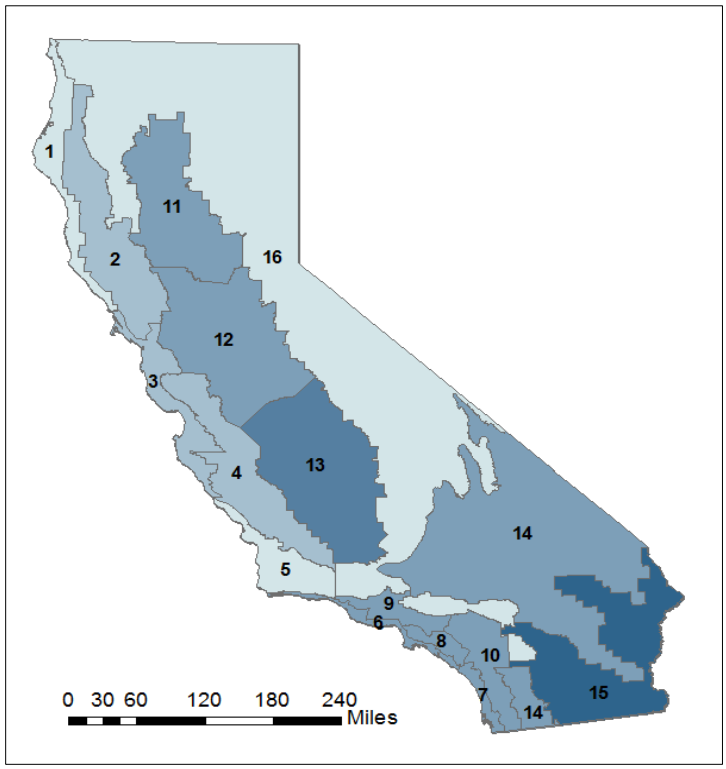


Figure 1. A California map showing the 16 California Energy Commission Designated Climate Zones (CEC, 2015)

Table 1. Counties in each Climate Zone (CEC, 2015)

Climate Zone	Counties Covered by Climate Zone*
1	Del Norte, Humboldt, Mendocino
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

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

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 2011-15, 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 2011-15 during the warm seasons (May to October), the mean average temperature ranged from 57 to 67°F and the mean maximum temperature ranged 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 2011-15, 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 2011-15, 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 and mountainous areas. Climate in the region is mild in summers but cold and snowy in winters. The mean average temperature was 69°F and mean maximum temperature was 85°F in the warm seasons in 2011-15.

Figure 2 displays the five climate regions on a map and also indicates the locations of synthetic turf fields on the map. As can be seen from this figure, field distribution is not equal among the regions. There are more fields in or near metropolitan areas (e.g., San Francisco Bay Area, Greater Los Angeles Area, and San Diego). Table 2 lists the number of synthetic turf fields in each of the regions.

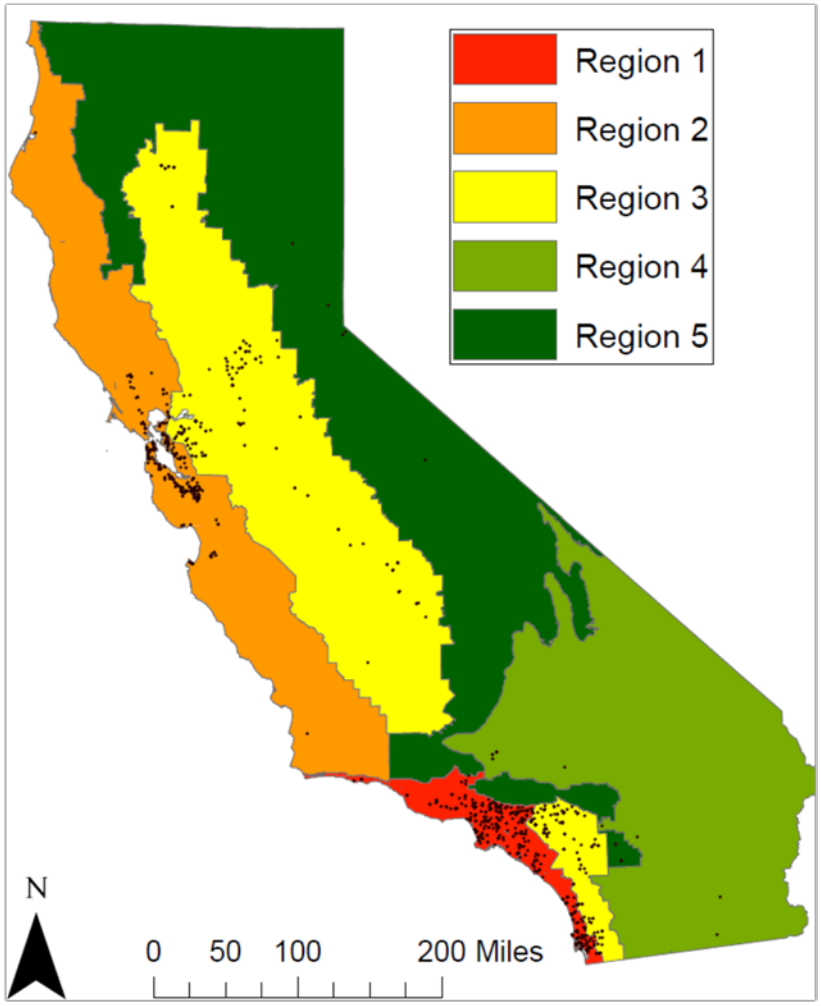


Figure 2. A California Map Illustrating the Five Climate Regions and the Location of Synthetic Turf Fields

Table 2. The Climate Regions in California and Distribution of Fields in Each Region

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

Age of Field. Aging of the synthetic turf fields is another important factor that can affect the nature and release of chemicals and fine particles into the environment. Figure 3 shows the age distribution of fields in California and Figure 4 shows the age distribution of fields in each region.

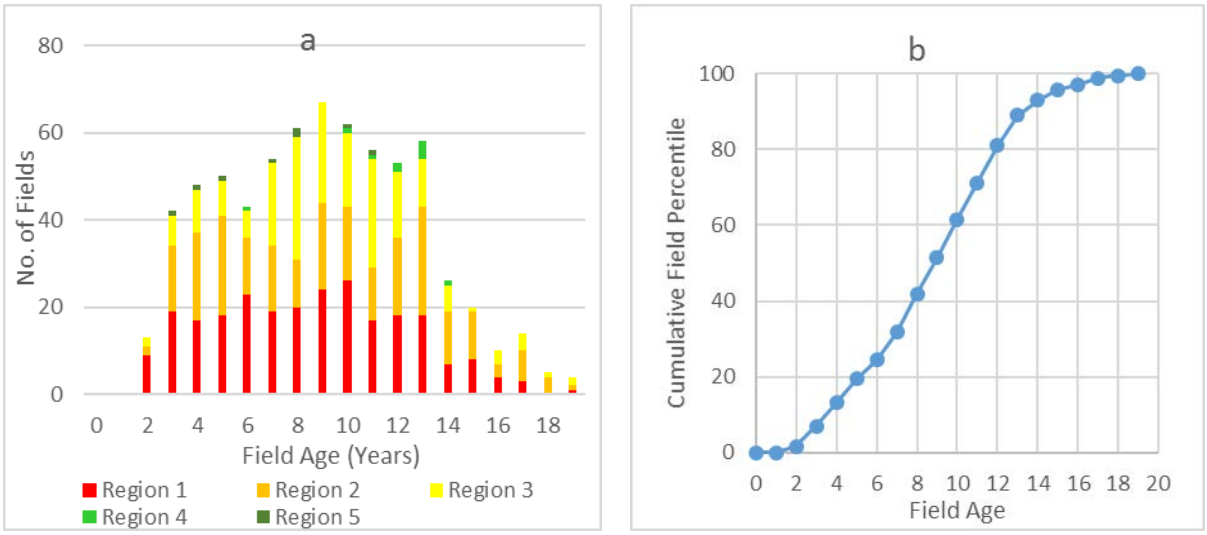


Figure 3. (a) Age Distribution of Fields in California; (b) Cumulative Distribution of Field Age in California

In California, 52 percent of the fields are at or below nine years of age (Figure 3b). For field selection purposes, we divided fields in each climate region into two age groups: 0 to <9 years old (new fields) and ≥9 years old (old fields) (Table 3). We chose nine years as the cut-off age based on information from some field owners that warranties for synthetic turf fields usually expire eight years after the field is installed.

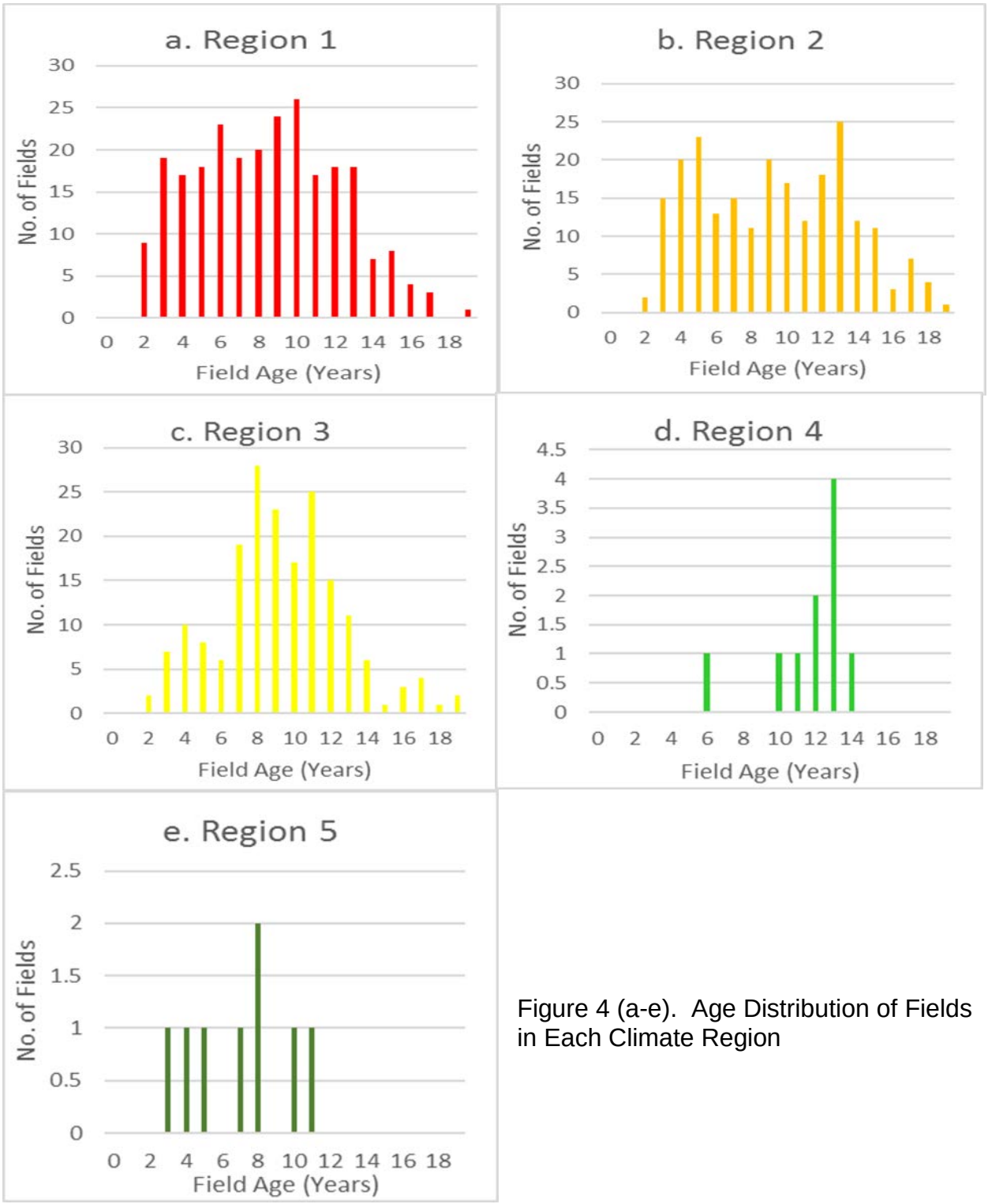


Figure 4 (a-e). Age Distribution of Fields in Each Climate Region

3.4. *Field Selection Process*

Applying the stratified random sampling approach, OEHHA divided the 905 fields into 10 subgroups: 5 climate regions × 2 field age groups per region. Table 3 shows the number of fields in each climate region and the two field age subgroups. The Climate Regions 1 to 3, which contain the major metropolitan areas in the state, have greater number of fields compared to the Climate Region 4 to 5 (Figure 4). The Climate Regions 4 and 5 respectively cover desert and mountainous areas of the state. There are only a few fields in these two climate regions, especially when the climate regions are subdivided into two field age groups. OEHHA, therefore, combined the Climate Regions 4 and 5 in the field selection process and aimed to randomly select two to three fields per field age group in the combined Climate Region 4/5. OEHHA aimed to randomly select five fields from each subcategory of climate region and field age group. Under this approach, a total of 35 fields would be sampled in the Phase 3 Study.

OEHHA followed these steps to select fields:

1. Randomly ordered fields in each subcategory
2. Developed a phone script (Appendix B) and a consent form for sampling fields (Appendix C)
3. Searched the internet to collect field owners' contact information
4. Contacted owners of the field following the order determined in (1) and used the developed phone script until a pre-determined number of fields were selected in each subcategory
5. Interviewed each selected field owner and completed a field questionnaire (Appendix D) and consent form
6. Conducted a field visit to ensure that the field met the study criteria
7. Updated field information in the database, if needed
8. Followed the finalized field sampling protocols to sample the fields and document the procedures and findings (Appendix A)

Table 3 below summarizes the field distribution and the targeted sample size in each subgroup.

Table 3. Stratification of Fields into Climate Region and Field Age Subgroup and Number of Fields Sampled in Each Stratified Category*

Climate Region	Field Age (Years)	No. of Fields	Targeted Sample Size	No. of Fields Sampled
Region 1	**New (0 to <9)**	125	5	8
	Old (≥9)	127	5	3
	Unknown**	124	0	0
	cork/rubber mix	Unknown	0	2***
	Total	376	10 (2.7%)	13 (3.5%)
Region 2	**New (0 to <9)**	99	5	4
	Old (≥9)	130	5	5
	Unknown	43	0	0
	Total	272	10 (3.7%)	9 (3.3%)
Region 3	**New (0 to <9)**	80	5	5
	Old (≥9)	108	5	6
	Unknown	45	0	0
	Total	233	10 (4.3%)	11 (4.7%)
Region 4/5	**New (0 to <9)**	7	5	2 (1 new + 1 old)
	Old (≥9)	11		
	Unknown	6		
	Total	24	5 (21%)	2 (8.3%)

* Values in parenthesis are percentage of fields sampled to the total number of fields in a climate region.
** Fields of unknown age were not targeted for sampling, and were not sampled.
*** These fields were originally listed as old crumb rubber fields in our database; they were replaced recently with fields containing cork and crumb rubber mixed infill.

3.5. *Field Selection Results*

Number and Distribution of Fields Sampled. In addition to the targeted number of fields, Table 3 shows the actual number of fields sampled in each subgroup. Overall, OEHHA sampled 35 fields in the Phase 3 Study, 33 crumb rubber infilled fields and two new synthetic turf fields containing crumb rubber/cork mixed infill (Table 3 and Figure 5). Ultimately, 3.9% of the California fields in our database were covered (35 out of 905 fields). The overall final sampling percentages of fields in Climate Regions 1 to 3 ranged from 3.3 to 4.7%. Unfortunately, after contacting all the field owners in the combined Climate Region 4/5, OEHHA was only able to sample two fields. However, because there were so few fields, proportionately more fields were sampled in the combined Region 4/5 (8%) than in the other regions.

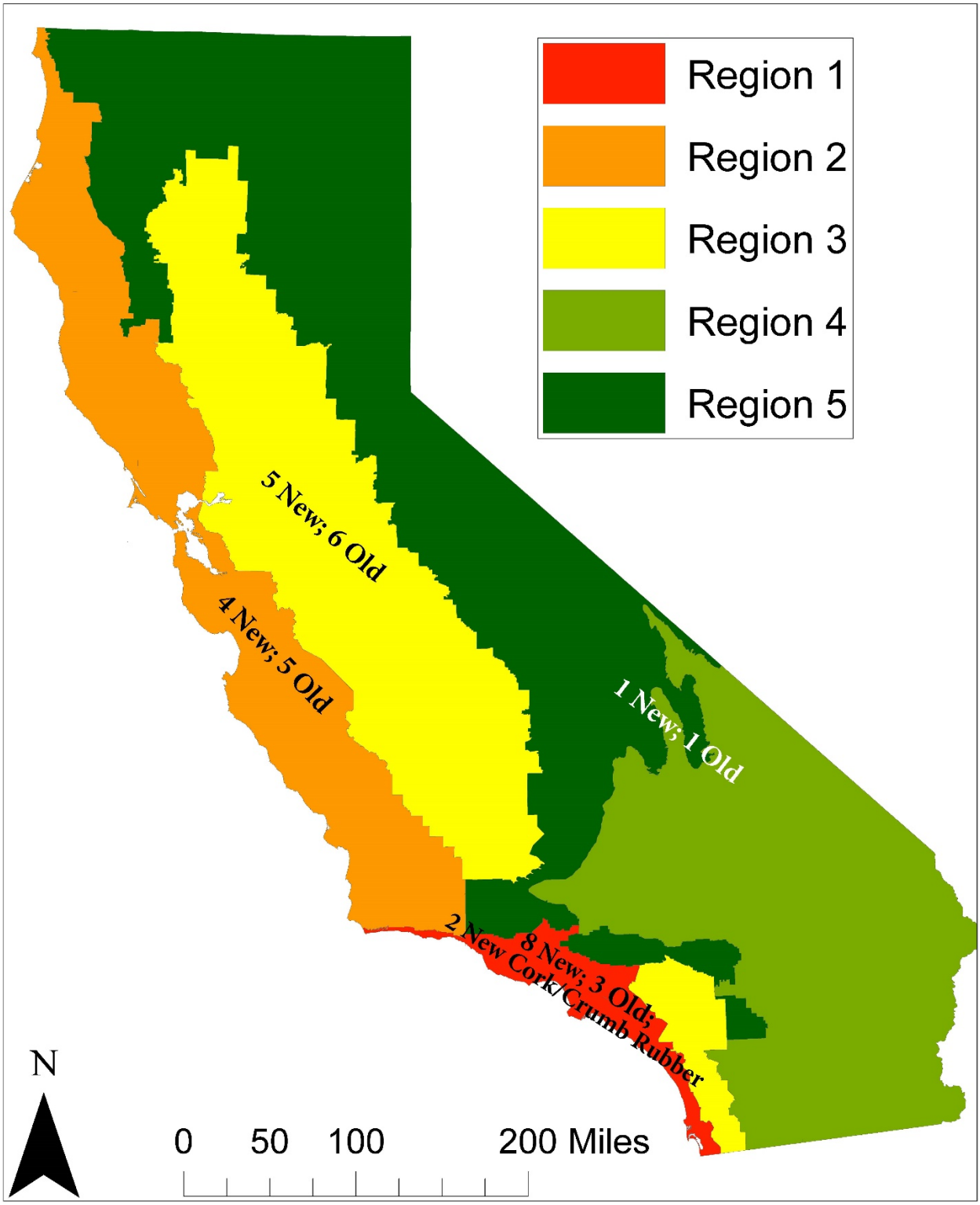


Figure 5. Numbers of Crumb Rubber Fields Sampled in Each Climate Region and Field Age Group

Age Distribution of the Fields Sampled. Figure 6 shows the cumulative age distribution of the crumb rubber fields sampled in the Phase 3 Study versus the distribution of fields in our database. The age distribution of fields sampled in the Phase 3 Study follows a very similar pattern to the cumulative age distribution of all the synthetic turf fields in California.

Among the fields sampled, the age distribution in the New Fields group (0 to <9 year old fields) is spread out. No fields less than one year old were sampled. However, in the Old Fields group, most of the fields sampled were between 9 and 11 years old. Based on interviews with field owners, planning to replace a field generally starts when the field is approximately 10 years old. It can take a few years to complete the planning process and secure the funding before the field is installed, which typically occurs by the time the field is 14 years old. This may be one of the reasons why there are relatively few fields 14 years and older (Figure 3) in California, and subsequently in the Old Fields group that we sampled (Figure 7).

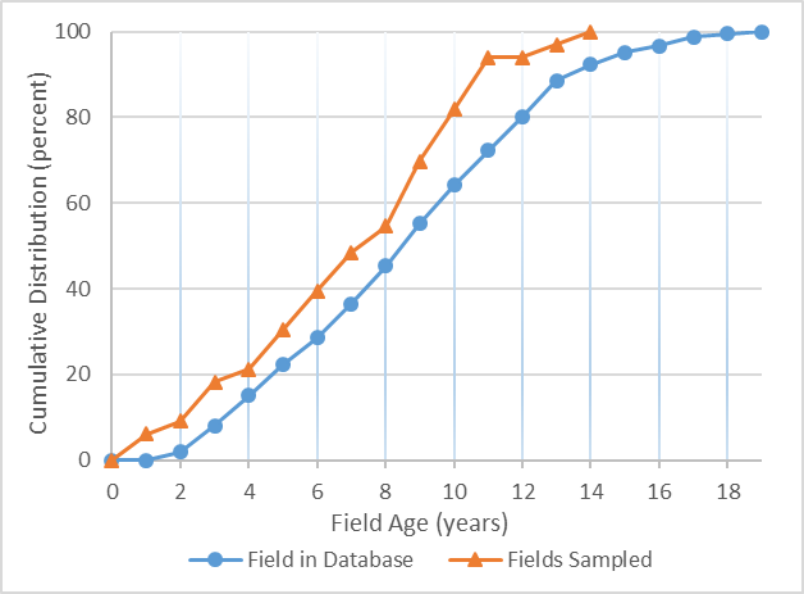


Figure 6. Cumulative Field Age Distributions of Crumb Rubber Fields in the California Database and Fields Sampled in the Phase 3 Study

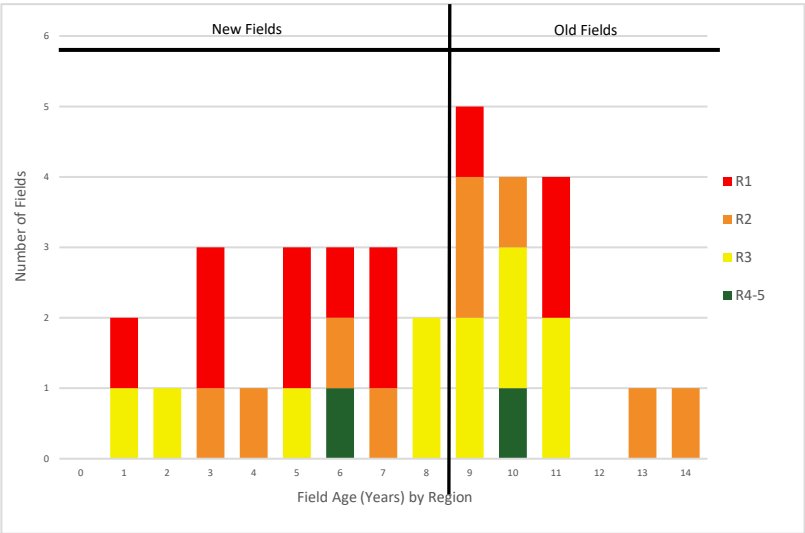


Figure 7. A Stacked Bar Graph Showing the Overall Age Distribution of Crumb Rubber Fields Sampled in Phase 3 Study

4. Deviations from the Original Study Plans

4.1. *Field Selection*

OEHHA contacted hundreds of field owners and experienced a low rate of approvals for sampling fields. As a result, in the Phase 1 Study, which was focused on developing analytical methods, OEHHA had planned on sampling four older fields but was only able to recruit two - one field in Northern and one in Southern California. OEHHA was able to meet its target in recruiting new fields in the Phase 1 study, two in Northern and two in Southern California.

In the Phase 3 Study, for the Combined Climate Region 4/5, all field owners were contacted. However, we were only able to recruit two fields, out of the targeted five fields. Nonetheless, as noted above, this region had the largest proportion of its fields sampled (8.3%), compared to the other three regions. We sampled two additional fields in the Climate Regions 1 and 3 in areas with hot and dry microclimates: a new field in the Climate Region 1 and an old field in the Climate Region 3.

4.2. *Discrepancies in Field Data*

OEHHA collected questionnaires from the participating field owners. We noticed some discrepancies between the owner-reported field age and the field age data in our database, especially for fields in the Climate Region 1. Some fields originally designated as old fields had been replaced and, therefore, these fields were re-categorized as new fields in our database. On the other hand, we found some fields to be older than they were listed in the database. This might be due to the lengthy field installation planning processes or long delays in field installation. Upon re-confirming the age of these fields with the owners, OEHHA updated the field ages in the database and re-categorized some of these fields.

Due to the field age re-categorization, two of the old fields sampled in the Climate Region 1 were later re-categorized as new fields. This changed the final number of old fields sampled to three from the original targeted five fields in this climate region.

4.3. *Cork and Crumb Rubber Mix Fields*

During the field recruitment, OEHHA learned that some old fields have been replaced with synthetic turf containing cork and crumb rubber mix infill. According to the field owners, the new infill mixture was developed to address concerns of heat exposure on the synthetic turf fields containing crumb rubber infill. OEHHA was able to identify and sample two cork and crumb rubber mix infill synthetic turf fields in the Climate Region 1 (Figure 5 and Table 3).

5. Conclusion

Overall, OEHHA achieved its goal of sampling fields across California. In the Phase 3 Study, we have completed collecting multimedia samples from 35 fields that are of various ages, located in different areas of the state and subject to a range of climatic conditions. Among them are 18 new fields, 15 old fields, and 2 new cork/crumb rubber mix fields. We experienced challenges in seeking approval from field owners for sampling. We also discovered some field age discrepancies in our field database. Together, these led to minor deviations from our field sampling plan. Ultimately, the fields that were sampled represented the range of synthetic turf fields in use throughout California.

In addition to crumb rubber sampling from fields, we have also collected environmental monitoring data on the fields and at selected off-field locations. The environmental data are presented in a separate document for this meeting and will be discussed in detail during the meeting.

6. References

CEC (1995) California Climate Zone Descriptions for New Buildings. California Energy Commission (http://www.energy.ca.gov/1995publications/P400-95-041.pdf)

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)

Attachment 1. Appearance of the Field Surface and Crumb Rubber

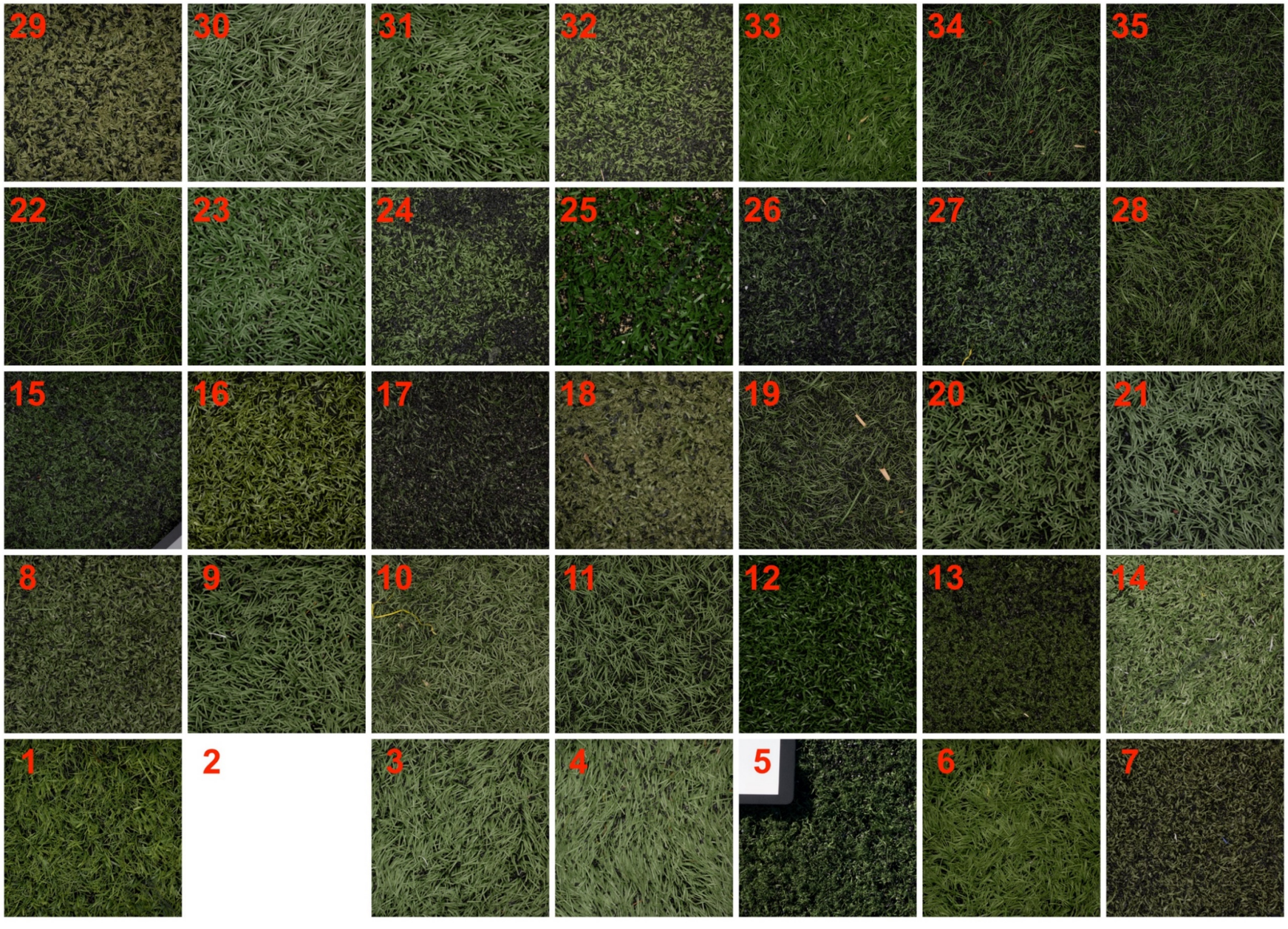


Figure 1. Color-graded surface images showing variation across fields. All images collected using field portable studio. Numbers are the field designation. Camera and studio equipment were not available at field 2.

Figure 2. Color-graded image of infill material as collected from each field illustrating variation in density and composition. All vials were filled with 3.0 grams of infill material. Numbers are the field designation and the reference image is pre-installed crumb rubber (directly from manufacturer).

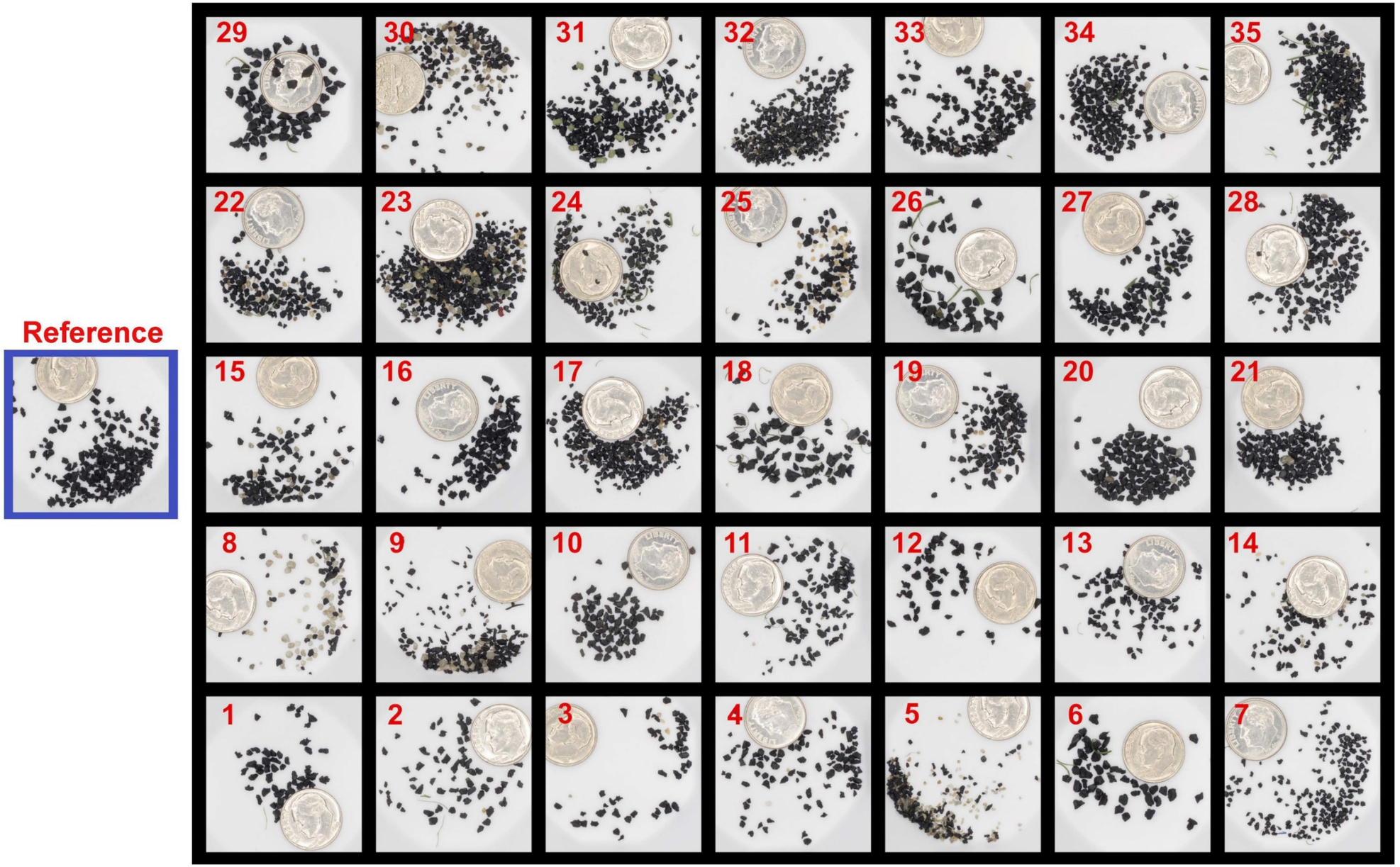


Figure 3. Color-graded images of infill material collected from each field showing variation in crumb rubber particle size and infill composition. Numbers are the field designation and the reference image is a sample of pre-installed material (directly from manufacturer).

Section 3.1.2
Particles in Air

Figures included in this section show the particle concentrations and numbers collected in air on each of the 35 fields. Tables 1 and 2 show the summaries statistics of particle mass data in Figure 2, and $PM_{2.5}$ data in Figure 3. The particle data will be used to evaluate the inhalation exposures of on-field human receptors.

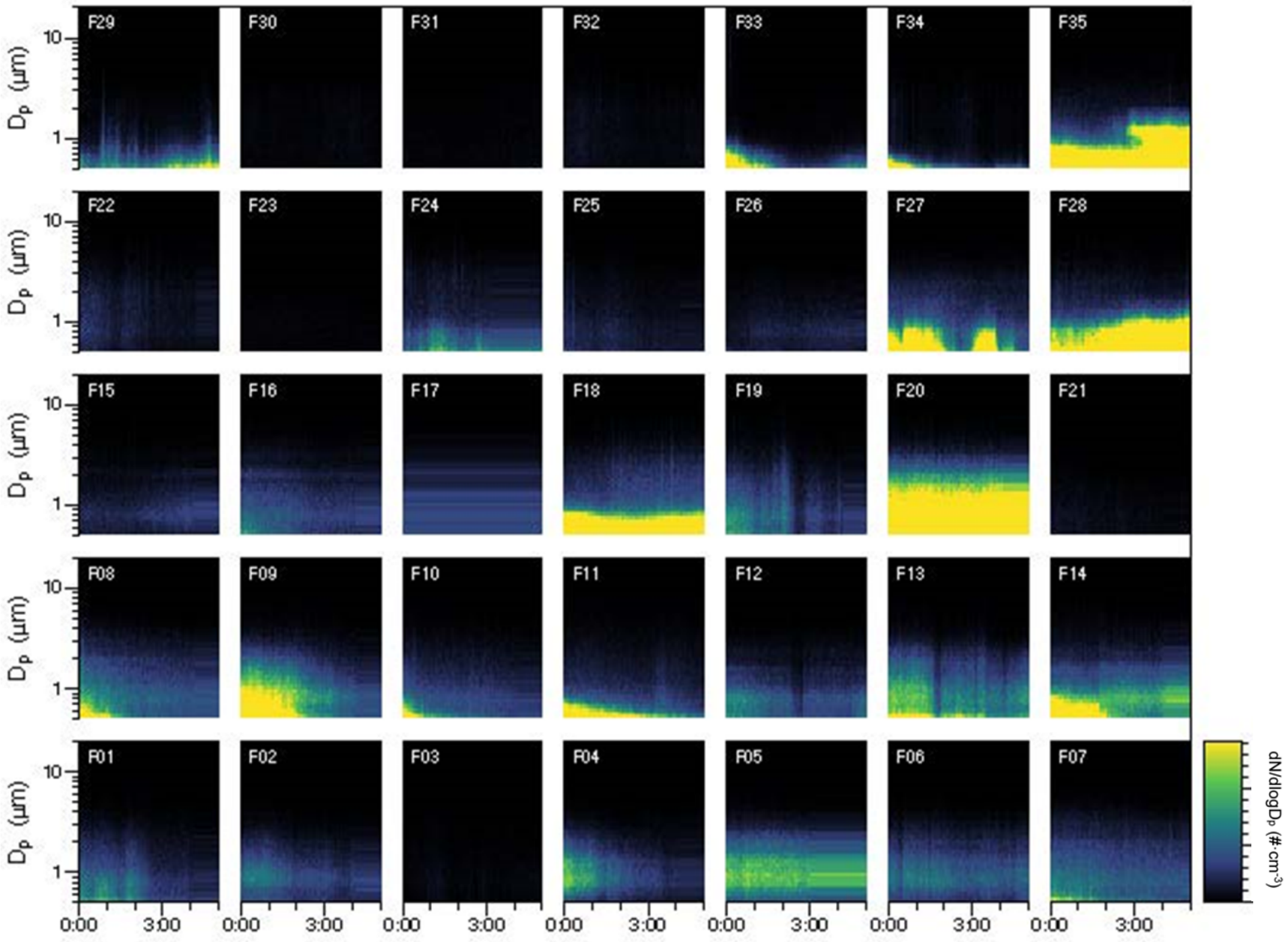


Figure 1. Time history of size resolved particle number concentration measured by TSI Aerodynamic Particle Sizer (APS) model 3321 at 9 inches above surface at Cart 2 (behind the goal). The distribution of particle number concentration is represented by a color contour plot

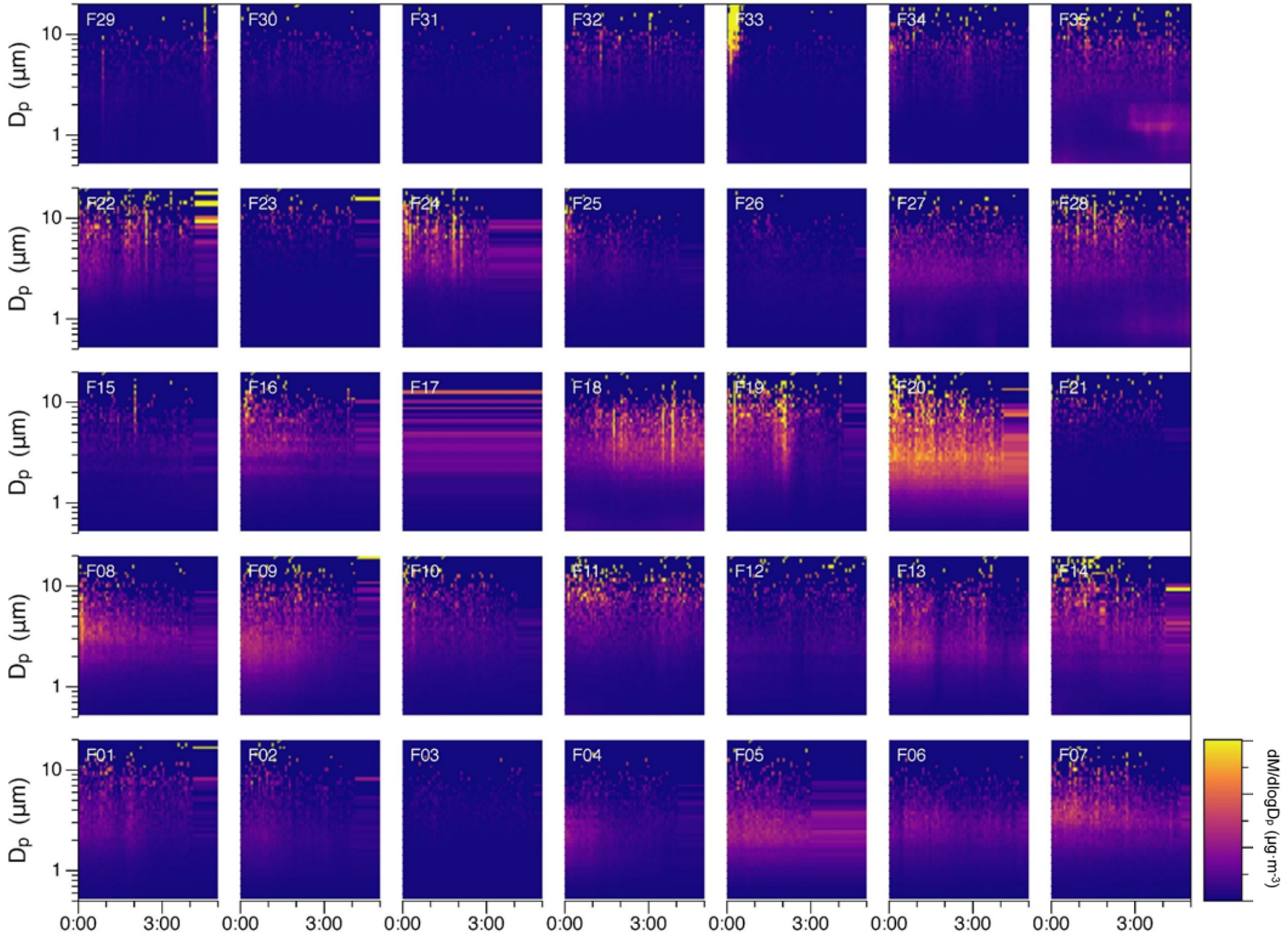


Figure 2. Particle Size Mass. A 7 x 5 grid of the time history of the particle size mass distribution as measured by the TSI Aerodynamic Particle Sizer (APS) model 3321. Numbers are the field designations. The distribution is represented by a color contour plot of dM/dlogDp. The x-axis shows the 5-hour measurement period with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking), and 4:00 to 5:00 is post-activity. Numbers are the field designation. For some fields not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

Table 1. Summary statistics of the estimated mass concentration measured by the TSI-APS instrument at 9 inches above surface at Cart 2 (behind the goal). The particle mass distribution of each field is described in color contour plots of dM/dlogDp in Figure 2. Data of the 35 fields are statistically analyzed by time: a column for each hour: first (pre-kicking), hours 2 through 4 (kicking), and hour 5 (post-kicking).

		Hour				
		Pre	Kicking			Post
	Stat	1st	2nd	3rd	4th	5th
$\mu g \cdot m^{-3}$	mean	13.1	10.1	8.2	6.9	6.5
	median	10.8	8.6	6.7	5.1	5.1
	25th	4.5	3.5	2.7	2.2	1.9
	75th	16.2	14.2	11.3	8.9	8.4
	10th	1.5	1.4	1.0	1.2	0.9
	90th	23.1	19.4	15.9	14.5	15.2
	min	0.3	0.2	0.2	0.3	0.3
	max	587.9	78.6	50.9	69.1	54.4
	stdv	20.8	8.5	7.4	6.6	6.0
	n	2041	2019	2041	1928	1071

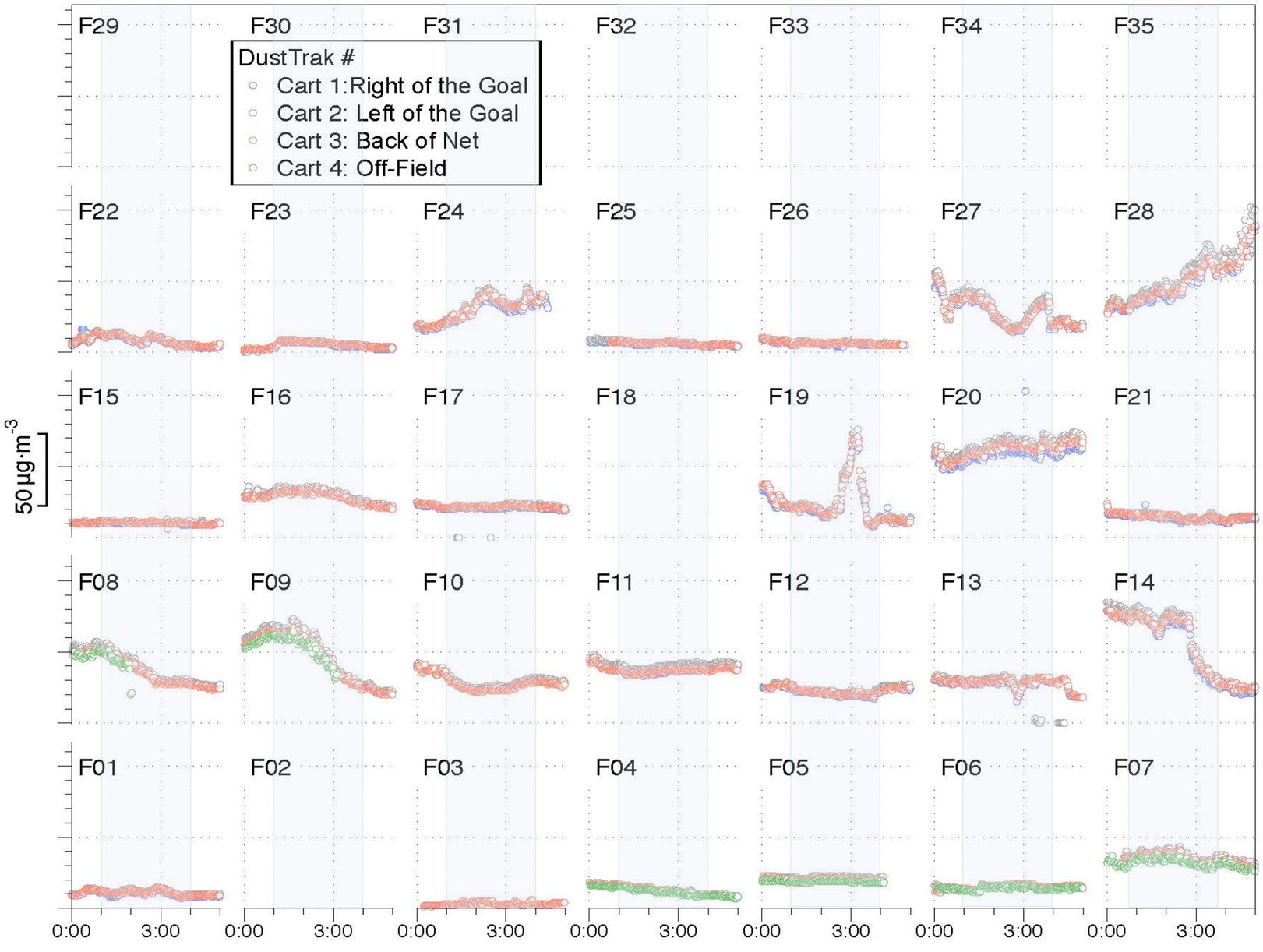


Figure 3. PM2.5 Profile. A 7 x 5 grid of the PM2.5 concentration profiles (expressed in µg/m^3) as measured by TSI DustTrak instrument model 8530 instruments. The instruments were both on (Carts 1 to 3) and off (Cart 4) the field. The x-axis shows the 5-hour measurement period with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking, shaded area), and 4:00 to 5:00 is post-activity. Numbers are the field designation. For some fields, not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

Table 2. Summary statistics of $PM_{2.5}$ concentrations in air. $PM_{2.5}$ mass concentration in air of each field is plotted in Figure 3. TSI DustTrak instruments were installed on Cart 3. The instruments were calibrated using an Arizona road dust. Data of the 35 fields are statistically analyzed by time: a column for each hour: first (pre-kicking), hours 2 through 4 (kicking), and hour 5 (post-kicking).

		Hour				
		Pre	Kicking			Post
	Stat	1st	2nd	3rd	4th	5th
$\mu g \cdot m^{-3}$	mean	27.3	26.3	25.4	23.3	21.3
	median	24.0	22.0	21.0	22.0	20.0
	25th	13.0	12.0	11.0	10.0	9.0
	75th	37.0	35.3	36.0	31.0	26.0
	10th	7.0	7.0	7.0	5.0	4.0
	90th	54.0	59.0	52.0	39.1	38.9
	min	1.0	2.0	2.0	2.0	2.0
	max	79.0	77.0	76.0	71.0	89.0
	stdv	18.3	17.8	17.6	16.1	17.1
	n	731	780	780	780	722

Figure 4. PM2.5 Profile. A 7 x 5 grid of the PM2.5 concentrations (expressed in µg/m^3) as measured by MetOne light scattering real-time instruments model BT645 (on-field, Cart 2) and ES642 (off-field, Cart 4). The x-axis shows the 5-hour measurement period with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking) and 4:00 to 5:00 is post-activity. For some fields, not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

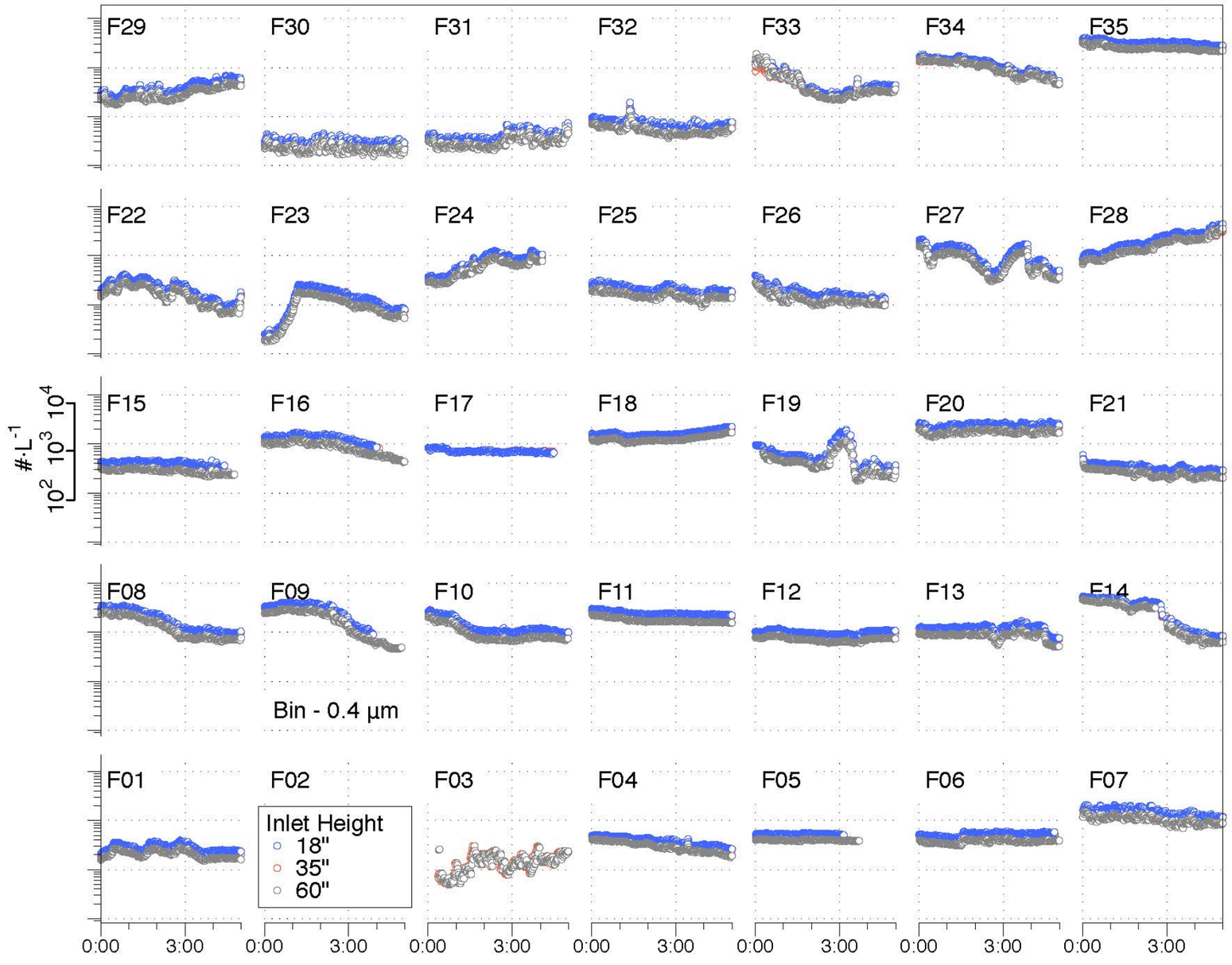


Figure 5. Particle Concentration. A 7 x 5 grid of the on-field particle concentration (expressed in number of particles per liter) from the 0.4 – 0.5 µm channel measured by a MetOne optical particle counter instrument (OPC) model BT637s. The x-axis shows the 5-hour measurement period with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking), and 4:00 to 5:00 is post-activity. Numbers are the field designation. For some fields, not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

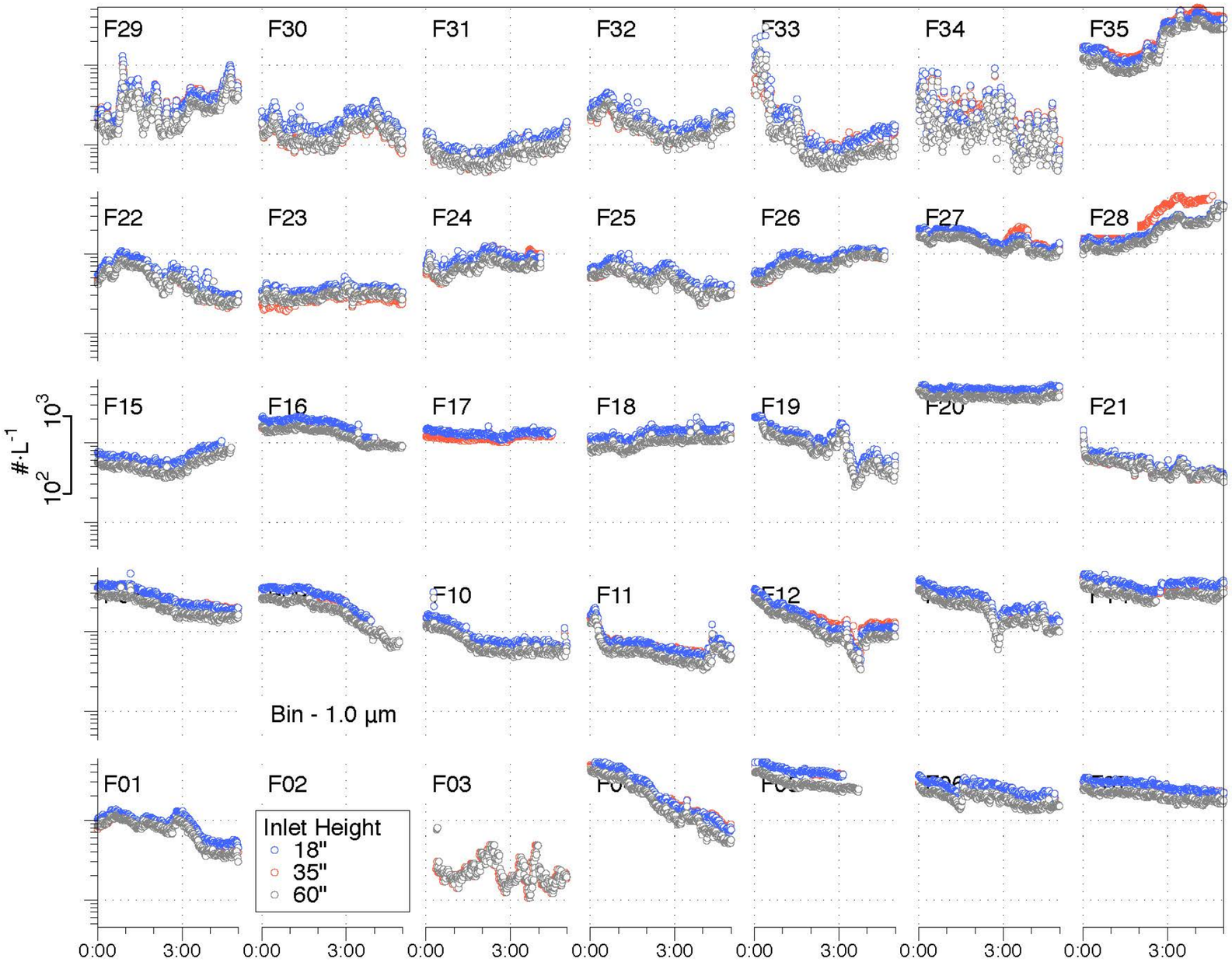


Figure 6. Particle Concentration. A 7 x 5 grid of the on-field particle concentration (expressed in number of particles per liter) from the 1.0 - 2.5 µm channel measured by a MetOne optical particle counter instrument (OPC) model BT637s. The x-axis shows the 5-hour measurement period with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking), and 4:00 to 5:00 is post-activity. Numbers are the field designation. For some fields, not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

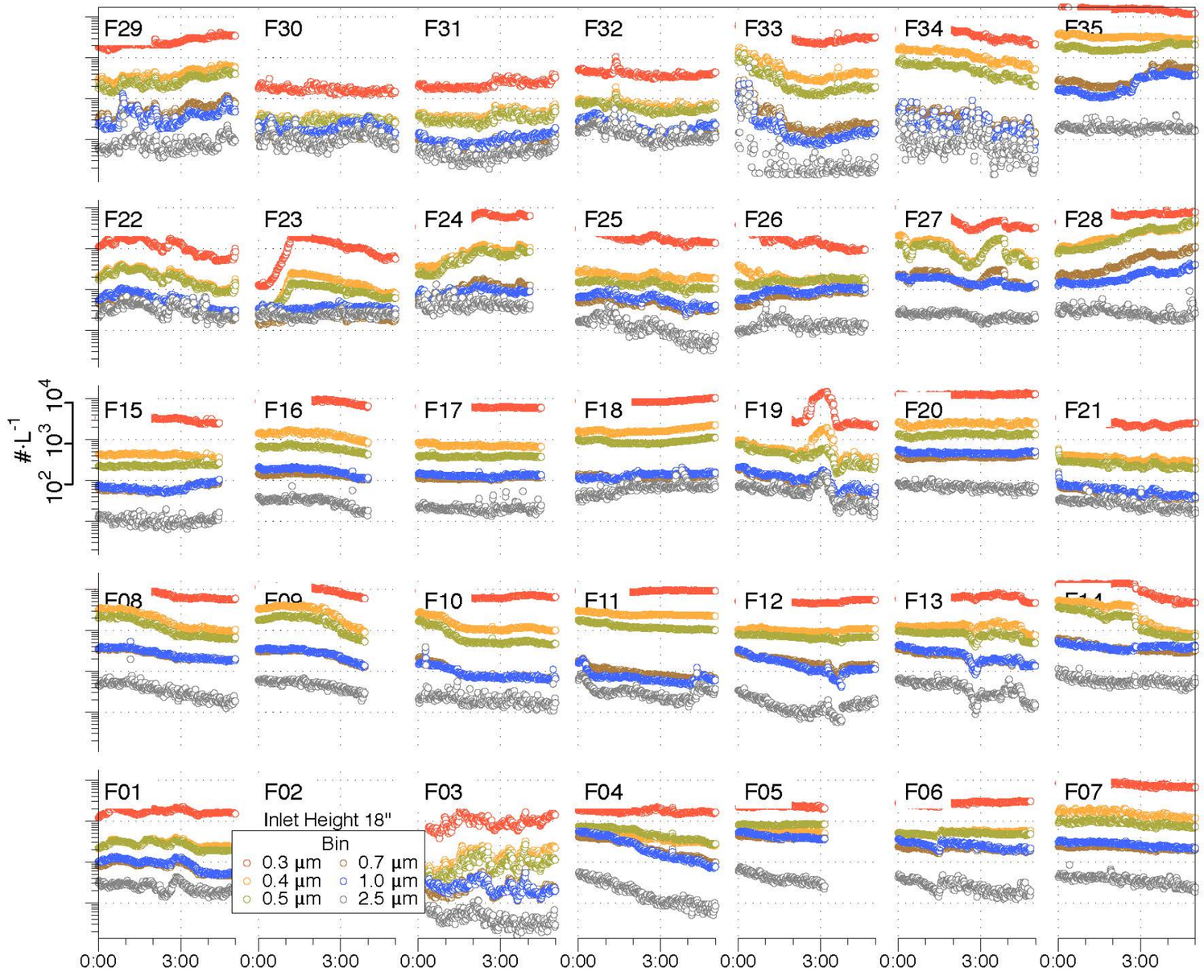


Figure 7. Particle Concentration. A 7 x 5 grid of the on-field particle concentrations (expressed in number of particles per liter) measured by the channels of a single MetOne optical particle counter instrument (OPC) model BT637s. The x-axis shows the 5-hour measurement period with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking), and 4:00 to 5:00 is post-activity. Numbers are the field designation. For some fields, not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

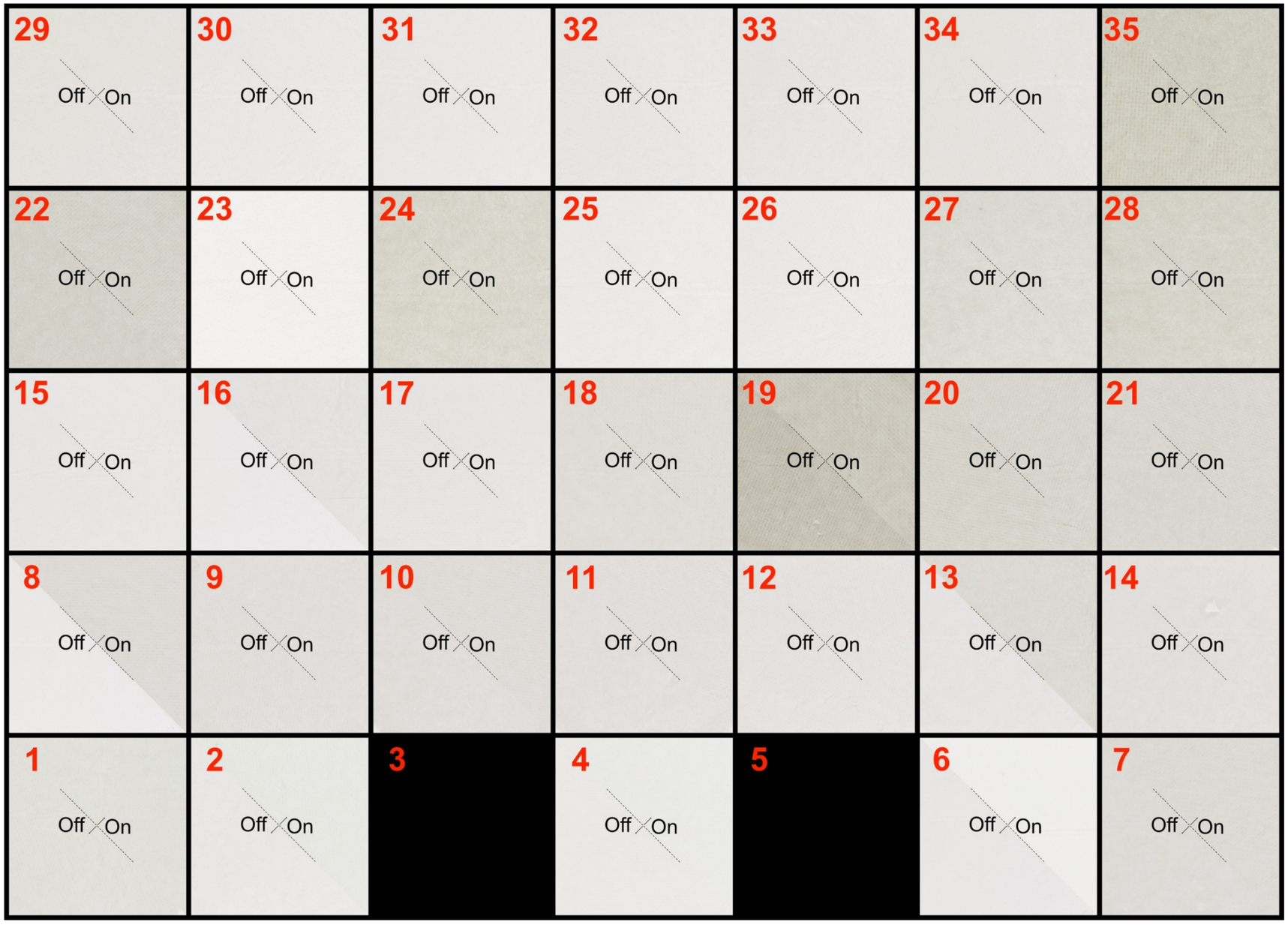


Figure 8. Particles on PEM Filter. A 7 x 5 grid of color-graded Polyester Multifilament (PEM) filter photos. Numbers are the field designations. For some fields not all instruments were deployed or operational, and as a result there is no image for that field on the figure.

Lawrence Berkeley National Laboratory
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

Section 3.1.3
Weather and Surface/Subsurface Temperature

Meteorological conditions including ambient ozone levels, surface and subsurface temperatures, and solar insolation, were monitored at each field sampling events.

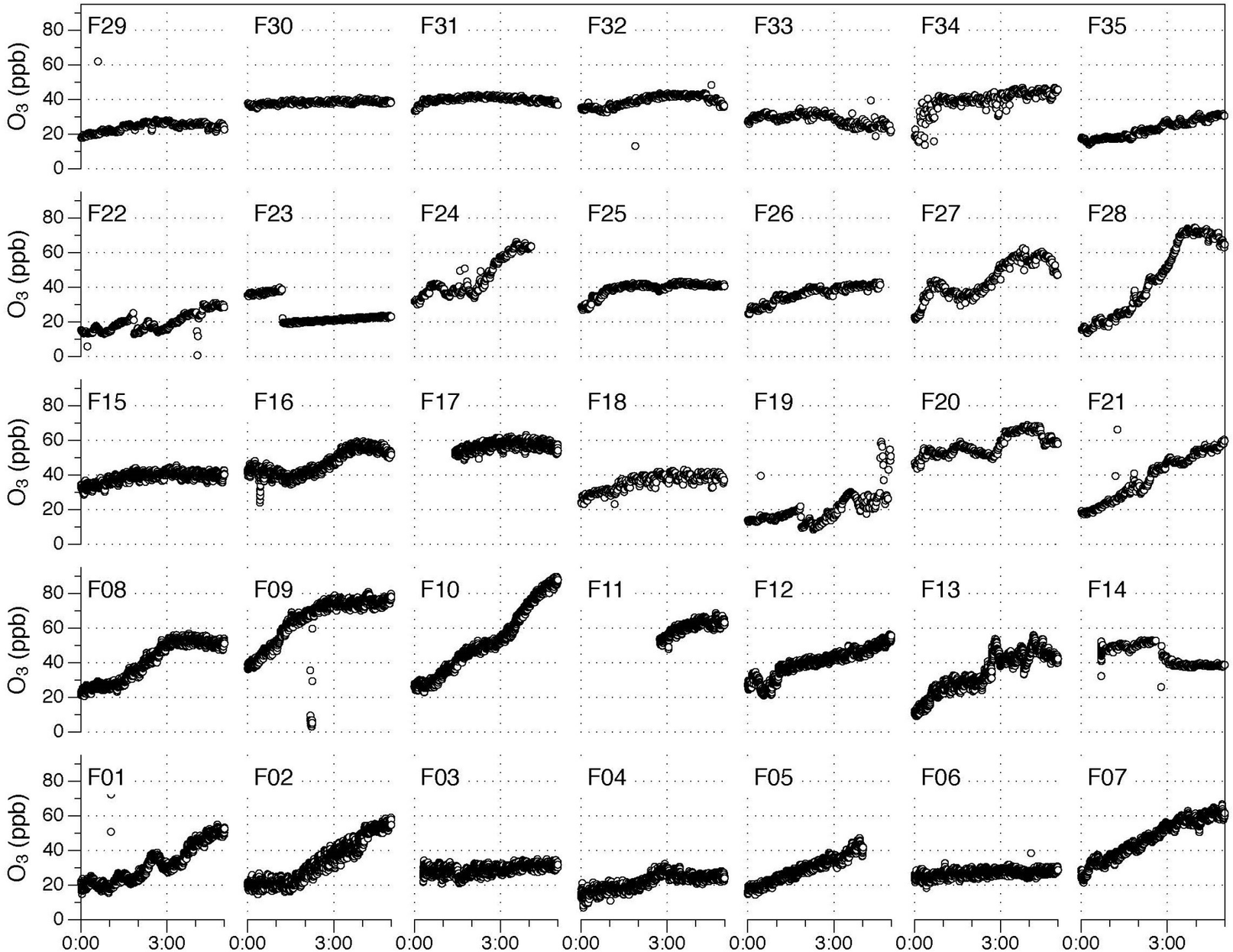


Figure 1. Ozone Level. A 7 x 5 grid of ozone concentrations (ppb) as measured by a 2BTech model 205 instrument. The x-axis represents the 5-hour measurement period with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking), and 4:00 to 5:00 is post-activity. Numbers are the field designation.

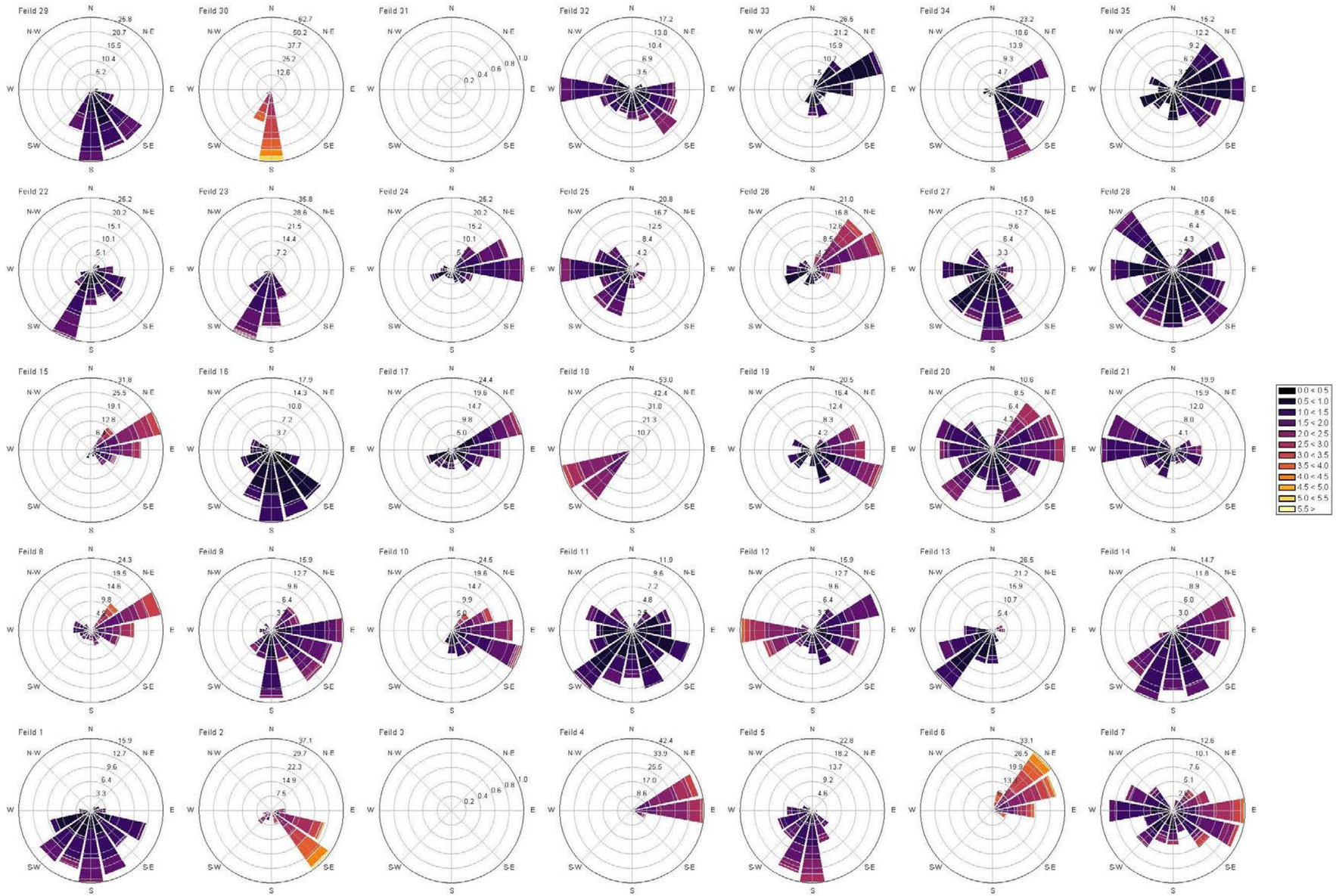


Figure 2. Wind Speed and Direction. A 7 x 5 grid of wind speed, direction, and frequency data over the 5-hour measurement period. Numbers are the field designations. For some fields not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

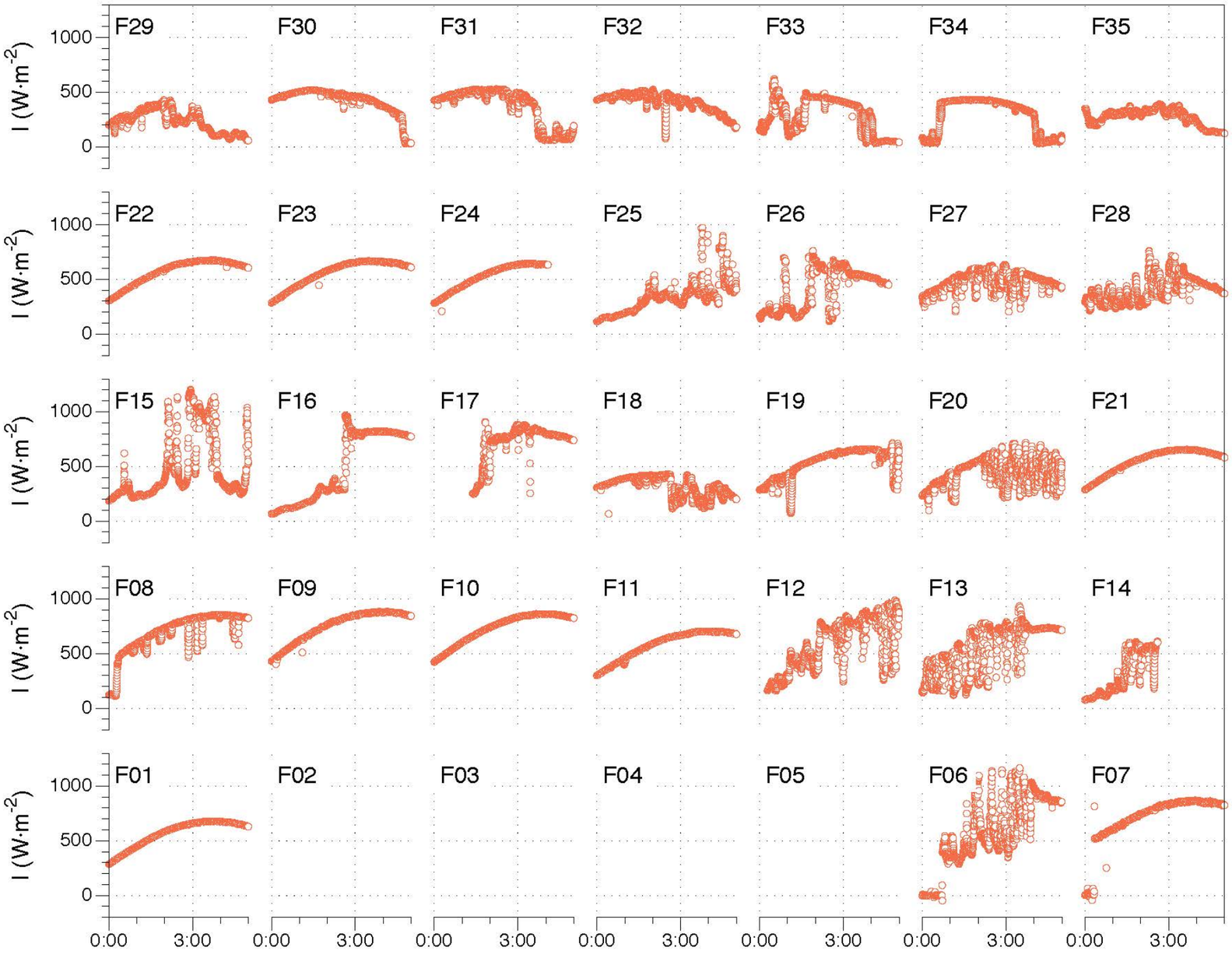


Figure 3. Solar Insolation. A 7 x 5 grid of the on-field solar insolation as measured by an Eppley Radiometer model PSP. Solar insolation ($W \cdot m^2$) represents the amount of sunlight that is shining down on the field. The x-axis shows a 5-hour time history with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking), and 4:00 to 5:00 is post-activity. Numbers are the field designations. For some fields not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

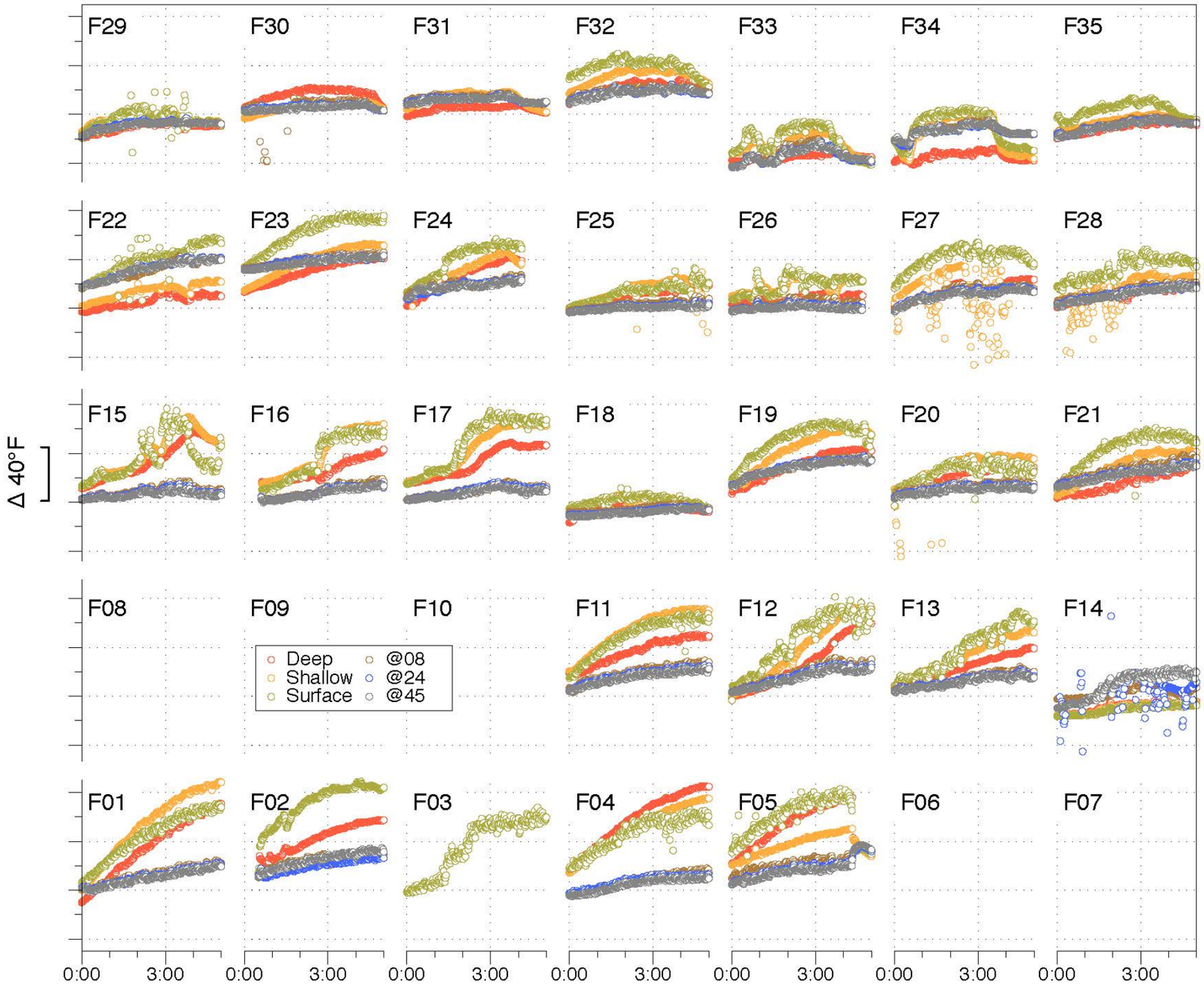


Figure 4. Vertical Temperature Profiles. A 7 x 5 grid of the on-field vertical temperatures (expressed in °F) profiles from thermocouples buried in the crumb (deeply and shallow), on the surface, and at 8cm, 24cm, and 45cm above the surface. The x-axis shows a 5-hour time history with 0:00 to 1:00 representing a period of no field activity, 1:00 to 4:00 is the on field activity (kicking), and 4:00 to 5:00 is post-activity. Numbers are the field designation. For some fields not all instruments were deployed or operational, and as a result there is no data for that field on the figure.

Section 3.1.4
Preliminary Metal Data of Crumb Rubber

Tables 1 and 2 show the concentration range of metals in crumb rubber collected from 35 synthetic turf fields.

Figure 1 shows data of six selected metals in all samples (n=10) collected from a randomly selected field. The Box-and Whisker plot illustrates the dispersion of data using non-parametric statistical analysis. Two additional sets of field data will be presented at the meeting.

Preliminary Metal Data of Crumb Rubber

Table 1. Elemental composition of 61 samples from 35 fields, using the EPA 3051A method[1] (full digestion). A total of 806 samples were collected in this study. Concentrations are expressed in µg per gram of sample.

Atomic number	Element	Mean concentration	Median concentration	Standard Deviation	Minimum concentration	Maximum concentration
3	Li	1.7	1.6	0.6	0.8	3.1
4	Be	0.02	0.02	0.01	0.00	0.05
5	B	5	3	6	1	22
11	Na	370	350	120	140	650
12	Mg	440	310	720	180	4600
13	Al	880	800	390	400	2300
14	Si	710	730	240	220	1100
19	K	490	460	230	260	1700
20	Ca	8300	1600	26000	940	116000
22	Ti	58	46	42	21	224
23	V	2.4	2.3	0.9	1.1	7.0
24	Cr	5	2	19	1	116
25	Mn	9	7	5	5	25
26	Fe	720	560	510	270	2600
27	Co	150	140	71	56	360
28	Ni	4	3	3	1	17
29	Cu	21	18	7	8	35
30	Zn	16500	17300	4400	7700	24700
33	As	0.8	0.6	0.4	0.3	2.1
34	Se	2.7	2.6	0.7	1.5	4.4
37	Rb	2	2	1	1	9
38	Sr	7	4	10	2	49
42	Mo	0.2	0.1	0.1	n.d.	0.5
47	Ag	0.6	0.2	1.6	n.d.	8.1
48	Cd	1.0	0.7	0.8	0.2	4.5
50	Sn	2	2	2	1	10
51	Sb	0.8	0.8	0.4	0.2	2.5
56	Ba	11	8	12	4	75
80	Hg	0.02	0.02	0.01	0.01	0.07
81	Tl	0.05	0.04	0.02	0.03	0.10
82	Pb	23	13	21	4	91

[1] U.S. EPA. 2007. “Method 3051A (SW-846): Microwave Assisted Acid Digestion of Sediments, Sludges, and Oils,” Revision 1. Washington, DC.

Table 2. Elemental composition of acidic extracts corresponding to 61 samples from 35 fields, determined by the ASTM F3188 method[2]. A total of 806 samples were collected in this study. Concentrations are expressed in µg per gram of sample.

Atomic number	Element	Mean concentration	Median concentration	Standard Deviation	Minimum concentration	Maximum concentration
3	Li	0.02	0.01	0.02	n.d.	0.11
4	Be	0.001	0.001	0.001	n.d.	0.003
5	B	0.1	0.01	0.24	n.d.	1.2
11	Na	53	37	57	5	280
12	Mg	25	16	36	4	170
13	Al	28	29	14	9	54
14	Si	44	21	48	n.d.	130
19	K	140	18	550	5	3200
20	Ca	850	110	3400	25	20000
22	Ti	0.3	0.3	0.2	n.d.	0.7
23	V	0.22	0.29	0.12	0.03	0.42
24	Cr	0.05	0.03	0.05	0.01	0.26
25	Mn	1.0	0.8	1.0	0.2	6.2
26	Fe	27	27	10	12	52
27	Co	1.1	0.9	0.8	0.2	3.5
28	Ni	0.15	0.11	0.17	0.04	0.84
29	Cu	2.2	1.9	1.5	0.8	9.7
30	Zn	210	170	120	55	570
33	As	0.007	0.005	0.006	n.d.	0.023
34	Se	0.02	0.01	0.01	n.d.	0.07
37	Rb	0.05	0.04	0.05	n.d.	0.29
38	Sr	1.1	0.5	2.2	0.1	10.7
42	Mo	0.008	0.007	0.005	0.002	0.024
47	Ag	0.20	0.06	0.68	n.d.	3.9
48	Cd	0.013	0.010	0.010	n.d.	0.047
50	Sn	0.0179	0.0151	0.0172	n.d.	0.0765
51	Sb	0.014	0.012	0.011	0.002	0.054
56	Ba	1.0	0.8	0.7	0.2	3.5
80	Hg	0.0006	0.0005	0.0007	n.d.	0.003
81	Tl	0.0006	0.0005	0.0004	n.d.	0.002
82	Pb	0.7	0.4	0.7	0.1	3.3

[2] ASTM F3188-16, Standard Specification for Extractable Hazardous Metals in Synthetic Turf Infill Materials, ASTM International, West Conshohocken, PA, 2016, www.astm.org

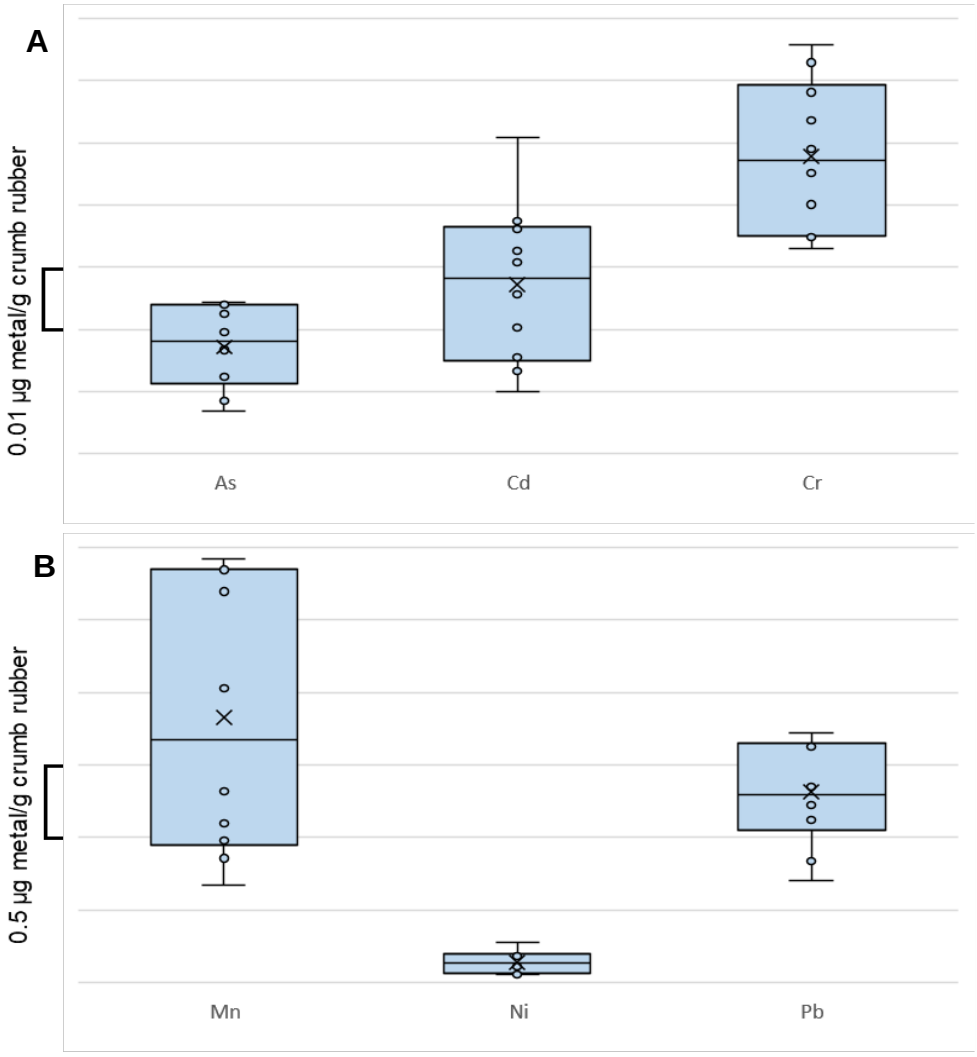


Figure 1. Box and whisker plots showing the distribution pattern of A. arsenic (As), cadmium (Cd), and chromium (Cr); B. manganese (Mn), nickel (Ni), and lead (Pb) detected in all of the 10 samples from a single field. Samples were extracted by ASTM F3188 method of simulate gastric extraction.

The Box and Whisker Plot is a non-parametric graphical presentation of data (descriptive statistics), which does not require underlying assumptions on the distribution of data. Each circle represents a data point. The cross (X) represents the mean value. The box is cut by a horizontal line representing the median value. The box spans the range of the data from the first quartile (Q1) to the third quartile (Q3), also known as the interquartile range (IQR). All data shown here lie within the range of their 1.5 times IQR below Q1 and 1.5 times IQR above Q3. The whiskers are set to represent the minimum and maximum data values.

Some datasets (not here) may have data lying outside of the range of 1.5 times IQR above Q3 and 1.5 times IQR below Q1. Those data could be considered as extreme values. In those cases, the whiskers would be plotted at the 1.5 time IQR below Q1 and 1.5 time IQR above Q3, respectively, and the extreme values represented in solid circles.

Section 3.1.5
Volatile Organic Compounds in Air

For background information, a detailed description of the VOC sampling method is provided in the *Volatile Organic Compounds and Aldehydes Sampling Protocol* in this section. Data are not currently included here, but will be presented and discussed at the meeting.

VOLATILE ORGANIC COMPOUNDS IN AIR:

VOLATILE ORGANIC COMPOUNDS and ALDEHYDES SAMPLING PROTOCOL

In the Phase 3 Study, the Office of Environmental Health Hazard Assessment (OEHHA) and Lawrence Berkeley National Laboratory (LBNL) collected environmental samples to evaluate exposures at on-field locations. Volatile organic compounds (VOCs) were measured in ambient air both on and off the fields during the study. Due to their high volatility, two toxicologically important aldehydes, formaldehyde and acetaldehyde, require a separate sample collection method (ALD) with slight differences in sampling protocols compared to the VOCs in general. The analytical data will be used to assess 1) differences in concentration for on-field and off-field locations, 2) difference in on-field concentrations on the field with-activity and without-activity and 3) inhalation exposure to these chemicals by synthetic turf field users.

Sampling Methods

The fields were tested during static (no activity) and active conditions. To simulate an active field condition, surface agitation in the monitoring area was created using recruited human subjects who conducted vigorous soccer drills (e.g. catch, dribble, touch, kick on goal, etc.) by interacting with a ball kicking machine to set the pace of activity. Details on field testing setup are described in the Field Sampling Protocols (Section 3.2.1, Attachment A).

Sampling packages for VOCs were setup on three carts (two on-field and one off-field) and one tripod (a stratification tower) and the ALD samplers were setup on two on-field carts as detailed in Table 3. The two on-field monitoring packages (Carts 1 to 3) were located to the left and right of the goal frame. The on-field stratification tower was located to one side of the center back sampling location (near Cart 2). The off-field sample location was typically selected to include different ground cover material and to provide a location that was minimally influenced by airflow across the field. The integrated environmental samples were collected using sampling boxes that were programmed to sequentially collect one-hour samples on five preconditioned thermal desorption tubes (VOCs) or individual programmable sampling pumps setup to collect a 3-hour integrated sample on commercially available sample collection cartridges (ALDs). Pump flows were calibrated/checked before and after each use.

VOC and ALD samples were collected on all the 35 fields with a total of 19 VOC samples at each field (one per hour for five hours in three locations plus four 1-hour samples collected simultaneously at different elevations on the stratification tower) and two ALD samples (collected simultaneously for three hours in two locations during activity on the field).

In summary, the VOC samples were collected each hour for five hours including an hour before scripted soccer activity, three hours during activity, and one hour after activity at two locations on the field and one location off the field. An additional four VOC samples were collected simultaneously at four different elevations over the field during the active period. The ALD samples were collected during the 3-hour activity at two locations on the field.

The detailed field protocol for VOC and ALD environmental sample collection was as follows:

VOC sampling activity prior to start and during first hour of testing (without field activity):

1. Setup soccer net at predetermined sample location on field.
2. Move monitoring carts 1, 2 and 3 into position around the soccer net (one at each side and one at rear)
3. Move cart 4 into position at off-field location.
4. Load pre-conditioned VOC tubes (shaded with foil) in multi-tube sampling boxes (5 sample tubes and one field-blank tube in each of three boxes)
5. Set time and launch sampling program in each multi-tube sample box
6. Move multi-tube sample boxes into position on Carts 1, 2 and 4 with inlets at 0.97 – 1.07 meter above surface
7. Program single-tube sample pumps (2 ALD and 4 VOC) and record pre-test calibration flows on all pumps
8. Mount ALD samplers on the Carts 1 and 3 with sample cartridges (shaded with foil) with inlets at 0.97 – 1.07 meter above surface
9. Mount 4 VOC pumps at predetermined elevations on stratification tower (w/o tubes) with inlets at 0.10, 0.51, 1.07 and 1.63 meters off surface
10. After test period begins, measure and recorded sample flows at least once per hour from the multi-tube VOC sample boxes using dry-cal flow meter

Three-hour active phase of testing:

11. Start and continue soccer activity in experimental area in front of the soccer net metered with ball kicking machine
12. Continued to record sample flows hourly from multi-tube sample boxes
13. Start pre-programmed ALD sampling pumps and run for three-hour sample collection period during activity.

14. Load preconditioned VOC sample tubes (shaded with foil) on previously mounted single-tube pumps on stratification tower and collect simultaneous 1-hour sample during last hour of active period

Last hour of test period during inactive phase:

1. Ball kicking activity stops
2. Continued to record sample flows from multi-tube sample boxes
3. Collect completed ALD samples and pumps and record post sampling flows placing labeled cartridge in ice-chest with blue ice
4. Collected VOC samples and pumps from stratification tower and record post sampling flows placing labeled tubes in ice-chest with blue ice

After completion of test period:

1. Collect multi-tube VOC samplers from carts and return all tubers to labeled storage containers and place in ice chest with blue ice
2. Breakdown field package and depart

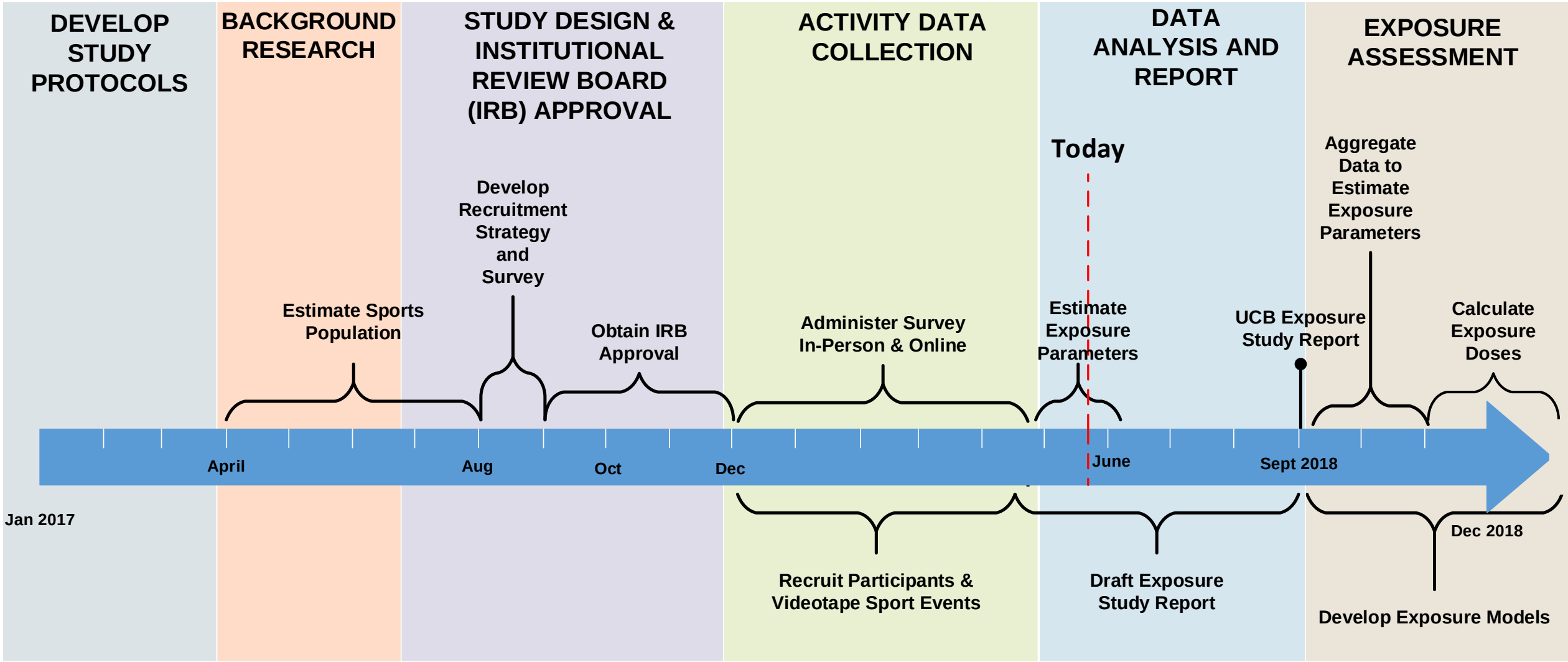
The collected VOC and ALD samples are shipped overnight back to the lab on blue ice for analysis. VOC samples are analyzed by thermal desorption GC/MS and the ALD samples extracted in acetonitrile and analyzed by HPLC.

Table 3: Instrument Package

Target Metric	Instrument method or device	Sample type	Cart S = left and right of the goal B = back of net O = off field
Volatile organic compounds (VOCs)	Hourly samples collected on thermal desorption sorbent tubes	Integrated	S & O
Stratified VOCs	One-hour sample collected at 4 levels above field on thermal desorption sorbent tubes	Integrated	B
Aldehydes (ALD)	EPA method TO11 or equivalent using DNPH cartridge	Integrated	S

Section 3.2
Exposure Scenarios of Synthetic Turf Fields

Task 3. Exposure Scenario Development



Section 3.2.1
Pathways of Exposures

Exposure Scenarios of Synthetic Turf Fields:

Pathways of Exposures

1. Introduction

In California, there are over 900 synthetic turf fields with crumb rubber infill[1]. These fields are used for soccer as well as other sports. According to statistics from the 2013-2014 season, there were over 320,000 active players on affiliated soccer teams and clubs in California (US Youth Soccer). In the OEHHA synthetic turf field study, we focused on examining the exposure of soccer players (athletes) and other soccer-related participants (e.g., coaches, referees, and bystanders) due to the popularity of soccer in California and close contact of players with the synthetic turf. In addition, soccer can be a life-long sport for some individuals. Exposures for players can span from a few years to several decades.

In order to evaluate the exposure of soccer players and other participants on synthetic turf fields, OEHHA is conducting, in collaboration with the University of California, Berkeley (UCB) and the University of Arizona (UA), a time-activity study to characterize the activity and exposure pattern of soccer players in California. The study uses in-person and online surveys to gather data on soccer players' activities patterns, histories, and individual behaviors at the field that can lead to exposure. Additionally, we videotaped soccer practices and games in selected locations in Northern California. The video footage is being translated into micro-level activity time series (MLATS) data about events that occur on- and off-field. These soccer-specific activity data will be used to derive model parameters for different exposure scenarios for estimating potential chemical exposures on the field, and for incorporation into the human health risk assessment. UCB's report—*Time Activity Exposure Patterns Occurring on Synthetic Fields*—is provided in section 3.2.3 of the meeting materials. UCB will make a presentation on the study at the Scientific Advisory Panel meeting.

The current document describes the exposure pathway model OEHHA developed to describe potential sources of exposure, exposure pathways, and activity categories for on-field human receptors.

[1] OEHHA's synthetic turf field database (last updated March 2017) was compiled with data collected by CalRecycle. The database does not include sports fields on federal facilities, fields not reported to CalRecycle by installers, or fields that did not receive funding from CalRecycle.

2. Exposure Pathway Model

This section describes an exposure pathway model for players, coaches, and by-standers for a synthetic turf field with crumb rubber infill. The on-field pathway model (Figure 1) shows, from source through to the receptors, the potential pathways of exposure:

- sources of potential chemical release from the synthetic turf field
- migration of chemicals between the environmental matrices
- exposure media
- routes of exposure
- on-field or near-field categories of human receptors (e.g., coaches)
- potential exposure pathways

2.1. Source of Exposure and Release to Environmental Matrices

Synthetic turf fields are composed of three main parts: synthetic grass blades, backing materials, and crumb rubber infill. On-field dermal and oral exposures can occur to all human receptor categories from crumb rubber infill, and probably to a lesser extent the synthetic grass blades and backing materials. Exposures may also occur to volatile or semi-volatile chemicals that may be evaporated from the synthetic turf and fine particles that may be suspended in the air above the field.

Off-field exposure may result from windblown dust or particles, or groundwater or surface runoff from the field. These pathways are not shown in Figure 1 and are expected to be a smaller source of exposure than the pathways displayed.

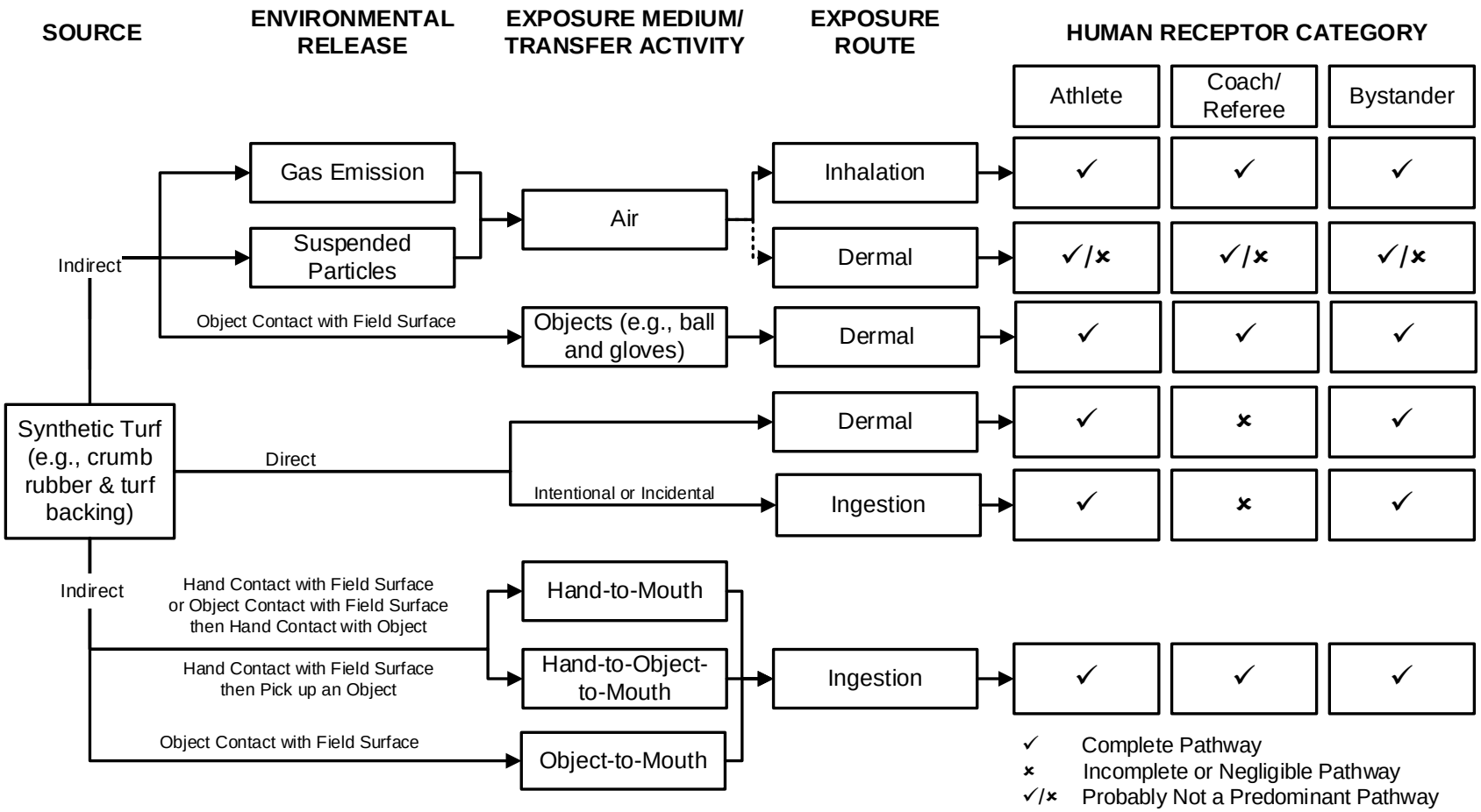


Figure 1. Exposure Pathway Model for on-field or near-field exposures: Potential Exposure Source, Exposure Pathways, and Receptor Categories

2.2. Human Receptor Categories

The primary receptor categories considered here are athlete, coach/referee, and bystander. Within the athlete and bystander categories, there is a wide range in individuals' age. Among them, young children are particularly of concern; they are different from adults in terms of behaviors, breathing rates and other physiological characteristics that can lead to higher exposures. In the time-activity studies (described in section 3.1.2. of the meeting materials), children of different ages are separately characterized by their behaviors. From these studies, age-specific parameters will be estimated and applied in the exposure evaluation. Also, as a group, young children are often inherently more vulnerable to exposure of environmental chemicals (Faustman *et al.*, 2000), and this will be considered in estimating risk.

The main receptor categories are defined as follows:

Athletes: Athletes are soccer players who participate in soccer practice or games in a season or year-round. Athletes who participate in organized soccer teams may play in one or multiple designated positions (e.g., forward, mid-fielder, defense/wingback, and goalkeeper). There can be different activities in each position, leading to different levels of exposure. The activity studies are characterizing micro-activities in the different positions. These characterizations will be used to estimate parameters for use in the exposure assessment.

Coaches and Referees: Coaches are soccer team leaders and trainers. In addition to coaching the athletes, they often organize team practices and schedule games. Referees are game officials who enforce game rules and provide arbitration on field activities.

Bystanders: Bystanders can be the family or friends of athletes, who are present at fields to observe soccer activities from near or off the field.

2.3. Exposure Pathways

The main pathways of human exposure to chemicals from synthetic turf fields are the:

1) inhalation exposure pathway: inhaling chemicals vapors and airborne fine particulates while on the field;
2) dermal exposure pathways: exposure via direct skin contact with synthetic turf components or to vapors released and taken up by the skin; and
3) oral exposure pathways: direct intentional and unintentional ("incidental") ingestion of synthetic turf components or indirect ingestion through hand-to-mouth, hand-to-object-to-mouth, or object-to-mouth activities.

These on-field exposure pathways, shown above in Figure 1, will be assessed using the chemical concentrations measured in field samples taken from the fields and the activity and behavioral parameters estimated from the exposure study. They are described below.

2.3.1. Inhalation Exposure Pathway

Breathing of air on-field that contains chemical vapors or airborne fine particulate matter released from the field results in inhalation exposures. Athletes are expected to have the highest exposures through this pathway. Running on the field may cause particles to be stirred up into the air and may cause athletes, who have increased breathing rates, to inhale increased volumes of chemical vapor and particulates. Falling or sliding of athletes on the turf may also cause particles to be re-suspended, and the breathing zone of the athlete during these plays may contain a greater density of particles. Goalkeepers may have high exposures through constant diving onto the field surface, especially during practice, as they inhale particles and chemical vapor in the air close to the field surface.

Due to their higher activity levels on the field, athletes, coaches and referees are expected to have correspondingly higher inhalation rates and inhalation exposures than bystanders, who have low- to moderate-activity levels associated with sitting, standing and cheering.

2.3.2. Dermal Exposure Pathways

Dermal exposure occurs when chemicals are transferred from the field onto the skin and enter the body via permeation through the skin. This exposure can occur directly via skin contact with the chemical sources or indirectly via chemical release from field materials into the air or onto objects, followed by skin uptake from the air or skin contact with these other objects, and then uptake through the skin into the body.

2.3.2.1.Direct Dermal Exposure Pathway

Direct dermal exposure pathway refers to the case when there is direct skin contact with the field surface. Crumb rubber particles may adhere to the skin during the contact. Chemicals can migrate from the adhered particles onto the skin, where they are available for dermal uptake. Moisture on the skin surface, like sweat, may enhance adhesion of crumb rubber particles onto the skin and facilitate transfer of chemicals across the skin.

Because of the moderate climate in California, and the outdoor environment of most of the synthetic turf fields, athletes often dress lightly (short sleeve shirts and short pants) during practices and games. Their arms and legs are often exposed and can come into direct contact with the field surface. They are in frequent contact with the field surface during practices and games: conducting warm-up exercises (sit-ups and push-ups) on the field; pushing off the field with hands to maintain balance or get up after a fall; lunging, jumping, and falling repeatedly onto the field (especially for goalkeepers).

Bystanders may sit directly on the field surface to watch practices or games. Toddlers and young children may play, crawl around, or roll on the field. They may also play with the crumb rubber. Their hands, legs, and other body parts can be in frequent or continuous contact with the field surface.

While coaches routinely spend time on the field, they have much less skin contact with the field compared to athletes. They seldom fall and do not dive onto the turf like athletes. They can be standing on the sidelines of the field during an entire game. Similarly, referees rarely have direct dermal contacts with the field surface.

2.3.2.2. Indirect Dermal Exposure Pathways

Dermal exposure may also occur indirectly through the air. During hot summers in certain regions of California, volatile and semi-volatile chemicals may be released from the field and into the air. These chemicals may be taken up dermally from the air. During soccer practices or games, ball kicking, running, and tackling activities agitate the field and disperse crumb rubber into the air, potentially providing further opportunity for release of chemicals from particles into the air. These fine particles may then settle onto the skin of players, where the vapors they contain may partition into the air that in turn may eventually lead to transfer of chemicals in the vapor phase through the skin to be absorbed. Alternatively, chemicals in or on these particles can pass through the skin and be absorbed. Players, coaches and by-standers may have continuous indirect dermal exposure of chemicals via these mechanisms. However, this indirect exposure pathway often is unlikely to be a predominant pathway, especially in an outdoor environment like most of the synthetic turf fields. The chemical concentration data from the field characterization study will be used to evaluate the significance of this pathway.

Indirect dermal exposure may occur through transfer of chemicals or particles to the skin by an object. Objects such as soccer ball, soccer gloves, and shoes are in constant or frequent contacts with the field surface. The object-field interactions may lead to adhesions of chemicals or fine particles on the objects. Subsequent dermal contact with these objects may transfer the adhered chemicals or particles from the object to the skin of the receptor. This chain of actions may eventually results in chemical absorption through the skin. All human receptor categories may be exposed through this indirect dermal pathway. Body parts, such as hands, lower legs, and forehead of the athletes are in frequent dermal contacts with these objects before, during, and after practice or game: forward heads the ball to score, athlete handles the ball or gets hit by the ball, athlete puts on and takes off the shoes, goalkeeper puts on or take offs the gloves etc. Coaches and referees often have dermal (especially the hands) contact with the ball and their shoes. Bystanders who assist in handling soccer equipment, play with the soccer equipment after the practice or game, pick up their water bottles that have been left on the field surface may also be exposed through this indirect dermal pathway. In addition, chemicals or particles transferred onto the hands through this indirect dermal mechanism may be ingested and result in adsorption of chemicals via an indirect ingestion pathway. The indirect ingestion

pathway is discussed in the section below.

2.3.3. Ingestion Exposure Pathways

Ingestion exposure occurs when particles of any sizes get in the mouth and are ingested. Ingestion of particles while engaging in activities on synthetic turf fields can be by either direct or indirect pathways.

2.3.3.1. Direct Ingestion Exposure Pathways

Direct ingestion exposure pathways can be divided into intentional ingestion and incidental ingestion. As shown in Figure 1, the direct ingestion exposure pathway is assumed to occur for athletes of all ages and young bystanders (0<2 and 2<16 age groups), but not for coaches, referees or adult bystanders.

Intentional ingestion exposure occurs when the receptor knowingly or purposefully puts crumb rubber into the mouth and swallows it. OEHHA does not anticipate intentional ingestion behaviors to be common for most of the receptors. However, toddlers and young child bystanders may crawl around on and play with crumb rubber on the sidelines of the field during sport events. Some young children may intentionally ingest varied amounts of crumb rubber in a sport event. Uncommonly, this pathway may be important for young children, particularly those who exhibit pica behavior. However, OEHHA does not anticipate this to be a significant exposure pathway for adult bystanders, athletes, or coach/referees.

Incidental ingestion of crumb rubber occurs when particles accidently enter the mouth and are swallowed. Athletes of all ages are expected to be exposed through this pathway. Falling onto the field or diving onto the field surface while playing soccer agitates the field and disperses particles of various sizes into the air. These airborne particles may then be incidentally ingested by the athletes. This may be an especially important exposure pathway for goalkeepers, who often lunge across the goal to block the ball and sometimes land face-down onto the turf.

It is assumed that coaches, referees, and adult bystanders do not fall on or dive onto the field. Thus, the direct ingestion pathway is not considered to be important for these age groups or receptor categories.

2.3.3.2. Indirect Ingestion Exposure Pathway

Indirect incidental ingestion occurs via carriers (hands or objects): Chemicals or particles are transferred from the field and eventually into the mouth via the following mechanisms:

- hand-to-mouth (HTM),
- object-to-mouth (OTM), and
- hand-to-object-to-mouth (HTOTM).

The indirect ingestion exposure pathway is considered to occur for all receptor categories and in all age groups. However, the exposure level may vary greatly among the age groups and individuals in different exposure categories.

Hand-to-Mouth Activities. Hands or fingers may come into direct contact with the field, or indirectly via objects that have contacted with the field, and then the hands or fingers touch the mouth or the peri-bucal area. Through HTM activities, fine particles or chemicals from the field are directly or indirectly transferred onto the face or into the mouth and eventually ingested.

All receptors of all ages may engage in HTM activities (of various frequencies). Common examples of the HTM behaviors observed on the field are toddler and young child bystanders crawling on the sidelines of the field or playing with crumb rubber and then sucking their fingers. Athletes or bystanders may bite their fingernails, touch their mouth (e.g., braces or mouth guard) or face (or teammate's face); or use their hands to wipe away sweat on their face. Coaches and referees may touch their face with their hands after touching the soccer ball and transfer chemicals or fine particles to the mouth or the peri-bucal area.

Object-to-Mouth Activities. Objects may come into contact with the field and then be put into the mouth or touched to the peri-bucal area. The object acts as a carrier which may transfer fine particles or chemicals from the field into the mouth. Exposure through OTM activities are considered to occur for all three receptor categories.

There are a number of obvious examples of OTM activities. To take their gloves off, some goalkeepers grab their gloves with their teeth. Athletes use their clothes to wipe away sweat on their face. Athletes or bystanders leave their water bottles on the field and drink through the drinking spouts that have come into contact with the field. Mouthing behaviors including touching the face or mouth with objects or putting them into the mouth, as well as licking, sucking, chewing, and biting are common in young children and adolescences (Groot *et al.*, 1998). Coaches and referees accidentally drop their whistles on the field and blow through the uncleaned whistles.

Hand-to-Object-to-Mouth Activities. Hands may come into contact with the field, and then pick up an object and the object may then be put into mouth. Hand-to-object-to-mouth activities involve indirectly transferring fine particles or chemicals from the field via the hand, to a carrier object and into the mouth when the carrier touches to or near the mouth. This exposure pathway involves two carriers, the hand and then the object. OEHHA anticipates that the level of exposure from each event of HTOTM may be lower than that of HTM or OTM. Similar to the HTM pathway, the HTOTM exposure pathway is considered to occur for all receptor categories.

Mouthing behaviors are common in toddlers and young children. For example, they touch the field or crumb rubber and use their unwashed hands to pick up an object, such as a pacifier or a toy, and ultimately put the objects into their mouth. Athletes and

bystanders may touch the field surface and then handle and eat food with their unwashed hands (OEHHA, 2012), or touch the drinking spout of their water bottles and then drink through it. Bystanders may put the arms of their sunglasses into their mouth while watching a practice or game.

Coaches or referees may exhibit HTOTM (e.g., whistling blowing) activities. Even though coaches and referees rarely have direct dermal contact with the field surface, indirect ingestion exposure may still occur through a sequence of events such as— indirect dermal exposure activity (touching an object that had contact with the field surface) followed by a HTOTM activities— coach or referee holds the ball and then picks up the whistle and blows). Depending on the frequency of these event sequence, individuals may have various levels of exposure through the indirect ingestion pathway.

3. Time-Activity Study

In order to evaluate the exposures via various exposure pathways, OEHHA conducted a time-activity study to characterize the activity and exposure pattern of soccer players in California, in collaboration with the UCB and the UA. The study focused on soccer activities occurring on synthetic turf fields with crumb rubber infill. The main goals of this study are to 1) understand the types, frequency, and duration of typical activities occurring on and off the field that contribute to exposure by the identified pathways, 2) understand how often players play on synthetic turf fields (as opposed to natural turf fields), 3) learn about players' history playing soccer, and 4) obtain micro-level activity data of players' interactions with the field. These soccer-specific activity data will be used to model exposure scenarios, develop synthetic turf specific exposure parameters, and estimate potential chemical exposures on the field for final incorporation into the human health risk assessment.

The time-activity study was conducted following protocols approved by the Institutional Review Boards of the State of California, UC Berkeley, and UA. Two approaches were used to obtain the time-activity data. The first approach involved the administration of an in-person questionnaire and an online survey *(Appendix A)* to gather information about the types of activities soccer players, ages seven through adulthood, engage in during practices and games, and the types of direct contact they may have with the field. Activities of interest included on- and off-field activities such as soccer drills, dive or fall on the field, and snacking or drinking or other activities on the sidelines that may result in exposure. Information about the frequency of practices or games, types of uniforms worn, personal hygiene practices, and soccer history of the player was also collected in the questionnaire. Participants of the in-person questionnaire were recruited through contacting soccer coaches and team managers in the Sacramento and San Francisco Bay Areas. A total of 40 questionnaires were completed. Participants of the online survey were recruited through contacting soccer coaches and team managers throughout California who reached out to soccer parents and players. All participants were asked to sign consent forms to participate in the study (*Appendix B*) before they completed the in-person questionnaire or the

online survey. Over 1,000 surveys were completed. Data collected from questionnaires and surveys were compiled and aggregated to provide information to estimate exposure parameters and build exposure scenarios for soccer practice and game.

The second approach used videography and video translation to collect micro level activity time series (MLATS) data about events that occur on and off the field. Soccer players were videotaped during practices or games and the video was decoded to obtain data on the duration and frequency of contacts occurring on and off the field. Consented participants recruited in the in-person questionnaire were videotaped. For each event, participants were continuously videotaped from the time they entered the field until they left the field at the conclusion of a practice or game. The videographer aimed to keep the whole body of the participant in view of the camera at all times, including the times when the participant was resting on the sidelines. A total of 40 participants were videotaped in 5 practices and 5 games. On average, four participants were videotaped per event, one for each of the four soccer positions: forward, defender, midfielder, and goalkeeper.

Video was translated using a specialized software, VirtualTimingDevice™, as described in previous studies (Beamer *et al.*, 2008; Beamer *et al.*, 2012; Ferguson *et al.*, 2006). Briefly, while viewing video footage, a translator interacts with a video palette to record data (*Appendix C*). Every palette is tailored to the needs of a specific project and contains grids that can represent different designations such as location, object, or contact type. Translators activate cells in each grid of the palette that correlate with the activity and contact occurring in the video. Once a cell is activated, a timer is activated that records the length of each activity and contact. If a new cell is activated, a new timer will begin. Through this process, activity data are collected that translate to the types of contacts being made with the contact frequencies and durations. This can be repeated to gather data for all the body parts of interest. For example, data on the contact frequencies and durations with turf can be used for the assessment of hand-to-mouth ingestion and direct dermal exposure pathways.

Additionally, video footage from previous studies (AuYeung *et al.*, 2006; AuYeung *et al.*, 2004; Ferguson *et al.*, 2006) was reviewed and translated to gather MLATS data on the hand-to-mouth activity of young children playing outdoors. This data was used to develop exposure parameters for child bystanders who may play on synthetic turf field sidelines. These studies are described in section 3.3.2 *Preliminary Children Hand-To-Mouth Activity Data* and will be discussed during the meeting.

Approvals *(Appendix D)* from the State of California Committee for the Protection of Human Subjects (CPHS), the UCB CPHS, and the UA Human Subjects Protection Program were received for all human subject protocols including the study plan, subject recruitment plans, questionnaire and survey administration plans, consent forms, data handling protocols, and procedures for the protection of human subject personal information.

3. References

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Section 3.2.2
Time-Activity Behavior Study

Up to the beginning of May 2018, the University of California, Berkeley has received more than 1,000 surveys and is analyzing all the data. At the time of the preparation of the Scientific Advisory Panel Meeting materials, only preliminary data of 809 online surveys are available. These data are described in this section. Measured video data are being analyzed and compiled.

Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

Time-Activity Exposure Patterns Occurring on Synthetic Turf Fields

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1 Overview:

Synthetic turf fields have become popular alternatives to natural grass in many communities. These synthetic turf fields often contain “crumb rubber” infill materials to improve the playability of the field surfaces. Crumb rubber is manufactured by grinding recycled automobile tires into sub-grain-sized particles. Health concerns have been raised about exposure to chemicals from pulverized tire. Exposure to these chemicals may be of particular concern for soccer players, which is one of the most popular sports in California. Soccer is also played year-round in California and can be a life-long sport. Compared with adults, children and teenagers are often more vulnerable to adverse health effects resulting from exposures to environmental chemicals. Exposure studies are needed to improve our understanding of child and adult exposures and health risks due to use of synthetic turf fields.

The objective of this study is to provide information on exposure-related human activity patterns in support of the California Environmental Protection Agency’s Office of Environmental Health Hazard Assessment (OEHHA) efforts to estimate chemical exposures resulting from use of synthetic turf fields. The exposure assessment will then be used to evaluate potential human health risks from use of synthetic turf fields.

This project includes three main components:

1. an online survey to obtain information regarding player history and other exposure-related information for California soccer players. These data will provide broad descriptive information about soccer players and potential exposures and inform parameters such as exposure frequency and duration over the life course;
2. videotaping soccer players 7-25 years old playing on synthetic turf fields to characterize individual-level exposure-related behaviors and provide parameters for models used to estimate chemical exposures;
3. review of archived videos to characterize exposure-related behaviors in children 1-12 years old spending time outside to provide parameters for models estimating chemical exposures from playground mats.

2 Soccer Participation in California

Soccer is considered a lifelong sport and has been increasing in popularity in California in recent years. The abundance of recreational and competitive soccer leagues in California attracts diverse participants of varying ages. Soccer is also popular among both boys and girls in elementary, middle, and high school. While there are not readily available data regarding how often soccer practices and games take place on synthetic turf fields, factors such as the minimal water requirements have caused the installment of synthetic turf fields to increase across the United States and in California (USEPA, CDC et al., 2016). Currently, California has over 900 synthetic turf fields that are located primarily in the Bay Area, the Greater Los Angeles Area, and San Diego County (Gutierrez, 2016).

According to US Youth Soccer, a national soccer organization, over 320,000 boys and girls ages 18 and under were involved in recreational or competitive club soccer in California between 2013 and 2014 (US Youth Soccer). Among the most popular high school sports and the most often played sports on synthetic turf fields (e.g. football, baseball, and soccer), soccer has one of the highest number of high school participants in California. Participation in football topped the high school boys' sports in 2016 (100,205 boys), while soccer ranked the third (52,266 boys). In the same year, soccer was the most popular high school girls' sport (46,778 girls) (CIF, 2016). The California Interscholastic Federation reported that nearly 100,000 males and females participated on high school soccer teams in 2016, representing nearly 13% of California's population of high school student athletes and over 5% of the total high school population in the state (CDE, 2016; CIF, 2016). Participation in high school soccer has increased in recent years; since 2005, participation among male and female high school students in California has increased by 25% and 32.5%, respectively (CIF, 2016). While participation in competitive soccer teams is lower at the collegiate, semi-professional, and professional levels, college intramural and adult recreational leagues are common in California.

In addition to being a favorite sport for recreational and competitive players of all ages, the Latino population in California has grown significantly in recent years and soccer has long been an important part of the Latino culture in California. Data from the March 2016 Census Bureau Current Population Survey indicate that Hispanic/Latinos made up 38% of California's population in 2015 (The Henry J. Kaiser Family Foundation; US Census Bureau, 2016). In 2014, the estimated Latino population in California was nearly 15 million, compared to 7.7 million in 1990 and 2.4 million in 1970 (Panzar, 2015). An online blog titled "Hispanic Media" described soccer as an "outlet of cultural pride for Hispanics" (de la Torre, 2016) and a study on the impact of soccer in the Latin American community in Richmond, CA indicated that the sport plays a "central role" within the Latino community and creates "social networks through the community's relationship with teams and clubs centered in Richmond" (Messeri, 2008). While data are not

currently available regarding soccer enrollment among different ethnic groups, there are indications that soccer continues to grow in popularity in California due to various factors, including the increasing Latino population in the state.

Factors such as increasing participation at the high school level, the widespread availability of recreational and competitive leagues for adults, and popularity among groups of diverse demographic backgrounds make soccer one of the most popular sports in California. Although there is no official information on the number of soccer athletes that play on synthetic turf fields, there are approximately 440,000 individuals involved with some form of recreational or competitive soccer in California who have various levels of contact with synthetic turf fields (Table 1).

Table 1. Estimate Number of Soccer Players in California (CA)

Competitive Level	Gender	Age Range	Estimate	Year
Recreational/competitive youth (US Youth Soccer)	Both	4-18	162,297[a,b]	2013-2014 seasonal year (Northern CA)
			159,278[a,b]	2013-2014 seasonal year (Southern CA)
High school (CA Interscholastic Federation)	Boys	14-18	52,266[b,c]	2016
	Girls		46,778[b,c]	2016
College (Divisions I-III)	Men	18-22	1,614[d]	2016-2017
College (Divisions I-III)	Women		1,681[d]	2016-2017
College Intramural	Both	18-22	5,000[e]	2017
Adult Recreational (Cal North and Cal South Adult Soccer Leagues and Clubs)	Both	18+	11,000[f]	2017
Professional and Semi-Professional (MLS and Premier Leagues)	Men	18+	566[g]	2015-2017
Professional and Semi-Professional (United Women's Soccer and Premier Leagues)	Women	18+	241[g]	2015-2017
Total 440,721				

[a] US Youth Soccer National Tournament Database (http://www.usyouthsoccer.org/media_kit/keystatistics/)
[b] High school players may participate in US Youth Soccer club teams and high school teams.
[c] 2016 California Omterscholar Federation Sports Participation Survey data (http://www.cifstate.org/coaches-admin/census/2016_CIF_Participation_Census.pdf)
[d] Calculated by tallying rosters of all NCAA and NAIA collegiate teams in CA for 2016-2017 season.
[e] Estimate based on number of universities and colleges in CA, assuming two intramural teams per school and 15 players per team.
[f] Estimate based on number of teams affiliated with California Soccer Association-North (Cal North), California Soccer Association-South (Cal South), or other adult soccer leagues in California. Assumed 15 members per team for teams that did not provide number of participants.
[g] Calculated by tallying rosters of all semi-professional and professional teams in CA.

3 Routes of Exposure to Chemicals from Crumb Rubber

Soccer players, coaches, referees, bystanders, and others spending time on or near synthetic turf fields with crumb rubber may be exposed to chemicals present in crumb rubber via ingestion, inhalation, and dermal contact.

3.1 Non-dietary Ingestion

- can be intentional (i.e., infant/toddler mouthing, pica behavior) or accidental (non-dietary ingestion);
- may occur during activities where hands, fingers, or other objects come in contact with the turf surface and then touch the face or mouth of an individual (i.e., when eating, scratching, etc.);
- another source of non-dietary ingestions exposures occurs when large dust particles are trapped in the upper respiratory system before entering the lungs and then transported to the throat and swallowed.

3.2 Inhalation

- occurs when chemicals emitted from the turf or very small dust particles are inhaled;
- distinct odors are apparent on the synthetic turf fields; other chemicals in air may be present but below odor thresholds;
- monitoring indicates the presence of volatile organic compounds (VOCs) or semi-volatile organic compounds (SVOCs) in air near synthetic turf fields;
- the level of exertion is a key determinate of inhalation exposures, with high intensity activities increasing breathing rates, resulting in higher inhalation exposures.

3.3 Dermal Absorption

- soccer players routinely contact the field during games and practices;
- in addition to diving and sliding, players may fall, stretch, rest, or engage in other activities that involve contact with the field;
- anecdotal reports from parents often refer to extensive crumb rubber dust on children's skin or granules and dust in shoes, clothing, or hair;
- dermal exposures may occur when chemicals in particles adhering to skin are absorbed or by absorption directly from vapors in air.

4 Exposure-Related Behavior Assessment Methods:

4.1 Videotaping: Soccer player exposure-related behaviors

Population – up to 40 participants

One male and one female soccer team in each of the following age categories:

- under 9 years;
- 9-12 years;
- 12-15 years;
- 15-18 years;
- 18-25 years.

Recruitment

- Email and personal outreach to soccer clubs and teams in the SF Bay Area and Sacramento metropolitan regions.

Data Collection

- player assigned to videographer;
- recorded participant upon arrival to the field and end of game or practice;
- noted contacts with field and type of any objects touched (i.e., water bottle; backpack, etc.);
- completed questionnaire;
- data backed up and securely transferred to University of Arizona.

As of March 24, 2018, 27 players have been videotaped at seven events from four practices and three games, including male and female players with a range of ages and soccer positions:

Event Type	Gender	Age (Years)	Positions Videotaped	Number Videotaped
Game	Female	9	Defender/Goalie Midfielder (2)	3
Practice	Female	11-12	Defender Defender/Goalie Forward Midfielder	4
Practice	Male	11-12	Forward Goalie Midfielder	4
Practice	Female	14	Defender/Midfielder Forward Forward/Goalie Forward/Midfielder	4
Game	Female	16-17	Defender (2) Defender/Forward/Goalie Forward	4
Game	Male	16-18	Defender (2) Goalie Midfielder	4
Practice	Male	19-22	Defender Defender/Midfielder Goalie Midfielder	4

We will continue videotaping soccer players until April 15, 2018. In particular, we are recruiting teams with boys 9 years and younger, boys between 12 and 15 years, and women between 18 and 25 years. Following the completion of the videotaping, we will work in collaboration with UA and OEHHA to analyze the time-activity findings and estimate exposure parameters to inform exposure modeling.

4.2 Online Survey: Soccer player exposure-related behaviors and player history (self-reported)

4.2.1 Demographic Information

As of March 3, 2018, 801 individuals had completed the online survey available in English and eight individuals had completed the online survey available in Spanish. Table 2 shows the demographic information of the online survey respondents (n=809). Approximately 58% of online survey respondents were Caucasian and 15% of respondents were Hispanic/Latino.

Table 2. Demographic Characteristics of Online Survey Respondents (n=809)

	n (%)
Age of player	
< 8	7 (0.98)
9-12	172 (21.3)
13-17	389 (48.1)
18-25	105 (13.0)
26-30	12 (1.5)
31-40	38 (4.7)
41-50	53 (6.6)
> 50	24 (2.9)
Prefer not to answer	9 (1.1)
Gender	
Male	415 (51.3)
Female	388 (48.0)
Prefer not to answer	6 (0.7)
Ethnicity	
Asian/Pacific Islander	39 (4.8)
Black/African American	12 (1.5)
Caucasian	472 (58.3)
Hispanic/Latino	119 (14.7)
Native American	4 (0.5)
Mixed	121 (15.0)
Other	16 (2.0)
Prefer not to identify	26 (3.201)
Survey Language	
English	801 (99.0)
Spanish	8 (1.0)

4.2.2 Soccer Player Characteristics

Table 3 shows soccer player characteristics reported by the online survey respondents, including soccer position and percent of soccer practices and games that take place on a synthetic turf field with crumb rubber. Approximately 11% of the survey population played goalie, 10% played forward, 24% played midfielder, and 23% played defender. The majority (>80%) of online survey population only played competitive soccer, with approximately 7% playing recreational soccer and approximately 12% playing both recreational and competitive soccer.

Table 3. Soccer Player Characteristics (n=809)

	n (%)
Soccer Position	
Goalie	93 (11.5)
Forward	84 (10.4)
Midfielder	199 (24.6)
Defender	190 (23.5)
Multiple Positions	235 (29.1)
DK[1]	8 (1.0)
Recreational/Competitive Soccer Player	
Recreational	59 (7.3)
Competitive	651 (80.5)
Both	95 (11.7)
DK[1]	4 (0.5)
Plays Soccer Year-Round	
No	64 (7.9)
Yes	741 (91.6)
DK[1]	4 (0.5)
Percent practices on synthetic turf with crumb rubber	
0%	87 (10.8)
> 0 – 25%	137 (16.9)
> 25 – 50%	118 (14.6)
> 50 – 75%	123 (15.2)
>75%	340 (42.0)
DK[1]	4 (0.5)
Percent games on synthetic turf with crumb rubber	
0%	11 (1.4)
> 0 – 25%	138 (17.1)
> 25 – 50%	177 (21.9)
> 50 – 75%	193 (23.9)
>75%	287 (35.5)
DK[1]	3 (0.4)

[1]Don't Know/Prefer not to answer

4.2.3 Geographic Information

Figure 1 shows the state regions where the respondents lived. While the majority of respondents were located in the San Francisco, Sacramento, Los Angeles, and San Diego metropolitan areas, reflecting areas with the greatest population. California's synthetic turf playing fields containing crumb rubber are located primarily in the San Francisco Bay Area and Los Angeles County.[14]

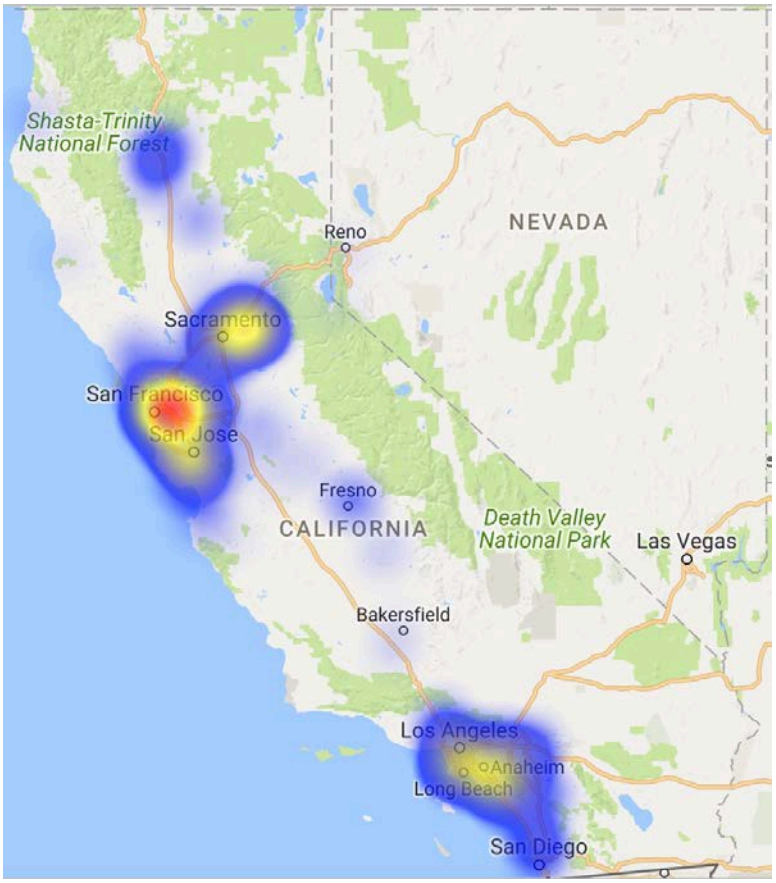


Figure 1. Heat Map of Zip Code Reported by Online Survey Participants.

4.2.4 Exertion and Activity Levels During Practices and Games

Tables 4 and 5 highlight the activity levels players reported during practices and games. We asked participants to report the percent of the time they were resting, lightly active, moderately active, and highly active during practices and games. Tables 4 and 5 include the results from participants whose responses totaled 100% across the four activity levels (n=600 for practices and 363 for games). These results are also illustrated in Figures 2 and 3.

Table 4. Percent of the time participants reported different activity levels during practice[1]

	Resting n (%)	Lightly Active n (%)	Moderately Active n (%)	Highly Active n (%)
0 – 25%	580 (96.7)	521 (86.8)	211 (35.2)	208 (34.7)
> 25 – 50%	19 (3.2)	74 (12.3)	342 (57.0)	272 (45.3)
> 50 – 75%	1 (0.2)	4 (0.7)	42 (7.0)	105 (17.5)
> 75%	0 (0)	1 (0.2)	5 (0.8)	15 (2.5)

[1]Complete responses from 600 participants

Table 5. Percent of the time participants reported different activity levels during games[1]

	Resting n (%)	Lightly Active n (%)	Moderately Active n (%)	Highly Active n (%)
0 – 25%	349 (96.1)	315 (86.8)	148 (40.8)	97 (26.7)
> 25 – 50%	11 (3.0)	46 (12.7)	197 (54.3)	163 (44.9)
> 50 – 75%	3 (0.8)	2 (0.5)	16 (4.4)	80 (6.3)
> 75%	0 (0)	0 (0)	2 (0.6)	23 (6.3)

[1]Complete responses from 363 participants

Players were asked to report the longest amount of time they spent practicing and playing games on synthetic turf fields with crumb rubber in the past year (Tables 6 and 7, respectively). There was a slight increase in the longest amount of time players reported practicing or playing soccer as the age of the player increased, however across all age groups, the most common responses were 1-2 or 2-4 hours.

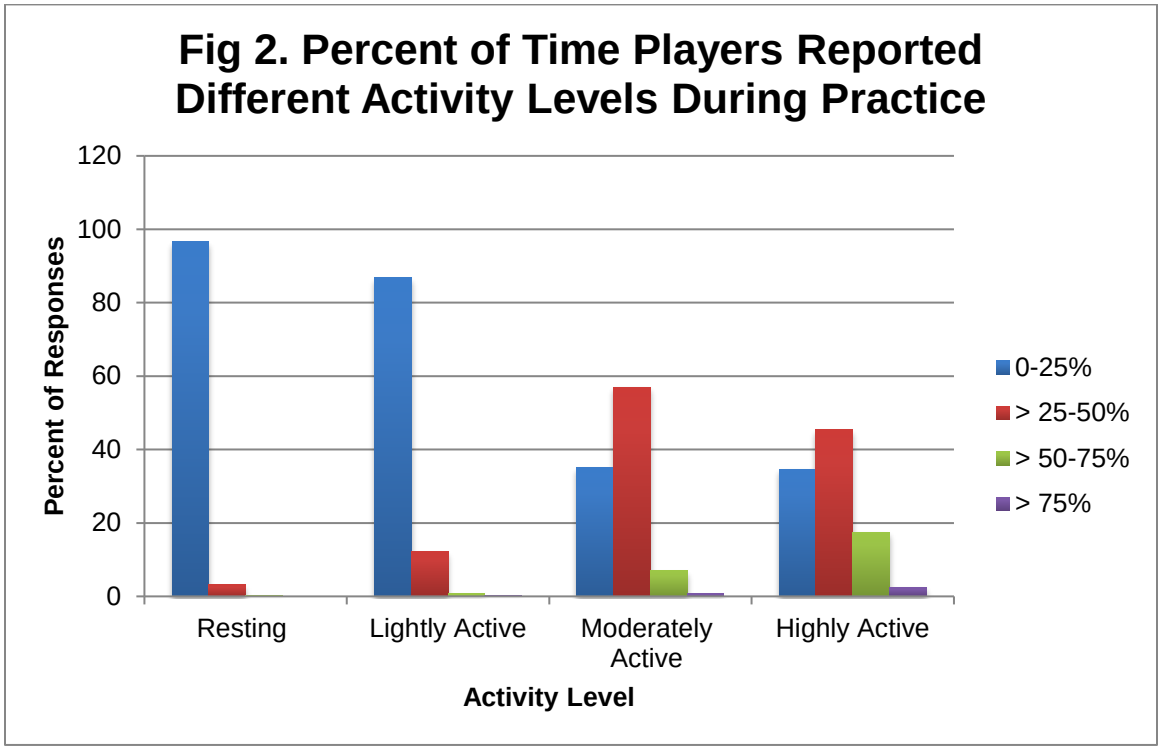


Fig 2. Percent of Time Players Reported Different Activity Levels During Practice
120
100
80
60
40
20
0
Percent of Responses
Resting
Lightly Active
Moderately Active
Highly Active
Activity Level
0-25%
> 25-50%
> 50-75%
> 75%

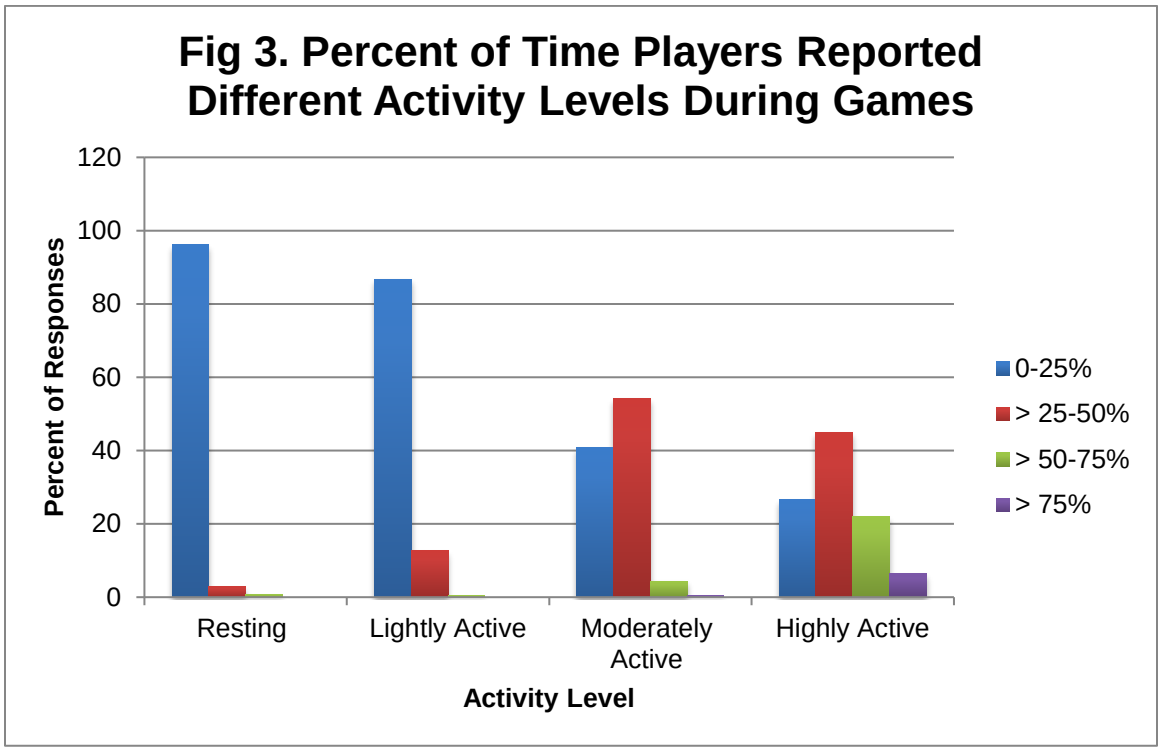


Fig 3. Percent of Time Players Reported Different Activity Levels During Games
120
100
80
60
40
20
0
Percent of Responses
Resting
Lightly Active
Moderately Active
Highly Active
Activity Level
0-25%
> 25-50%
> 50-75%
> 75%

Table 6. Longest Amount of Time Players Practiced on Synthetic Turf Field with Crumb Rubber in Past Year by Age Group

Age Range (Years)[1]	Time (Hours)					
	<1 n (%)	>1-2 n (%)	>2-4 n (%)	>4-5 n (%)	>5 n (%)	DK[2] n (%)
4-8	0 (0)	5 (45.5)	5 (45.5)	0 (0)	1 (9.1)	0 (0)
9-12	4 (2.3)	71 (41.3)	60 (34.9)	8 (4.7)	11 (6.4)	18 (10.5)
13-17	7 (1.8)	131 (33.7)	162 (41.6)	30 (7.7)	25 (6.4)	34 (8.7)
18-25	0 (0)	21 (20.0)	59 (56.2)	10 (9.5)	6 (5.7)	9 (8.6)
> 25	2 (1.5)	43 (32.6)	35 (26.5)	9 (6.8)	13 (9.9)	30 (22.7)

[1]Responses collected from 11 players 4-8 years, 172 players 9-12 years, 389 players 13-17 years, 105 players 18-25 years, and 132 players >25
[2]Don't Know/Prefer not to Answer

Table 7. Longest Amount of Time Players Played Games on Synthetic Turf Field with Crumb Rubber in Past Year by Age Group

Age Range (Years)[1]	Time (Hours)					
	<1 n (%)	>1-2 n (%)	>2-4 n (%)	>4-5 n (%)	>5 n (%)	DK[2] n (%)
4-8	0 (0)	7 (63.64)	3 (27.27)	1 (9.09)	0 (0)	0 (0)
9-12	9 (5.23)	58 (33.72)	72 (41.86)	19 (11.05)	9 (5.23)	5 (2.91)
13-17	8 (2.05)	108 (27.76)	172 (44.22)	66 (16.97)	31 (7.97)	4 (1.03)
18-25	2 (1.90)	24 (22.86)	43 (40.95)	21 (20.00)	11 (10.48)	4 (3.81)
> 25	3 (2.27)	46 (34.85)	52 (39.39)	17 (12.88)	10 (7.58)	4 (3.03)

[1]Responses collected from 11 players 4-8 years, 172 players 9-12 years, 389 players 13-17 years, 105 players 18-25 years, and 132 players >25
[2]Don't Know/Prefer not to Answer

4.2.5 Soccer Player History

Tables 8 and 9 illustrate reported player history. Table 8 shows the number of weeks per year and hours per week parents/guardians reported their child played soccer on synthetic turf fields with crumb rubber between the ages of 4-8, 9-12, and 13-17. Using this information, we estimated the number of hours per year they played soccer between these ages (Table 9). The number of players in each age group in Table 8 does not equal the total number of surveys completed by parents/guardians (n=634) because parents/guardians were asked to report how often their child played soccer on synthetic turf fields with crumb rubber during each age category. For example, of the 634 parents/guardians who completed surveys for their child, 599 of those parents/guardians reported that their child played soccer on synthetic turf fields with crumb rubber between the ages of 4-8 and provided information regarding the frequency they played soccer at this age.

Table 8. Player History – Weeks Per Year and Hours Per Week Child Played on Synthetic Turf Field with Crumb Rubber Between the Ages of 4-8, 9-12, and 13-17 years

Age Range (years)	n[1]	Weeks Per Year Played						Hours Per Week Played					
		Percentiles				Mean	Range	Percentiles				Mean	Range
		25	50	75	95			25	50	75	95		
4-8	599[2]	0	2	12	40	9.2	0-52	0	1	2	12	1.7	0-20
9-12	602[3]	0	4	36	48	20.6	0-52	1	3	4.5	20	3.6	0-52
13-17	348[4]	15	35	45	52	29.8	0-52	3	5	7	12	5.8	0-40

[1]Total responses by age range > 634 because many children played in multiple age groups
[2]Number of responses from parent/guardian whose child played soccer on synthetic turf field between ages of 4 and 8 years
[3]Number of responses from parent/guardian whose child played soccer on synthetic turf field between ages of 9 and 12 years
[4]Number of responses from parent/guardian whose child played soccer on synthetic turf field between ages of 13 and 17 years

Table 9. Player History - Hours Per Year Child Played on Synthetic Turf Field with Crumb Rubber Between the Ages of 4-8, 9-12, and 13-17years[1]

Age Range (years)	Hours per Year Played					
	Percentile				Mean	Range
	25	50	75	95		
4-8	0	2	30	150	29.7	0-720
9-12	8	48	125	320	96.7	0-2704
13-17	50	160	276	500	184.5	0-1000

[1]Calcualted based on hours per week and weeks per year child played on synthetic turf field in each age range reported by parents in survey

4.2.6 Contact with Synthetic Turf During Practices and Games

Figures 4-9 illustrate the frequency survey respondents reported diving, sliding/tackling, and slipping/falling at practices and games taking place on synthetic turf fields with crumb rubber, stratified by the percent of respondents per soccer position. Overall, goalies reported diving at practices and games significantly more frequently than players of other soccer positions. For example, 60.5% and 55.4% of goalies reported diving more than 10 times at practices and games, respectively, whereas less than 5% of forwards, midfielders, or defenders reported diving more than 10 times at practices or games. Among all positions, the frequency of sliding/tackling and slipping/falling most commonly reported at practices and games was 1-3 times. The findings are consistent with anecdotal reports of higher turf contact by goalies, likely resulting in higher dermal and possibly ingestion exposures.

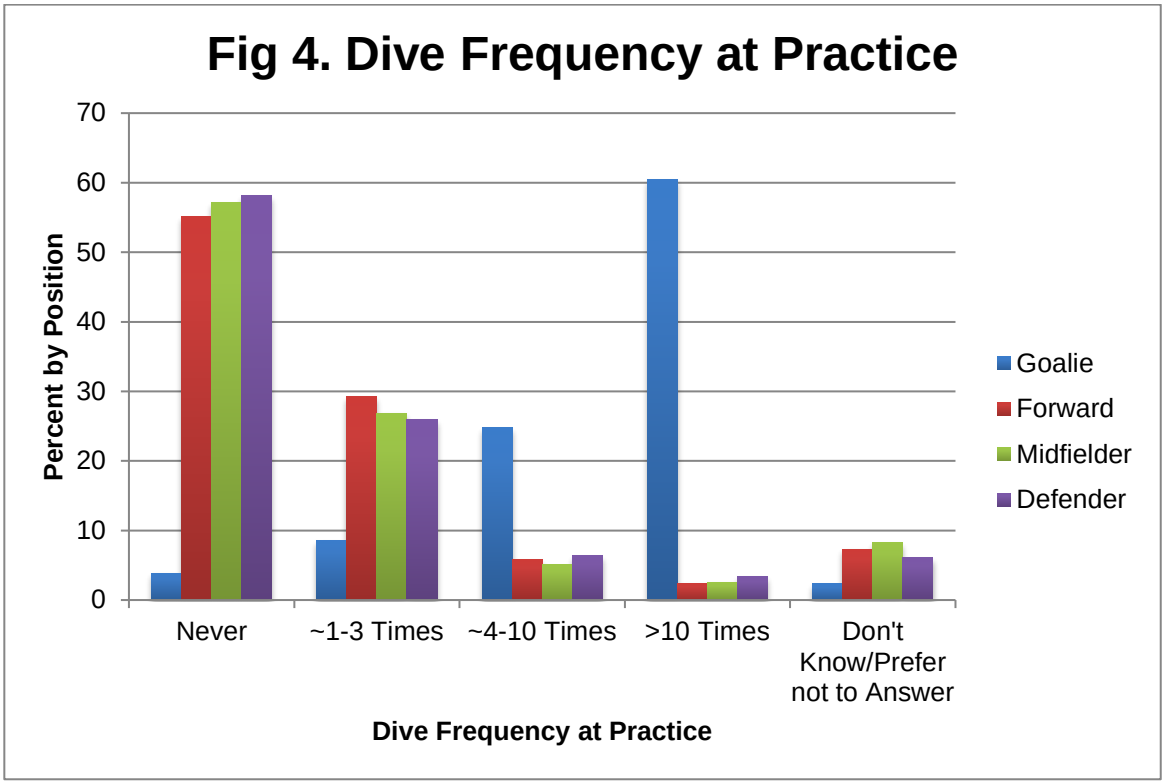


Fig 4. Dive Frequency at Practice
70
60
50
40
30
20
10
0
Percent by Position
Never
~1-3 Times
~4-10 Times
>10 Times
Don't Know/Prefer not to Answer
Goalie
Forward
Midfielder
Defender
Dive Frequency at Practice

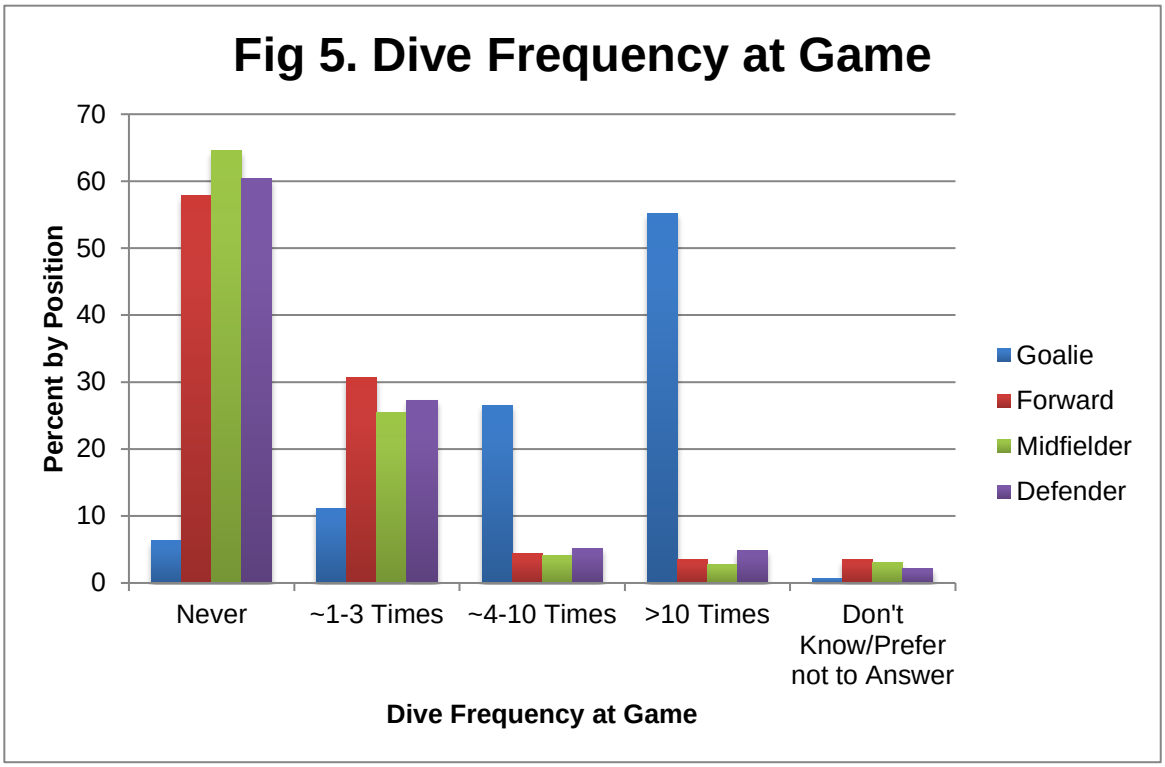


Fig 5. Dive Frequency at Game
70
60
50
40
30
20
10
0
Percent by Position
Never
~1-3 Times
~4-10 Times
>10 Times
Don't Know/Prefer not to Answer
Goalie
Forward
Midfielder
Defender
Dive Frequency at Game

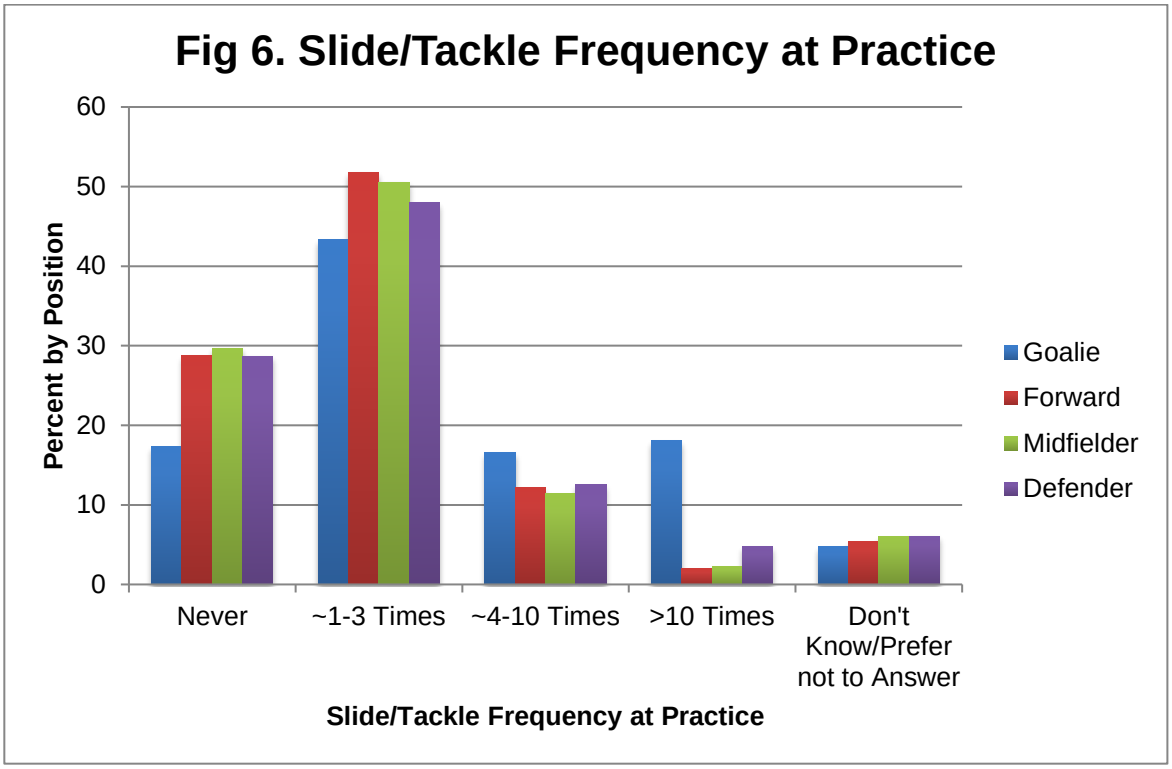


Fig 6. Slide/Tackle Frequency at Practice
60
50
40
30
20
10
0
Percent by Position
Never
~1-3 Times
~4-10 Times
>10 Times
Don't Know/Prefer not to Answer
Goalie
Forward
Midfielder
Defender
Slide/Tackle Frequency at Practice

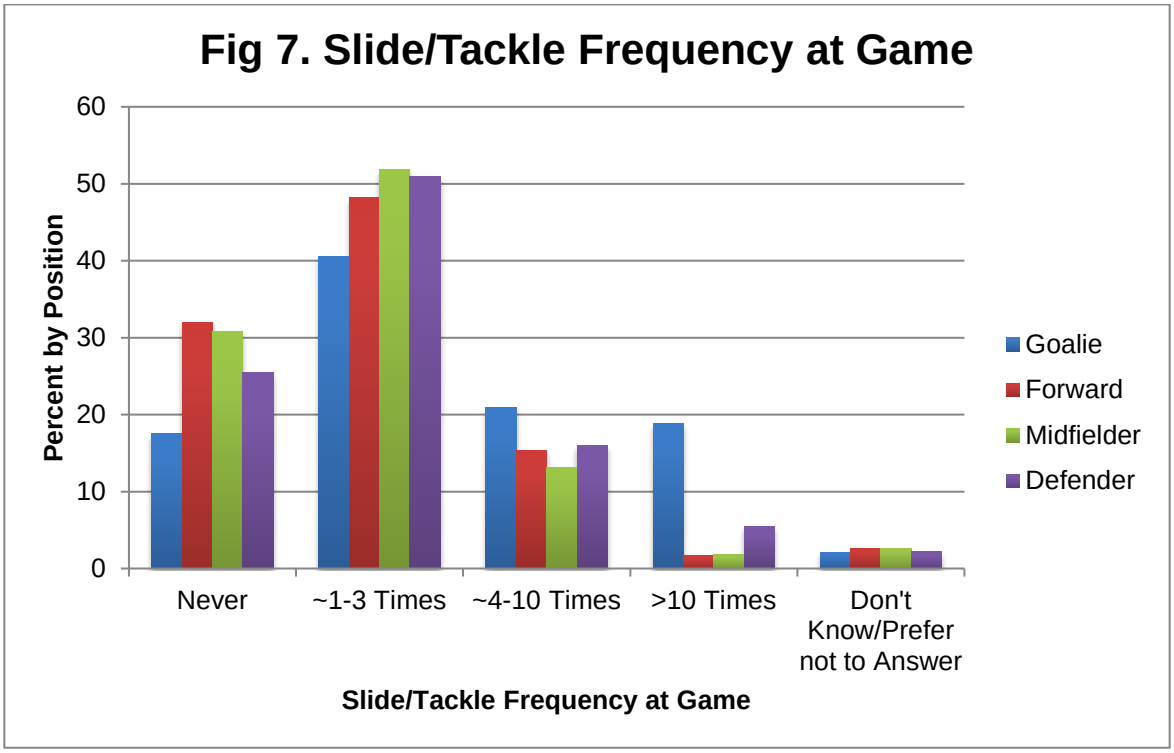


Fig 7. Slide/Tackle Frequency at Game
60
50
40
30
20
10
0
Percent by Position
Never
~1-3 Times
~4-10 Times
>10 Times
Don't Know/Prefer not to Answer
Goalie
Forward
Midfielder
Defender
Slide/Tackle Frequency at Game

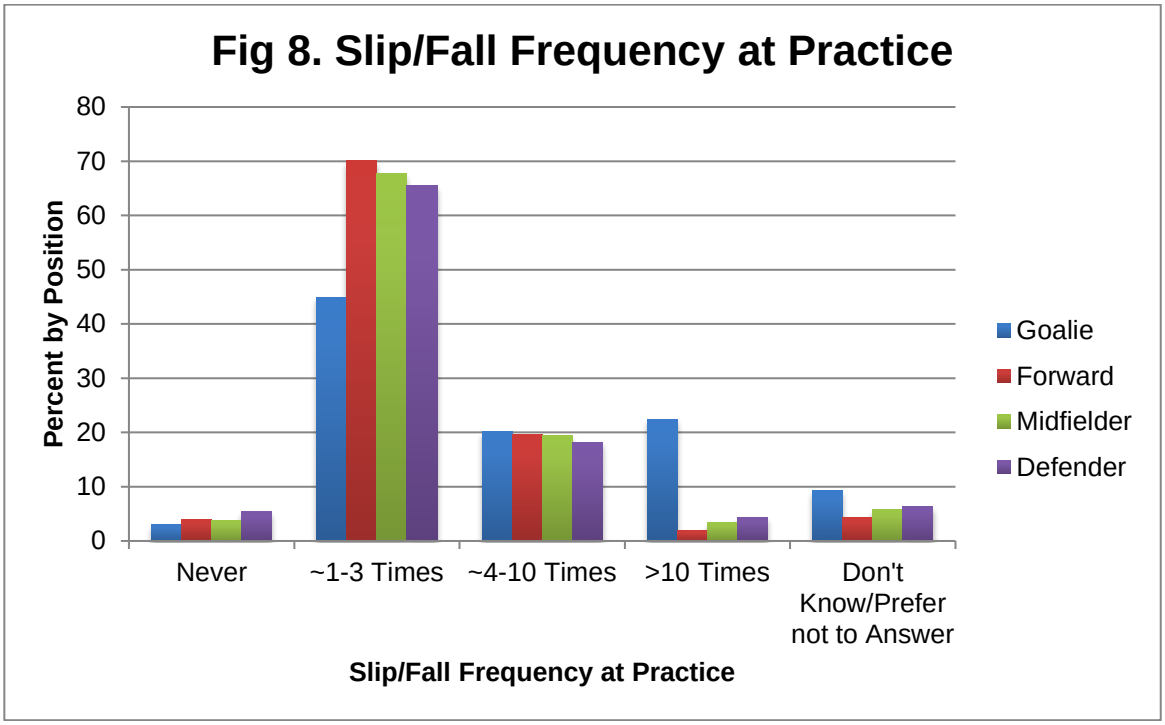


Fig 8. Slip/Fall Frequency at Practice
Percent by Position
80
70
60
50
40
30
20
10
0
Never
~1-3 Times
~4-10 Times
>10 Times
Don't Know/Prefer not to Answer
Goalie
Forward
Midfielder
Defender
Slip/Fall Frequency at Practice

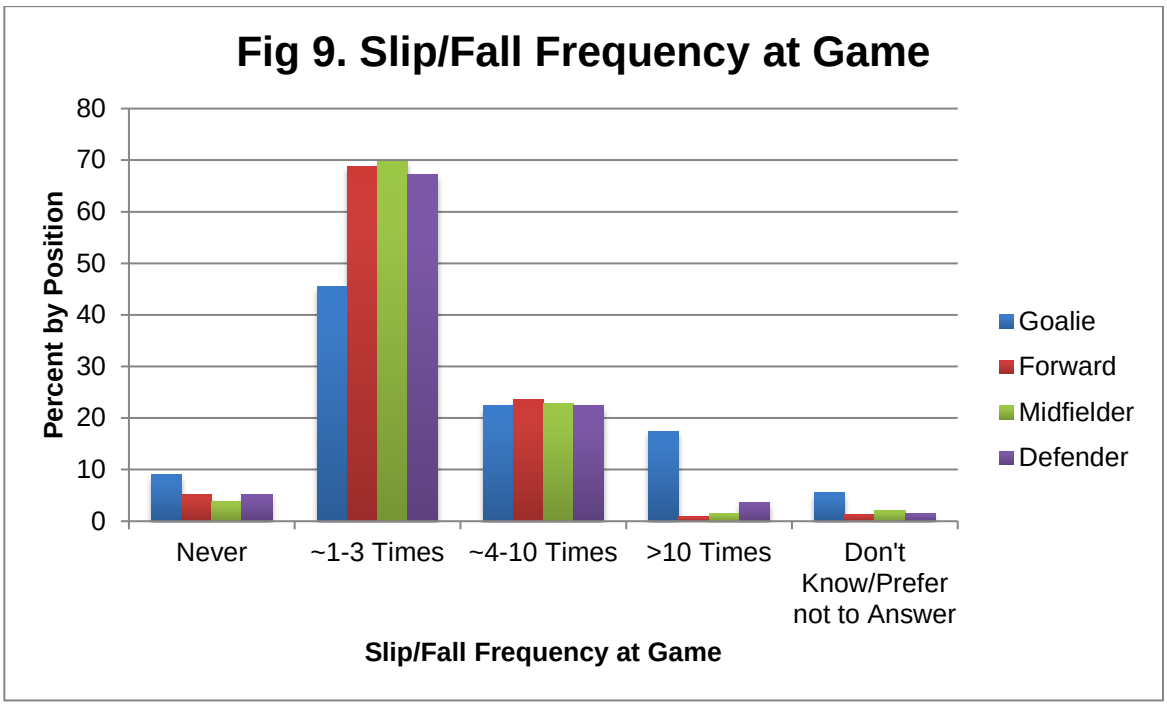
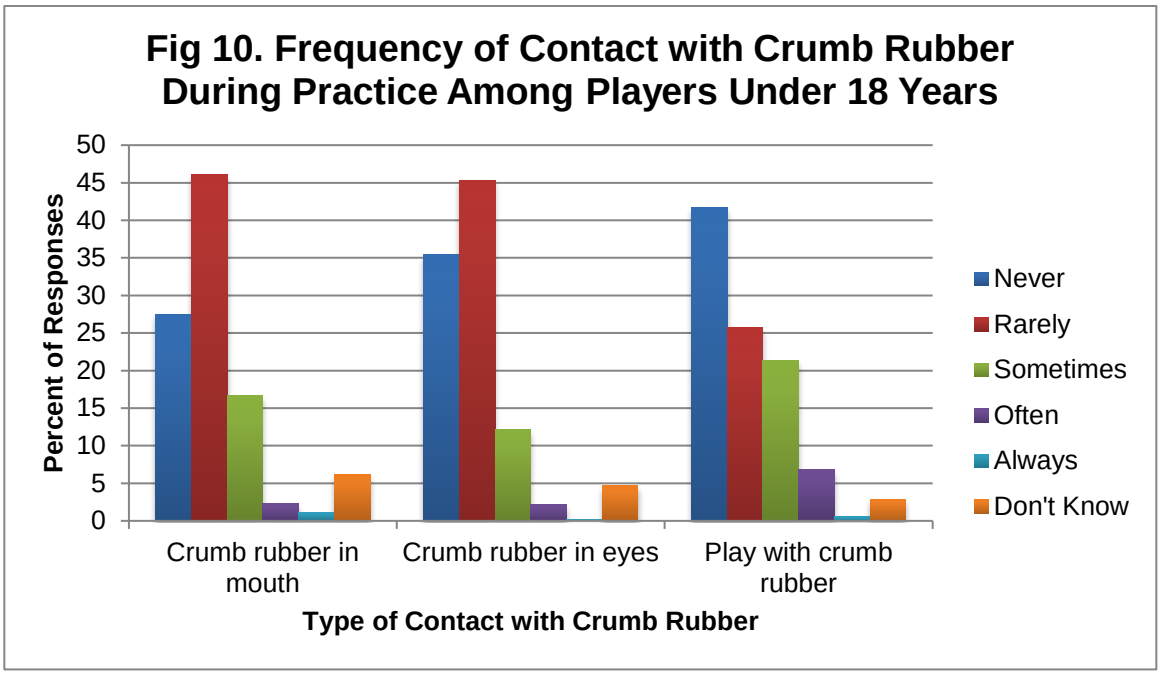


Fig 9. Slip/Fall Frequency at Game
Percent by Position
80
70
60
50
40
30
20
10
0
Never
~1-3 Times
~4-10 Times
>10 Times
Don't Know/Prefer not to Answer
Goalie
Forward
Midfielder
Defender
Slip/Fall Frequency at Game

Figures 10 and 11 illustrate the frequency that players < 18 years old reported crumb rubber in their mouth, eyes, or played with crumb rubber during practices and games. Figures 12 and 13 illustrate the frequency of these contacts with crumb rubber during practices and games among players ≥ 18 years old.

The majority of soccer players reported "Rarely" getting crumb rubber in their mouths or eyes. Additionally, there were no large differences in the frequency of these contacts with crumb rubber during practices and games. Among all participants, the frequency of playing with crumb rubber was slightly greater during practices than games. The distribution of the frequencies of players getting crumb rubber in their mouths, eyes, or playing with crumb rubber during practices and games was also relatively similar for players <18 years and ≥ 18 years old.



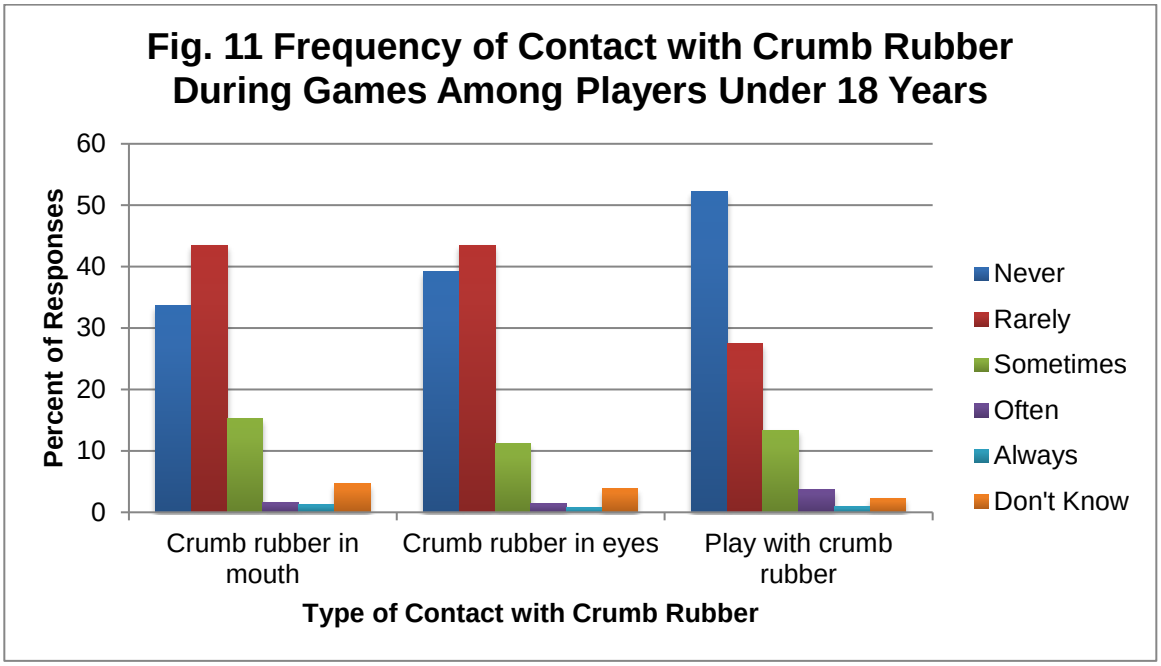


Fig. 11 Frequency of Contact with Crumb Rubber During Games Among Players Under 18 Years
Percent of Responses
60
50
40
30
20
10
0
Crumb rubber in mouth
Crumb rubber in eyes
Play with crumb rubber
Type of Contact with Crumb Rubber
Never
Rarely
Sometimes
Often
Always
Don't Know

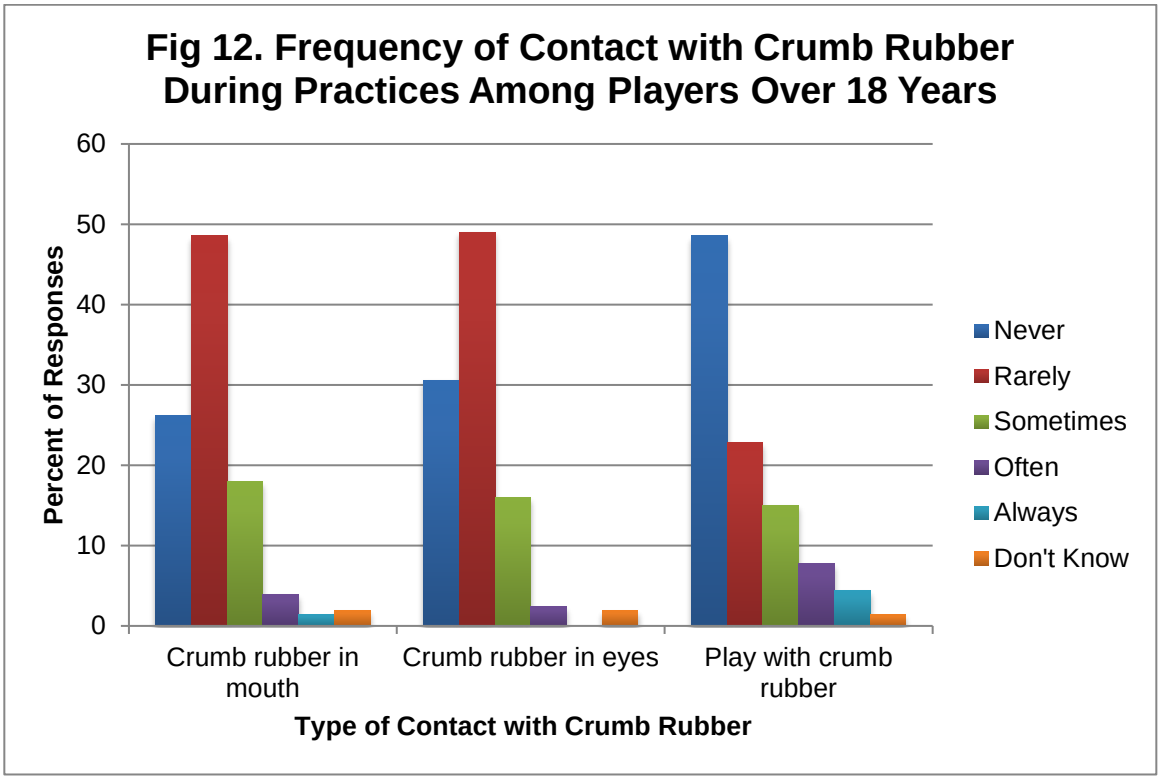
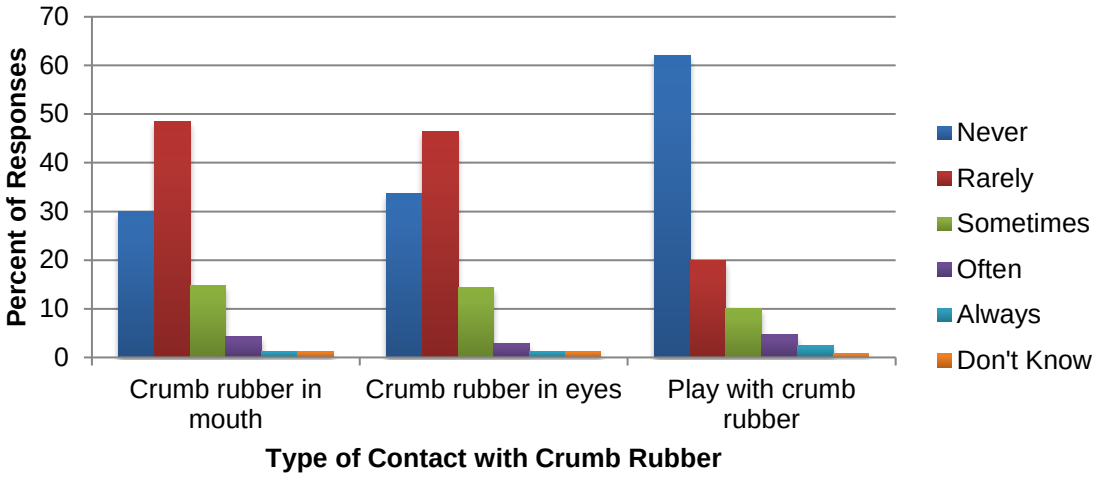


Fig 12. Frequency of Contact with Crumb Rubber During Practices Among Players Over 18 Years
Percent of Responses
60
50
40
30
20
10
0
Crumb rubber in mouth
Crumb rubber in eyes
Play with crumb rubber
Type of Contact with Crumb Rubber
Never
Rarely
Sometimes
Often
Always
Don't Know

Fig 13. Frequency of Contact with Crumb Rubber During Games Among Players Over 18 Years



4.2.7 Food and Water Consumption

Table 10 highlights the amount of time before practices and games participants reported eating or having a snack or meal. Table 11 highlights the frequency participants reported having a snack during practices and games. While the most common response was 1-3 hours, more participants reported having eaten <1 hour before practices than before games (31.3% vs. 19.0%, respectively). The majority of participants indicated they never had a snack during practices or games. Less than 1% of participants reported having a snack more than two times during practices or games (Table 11).

Table 10. Amount of time before practices and games participants reported eating or having a snack

	Practice n (%)	Game n (%)
< 1 Hour	253 (31.3)	154 (19.0)
> 1 -3 Hours	419 (51.8)	592 (73.2)
> 3 Hours	30 (3.7)	37 (4.6)
DK[1]	107 (13.2)	26 (3.2)

[1]Don't Know/Prefer not to answer

Table 11. Frequency of snack consumption during practices and games

	Practice n (%)	Game n (%)
Never	603 (74.5)	574 (71.0)
1 Time	71 (8.8)	181 (22.4)
2 Times	11 (1.4)	23 (2.8)
>2 Times	6 (0.7)	6 (0.7)
DK[1]	118 (14.6)	25 (3.1)

[1]Don't Know/Prefer not to answer

The majority of participants reported consuming between 16 and 32 ounces of water during practices and games (Table 12). Less than 2% of players reported drinking more than 64 ounces of water during practices and games, respectively.

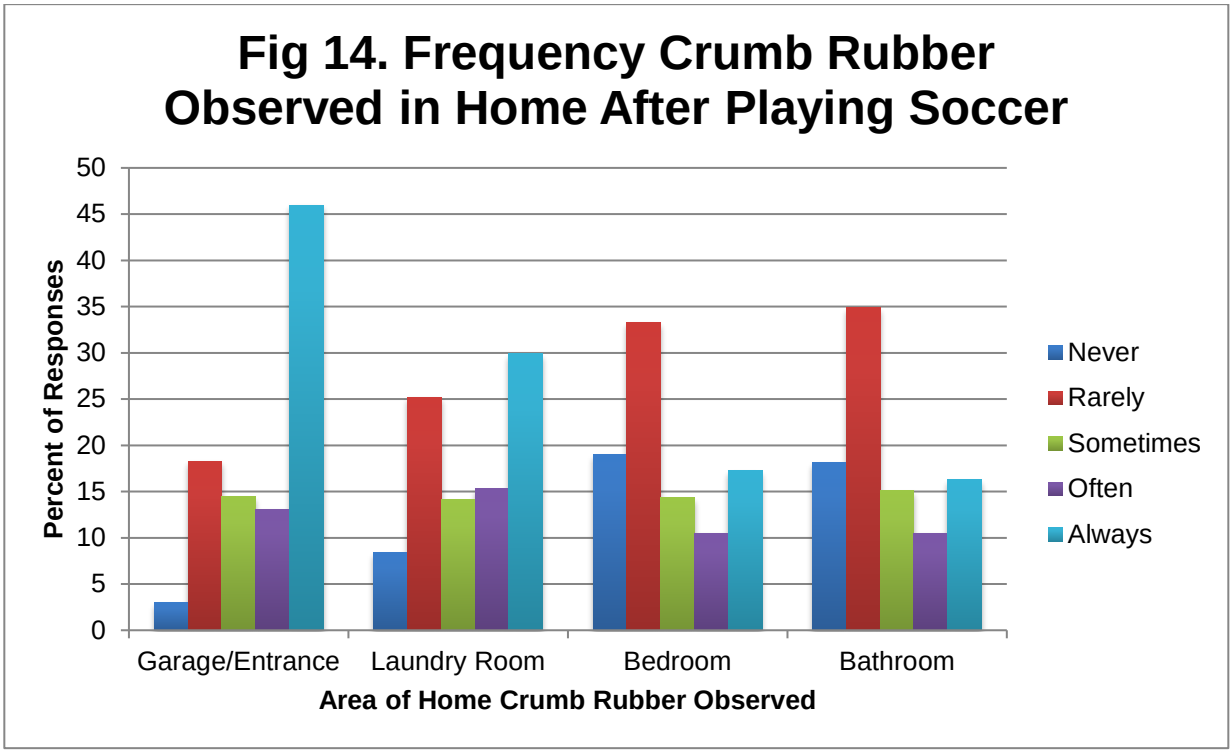
Table 12. Amount of water consumed during practices and games

	Practice n (%)	Game n (%)
8 ounces	31 (3.8)	16 (2.0)
16 ounces	194 (24.0)	161 (19.9)
24 ounces	258 (31.9)	275 (34.0)
32 ounces	185 (22.9)	242 (29.9)
48 ounces	22 (2.7)	48 (5.9)
64 ounces	22 (2.7)	40 (4.9)
> 64 ounces	6 (0.7)	14 (1.7)
DK[1]	91 (11.3)	13 (1.6)

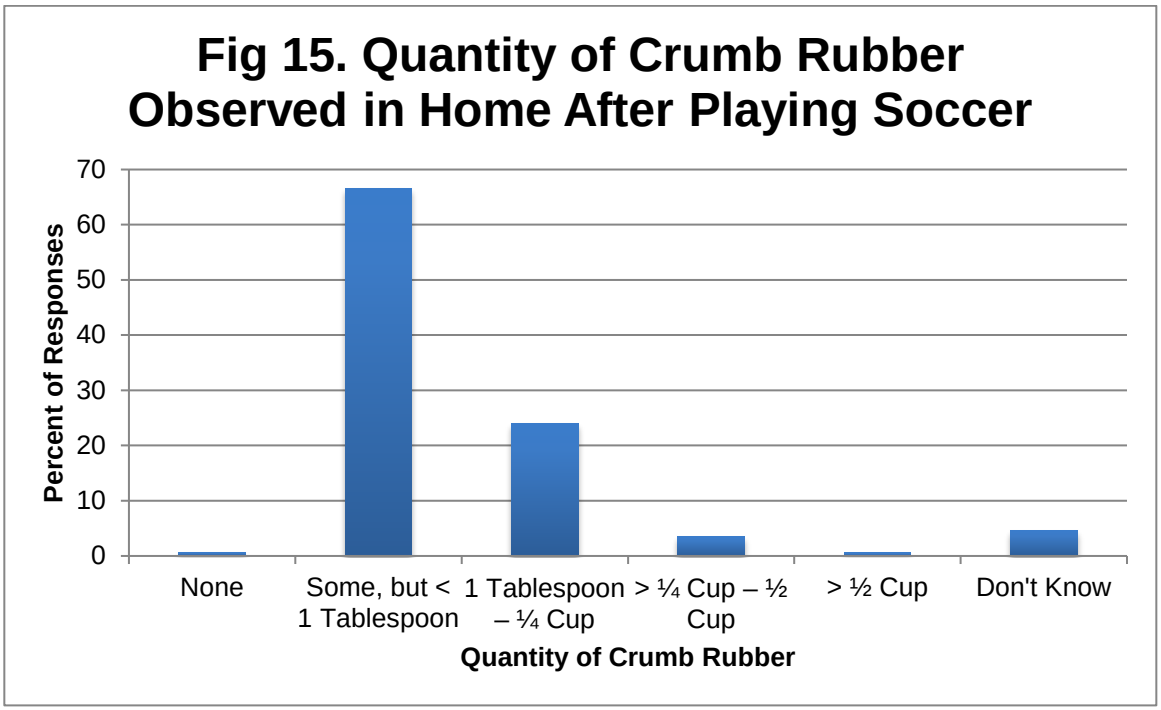
[1]Don't Know/Prefer not to answer

4.2.8 Crumb Rubber Take-Home Exposure Pathway

Figure 14 illustrates the frequency players and parents/guardians of players reported observing crumb rubber in various locations around the home after playing soccer on a synthetic turf field with crumb rubber. Nearly 46% of participants reported "always" observing crumb rubber in the garage/mudroom/entrance to their home. While participants reported observing crumb rubber in their laundry rooms, bedrooms, and bathrooms less frequently, 29.9%, 17.3%, and 16.3% of participants still reported "always" observing crumb rubber in these parts of their homes, respectively, after playing soccer on a synthetic turf field with crumb rubber. Only 18.3% and 30.0% of participants reported wiping, cleaning, or removing socks, shoes, shin guards, or other equipment more than 75% of the time before entering their car and their house, respectively (data not shown). These results underscore the potential importance of residential contamination and take-home exposure pathways.



When asked about the quantity of crumb rubber observed in their home each time after playing soccer on a synthetic turf field, the majority of participants reported they find some crumb rubber, but less than one tablespoon (Figure 15).



Figures 16 and 17 illustrate the frequencies that parents/guardians and players reported observing crumb rubber in their (or their child's) water bottle, on clothes, or on their body after playing soccer on a synthetic turf field with crumb rubber. The majority of participants reported never observing crumb rubber in their water bottle after playing soccer and observing crumb rubber on their clothes or on their bodies 0-25% of the time after playing soccer.

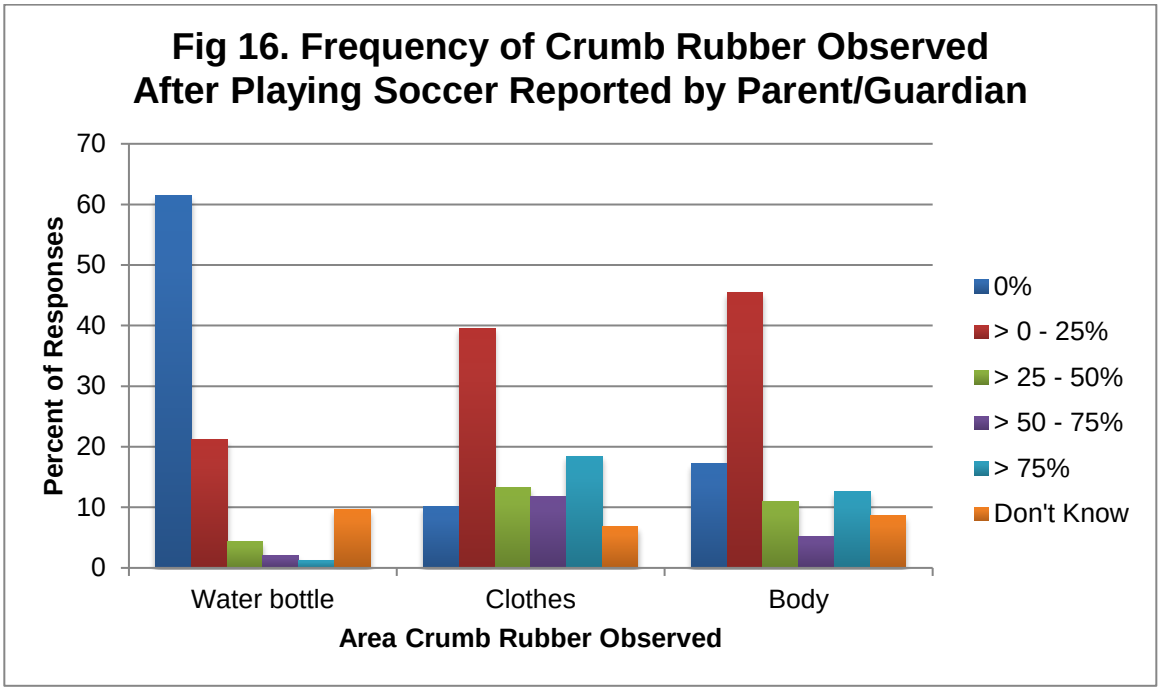


Fig 16. Frequency of Crumb Rubber Observed After Playing Soccer Reported by Parent/Guardian
Percent of Responses
70
60
50
40
30
20
10
0
Water bottle
Clothes
Body
Area Crumb Rubber Observed
0%
> 0 - 25%
> 25 - 50%
> 50 - 75%
> 75%
Don't Know

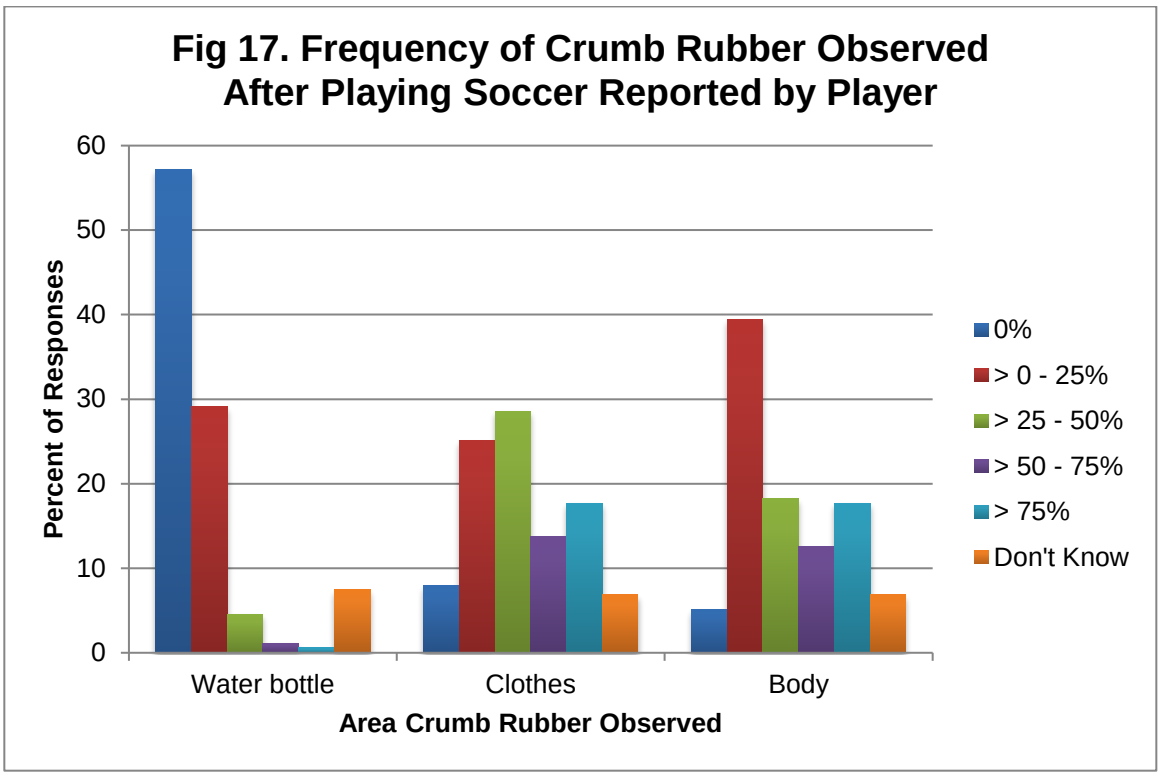
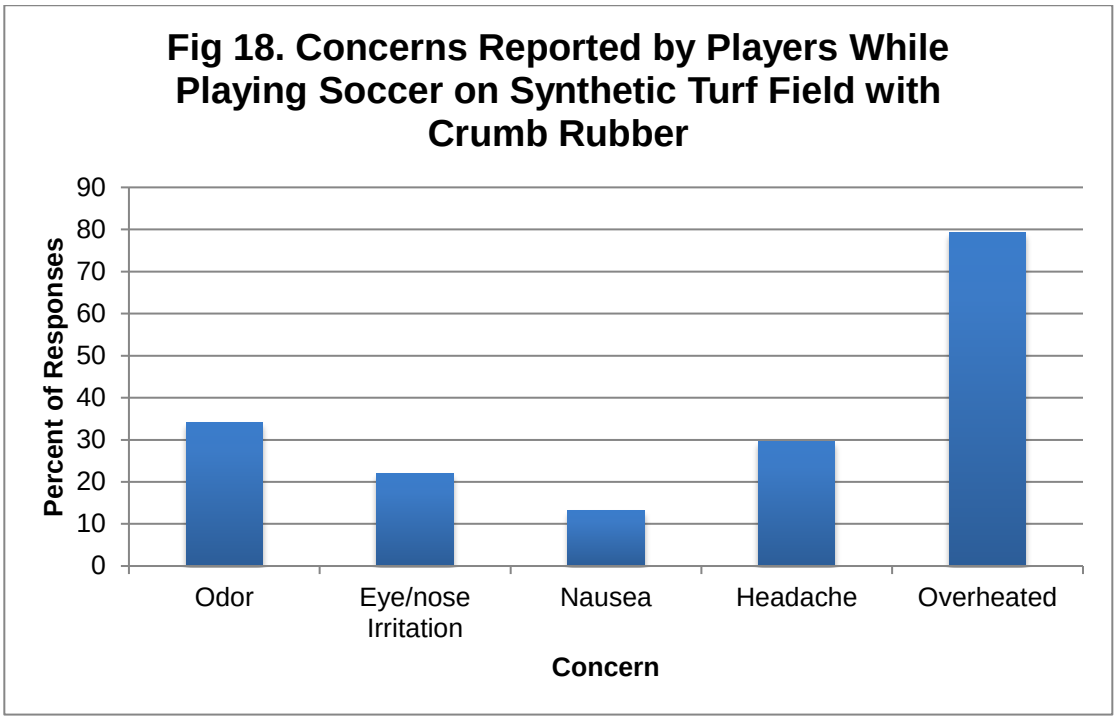


Fig 17. Frequency of Crumb Rubber Observed After Playing Soccer Reported by Player
Percent of Responses
60
50
40
30
20
10
0
Water bottle
Clothes
Body
Area Crumb Rubber Observed
0%
> 0 - 25%
> 25 - 50%
> 50 - 75%
> 75%
Don't Know

4.2.9 Participant Concerns

Figure 18 illustrates the percent of participants that reported ever noticing an odor, experiencing eye/nose irritation, nausea, or headaches, or feeling overheated while playing soccer on a synthetic turf field. Anecdotally, many players and parents have expressed concerns regarding the temperature of the synthetic turf fields with crumb rubber, and, unsurprisingly, nearly 80% of participants reported ever feeling overheated on these fields.



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Section 3.3
Playground Characterization Study

Section 3.3.1
Draft Playground Sampling Protocols

This section presents the draft protocol for playground sampling. We may modify the protocol based on inputs received in this meeting and the testing results from the pilot study. We will collect roller samples while the instruments are collecting the air and particle samples

PLAYGROUND CHARACTERIZATION STUDY:

Draft Playground Sampling Protocols

1. Playground Study

The California Office of Environmental Health Hazard Assessment (OEHHA) is conducting a small-scale study of the potential health effects associated with the use of playground mats made with recycled waste tires. OEHHA proposes to collect surface and environmental samples from outdoor playground mats to characterize the chemicals that may be released from the playground mats. Scientists from OEHHA and Lawrence Berkeley National Laboratory (LBNL) will collect surface samples from and conduct environmental measurements on a few playgrounds at selected locations in California. The analytical data will be used to assess the multi-route exposure to these chemicals by young children who play on these playground mats.

1.1. Surface Sampling Methods

OEHHA and LBNL developed the surface sampling protocols for the playground characterization study. The surface sampling will employ two standard methods: the American Society for Testing and Materials (ASTM) Standard D6333-17[1] "*Standard Practice for the Collection of Dislodgeable Pesticide Residues from Floors*" for dislodgeable residues and the ASTM Standard D5438-05[2] "*Standard Practice For the Collection of Floor Dust for Chemical Analysis*" for "surface dust" collections.
Up to three locations will be identified on each playground mat to provide a range of conditions (light, cover, wear and general condition) that represent the surface. At each location, two adjacent sampling areas each of one square meter will be marked using low residue masking tape (Figure 1). One area will be used to collect samples for metal analysis and the other for organic chemical analysis. Samples will be collected in a stepwise approach. Firstly, two total dislodgeable residue sample (dislodgeable fraction of surface dust + dislodgeable surface residue) will be collected using the roller sample method (described below) along the outside edge of each marked sample area (Figure 1, areas A and B).

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[1] ASTM D6333-17, Standard Practice for Collection of Dislodgeable Pesticide Residues from Floors, ASTM International, West Conshohocken, PA, 2017, www.astm.org

[2] ASTM D5438-17, Standard Practice for Collection of Floor Dust for Chemical Analysis, ASTM International, West Conshohocken, PA, 2017, www.astm.org

Secondly, the surface dust sample will be collected by the vacuuming method (described below) in each of the marked off sample areas, one for metal and one for organic chemical analyses (Figure 1, areas C and D). Thirdly, the dislodgeable residue sample will be collected using the roller sample method over the previously vacuumed sample location, again, one for metal and one for organic chemical analyses (Figure 1, areas E and F). The order of sampling is illustrated in Figure 1.

Briefly, the total dislodgeable residue samples (dislodgeable fraction of surface dust + dislodgeable surface residue) or surface dislodgeable residue samples will be collected using a roller apparatus constructed by LBNL and following the ASTM Standard D6333-17[3]. Figure 2 shows the complete roller apparatus and the extra Teflon rollers. The roller apparatus will be mounted with a polyurethane foam (PUF) sleeve when sampling for organics analysis and with a cellulose cloth (Ghost Wipe) when sampling for metal analysis.

After identifying and clearly marking the sampling locations (as discussed above), the total dislodgeable residue samples (dislodgeable fraction of surface dust + dislodgeable surface residue, Figure 1, Areas A and B) or surface dislodgeable residue samples (Figure 1, Areas E and Fwill be collected following these steps:

1. Mount a pre-cleaned PUF sleeve (sampling for organic chemical analysis, Figure 1, Areas A and E) or wrap a Ghost Wipe cloth (sampling for metal analysis, Figure 1, Areas B and F) onto the appropriate Teflon roller (Table 1 and Figure 2)
2. Mount the appropriate weight to the roller frame adjusted to apply a desired sampling pressure of 8000 Pa on the surface under the roller, corresponding to the approximate weight of a 9 kg (20 lbs) child crawling or walking
3. Place the sample frame over the area to be sampled and push the roller sampler along the frame at a constant speed of approximately 10 cm/s over a sampling distance of 1.0 m and then immediately pull in the reverse direction back over the same sampling area at the same rate of speed, ending at the original starting position
4. Remove the roller from the apparatus using laboratory tongs and transfer the PUF sleeve (Figure 3) to an air-tight pre-cleaned amber glass vial

Repeat the steps 1 to 3 to collect metal samples in the designated area for metal with the Ghost Wipe and store the wipe in a pre-cleaned polypropylene plastic vial after completing sampling. The samples will be processed using methods

[3] ASTM D6333-17, Standard Practice for Collection of Dislodgeable Pesticide Residues from Floors, ASTM International, West Conshohocken, PA, 2017, www.astm.org

developed for synthetic turf field characterization study where the PUF sleeves will be extracted by accelerated solvent extraction and the extracts analyzed by GC/MS and LC/MS for organic chemicals. The Ghost Wipe will be analyzed for metals using ICP/MS.

Surface dust will be collected from playground mats using a HVS3 vacuum sampler. Using the vacuum sampler, surface dust particles of approximately 5 µm mean aerodynamic diameter and larger will be collected by following these steps:

1. Identify and mark off the sampling area for surface dust collection as described above
2. Adjust flows and pressures on vacuum and install clean labeled collection jar (polypropylene for metals analysis or Teflon for organics analysis)
3. Wipe the wheels and nozzle lip with laboratory tissue to remove adhered dust particles immediately before sampling
4. Place the sampler head of vacuum in one corner of the sampling area
5. Turn on, set, and confirm that flow rate and pressure is at desired levels
6. At a constant rate, move the nozzle back and forth in a straight line within the sampling area
7. Repeat sampling the strip with four double passes before angle over the second strip on the next pass
8. Continue sampling until the whole sampling area is vacuumed
9. Remove the catch bottle from the vacuum, and then cap, seal, and label for storage

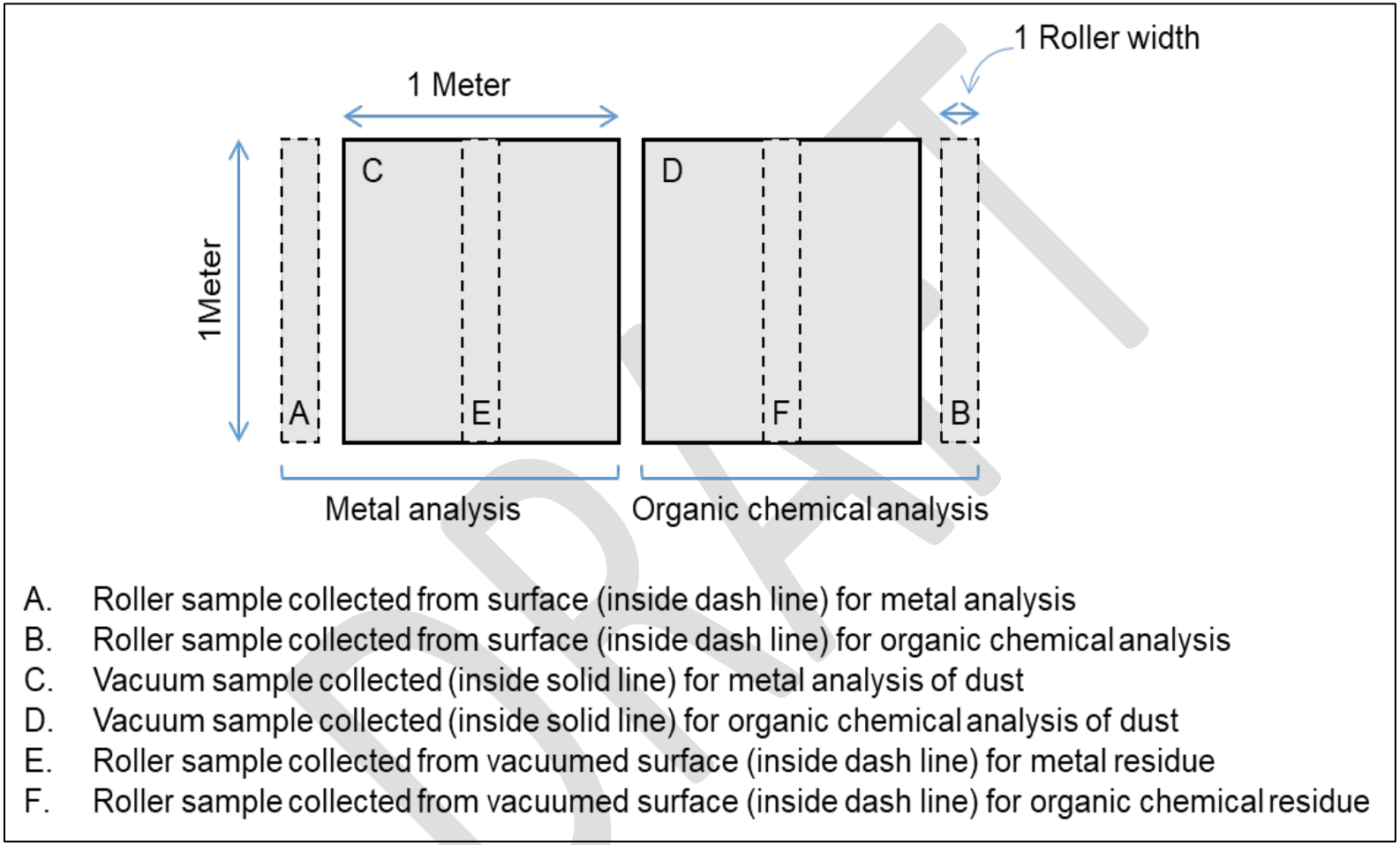
The surface dust samples will be processed and analyzed for organic chemicals by GC/MS and LC/MS and metals by ICP/MS using analytical methods established in the synthetic turf field characterization study.

2. Environmental Sampling Methods

The playground characterization study will include the collection of chemical vapor in the air and airborne particle, and playground conditions monitoring. The synthetic turf field sampling study protocols will be followed to collect air and particle samples, and meteorological measurements (e.g., ambient temperature, surface temperature, ambient ozone level) on playgrounds.

Table 1. Roller Apparatus Types for Sample Analysis

Analyte	Roller Type
Organic chemicals	PUF sleeve mounted Teflon roller
Metals	Ghost Wipe wrapped Teflon Roller



A. Roller sample collected from surface (inside dash line) for metal analysis
B. Roller sample collected from surface (inside dash line) for organic chemical analysis
C. Vacuum sample collected (inside solid line) for metal analysis of dust
D. Vacuum sample collected (inside solid line) for organic chemical analysis of dust
E. Roller sample collected from vacuumed surface (inside dash line) for metal residue
F. Roller sample collected from vacuumed surface (inside dash line) for organic chemical residue

Figure 1. Surface sampling area schematic

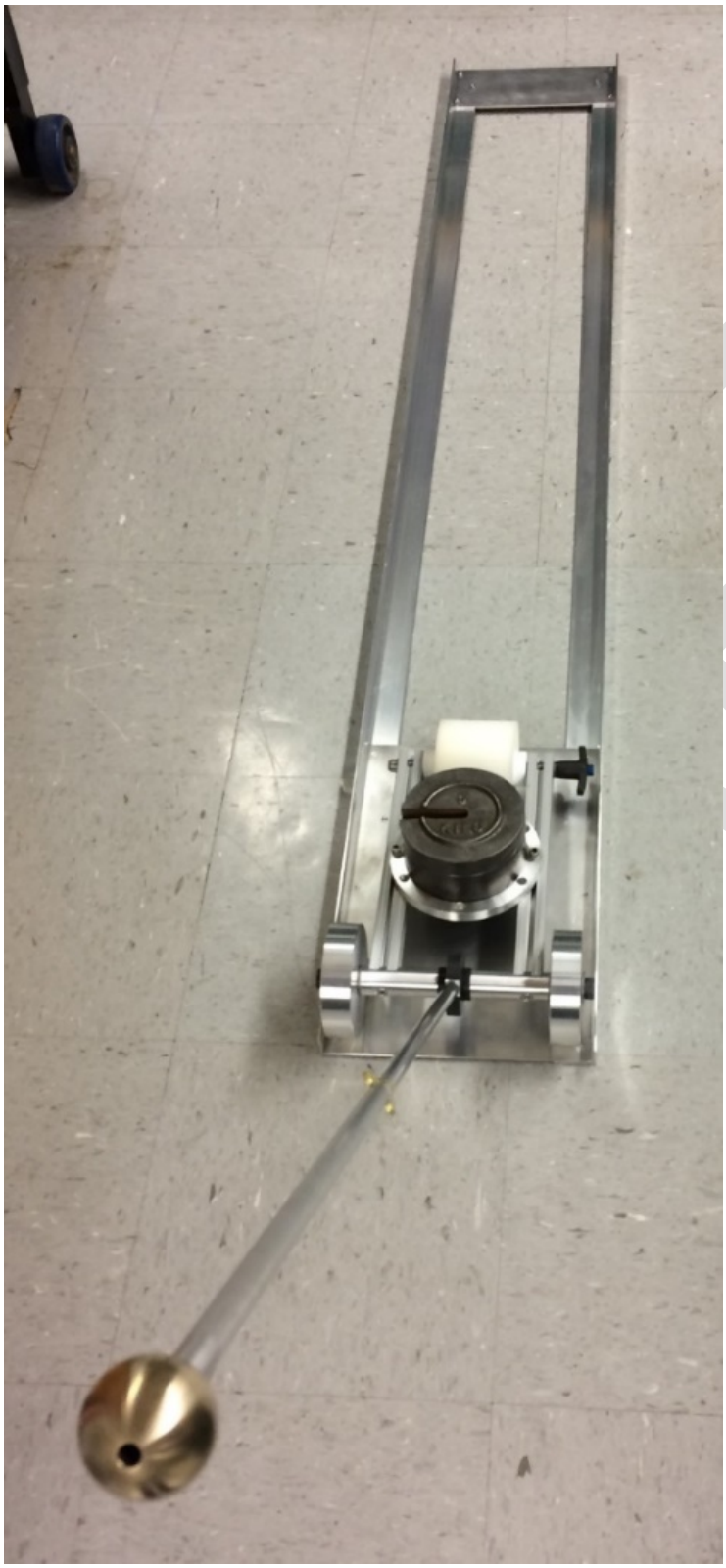


Figure 2. Roller sampler equipped with a PUF ring sampling apparatus and a guide track. The guide track helps keep the roller wheels from contacting the sampling area and define the sampling surface area.

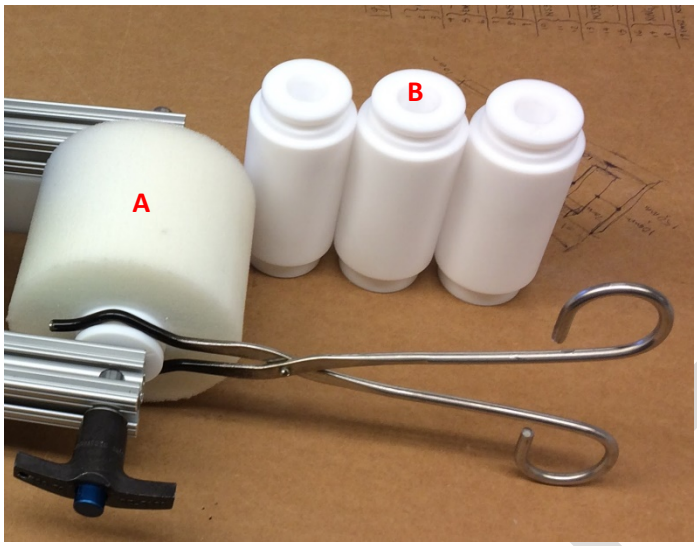


Figure 3. (A) A PUF ring mounted onto a roller sampler. (B) Teflon rollers. Laboratory tongs are used to handle and remove PUF ring and Teflon rollers.

Figure 4. A polyurethane foam (PUF) sleeve mounted on a Teflon roller.

Section 3.3.2
Preliminary Children Hand-To-Mouth Activity Data

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Quantification of Micro-Level Activities from a Pre-existing Dataset of Children Playing on Turf and Playgrounds

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Playground Characterization Study:
Preliminary Children Hand-To-Mouth Activity Data
Synthetic Turf Scientific Advisory Panel Meeting
May 25, 2018

QUANTIFICATION OF MICRO-LEVEL ACTIVITIES FROM A PRE-EXISTING DATASET OF CHILDREN PLAYING ON TURF AND PLAYGROUNDS

1. Objective:

The objective of this study was to quantify dermal and mouthing contact behaviors of children playing on turf and playground structures.

2. Methods:

To quantify the mouthing and dermal contact behavior while children play on turf and playground, we analyzed existing dataset and video footage of a total of 56 children.

2.1. Data collection

We analyzed micro-level activity time series (MLTAS) data from a pre-existing dataset collected by Stanford's Exposure Research Group.

- For this study, children MLTAS data and videotapes were obtained from two previous studies, the Outdoor Residential Exposure Task Force (ORETF) project and the EPA study
- The ORETF project collected MLTAS data for 15 body parts including hands and mouth by videotaping 36 children, aged 1-12 years playing outdoors
- The EPA study gathered MLTAS data for mouth and hands by videotaping 20 children, aged 1-6 years.
- Details on ORTEF and EPA methods have been previously described (AuYeung *et al.*, 2006; AuYeung *et al.*, 2004; Ferguson *et al.*, 2006)

2.2. Data Processing

The translated plain text files for all 56 children were managed before analyzing the data.

- **For children playing on turf,** the data with locations of yard, garden, and park was grouped as one turf-like location by using RStudio (Table 1a). The object/surfaces were selected as presented in Table 1a.
- **For children playing on playgrounds,** since playground was not categorized in the previous studies, all of the existing videotapes (n = 56) were re-watched to only select the footage where a playground structure was observed. The exact footage time when children played on playground

structures was recorded and then a specific "playground" location was added to each corresponding data file. The objects/surfaces selected for analysis are presented in Table 1b.

Note: all floor surfaces were grouped in one category for the playground locations (Table 1b) because we are assuming that nowadays many of these floors could be made with synthetic rubber and/or artificial turf

2.3. Data analysis

Using RStudio, right hand, left hand, and mouth contact frequency, hourly contact duration and median contact duration with the selected object categories (Table 1a-1b) were calculated for each child playing on turf and playground structures, separately.

- Contact frequency is the total number of contacts with a specific object divided by the total time that the child was in view. Hourly duration is the total time that hands/mouth were in contact with the object divided by the total time in view. The median duration for each child was calculated from the duration that his/her hands or mouth contacted an object.
- Data was summarized based on age and gender.
- Activity variables (contact frequency, hourly duration and median duration) were evaluated for significant differences between genders and age groups using non-parametric tests.
    - To determine if contact activities correlated with age, Spearman's rank correlation coefficient was computed using STATA.12.
- The data for each contact activity was summarized into five age groups by following the EPA age grouping guidance. The Kruskal-Wallis test was used to assess for comparisons across the five age groups. In case of significant differences by age groups, a binary analysis between the activities of the 1-5 year old children and the 6-12 year old children was conducted by using the Wilcoxon-rank sum test.
    - To determine differences between male and female participants, we used the Wilcoxon-rank sum test.
    - The Wilcoxon-rank sum test was also used to assess differences between right and left hand. If no differences were observed, then both hands combined will be reported.

2.4. Results

2.4.1. Children's description and footage length

Overall, 56 children (27 males and 29 females) were playing on turf and 24 children (11 males and 13 females) were playing on playground structures at some during the video recording.

There were no children in the older age group (11 to < 16 years old) playing on playgrounds.

- See Table 2a and Table 2b for details
- See Table 2c and Table 2d for details on participants divided into two age groups and gender

Approximately a total of 43 hours of footage was collected. The median footage time per child was 112 min (range: 60 – 133 min).

- From the total footage, children spent about 21% of the time playing on a playground and 71% of the time playing on turf. The median time per child spent playing on a playground was 21 min, while the median time spent on turf was 84 min.
- See Table 3a and Table 3b for details

2.4.2. Results from turf location only

Right and left hand results are presented on Tables 4a-b, 5a-b, and 6a-b. However, there were no significant differences on the contact frequency, duration or median duration with object/surfaces between right hand and left hand; therefore, both hands combined was summarized (Table 4c, 5c, 6c).

- The median grass contact frequency for *both hands* combined was 4.1 events per hour. The hourly contact duration for *both hands* was 0.2 min/h and the median contact duration was 2 seconds.

For the mouthing events, results are presented in Tables 4d, 5d, and 6d.

- The *mouthing* frequencies were 8.1 events/h and 11.8 events/h for hands and non-dietary objects, respectively.
- The median hourly *mouthing* duration was 1.0 min/h for all objects.
- Median *mouthing* contact duration was 1 .0s and 5.0 s for hands and non-dietary objects, respectively.

For the age and gender differences:

- Frequency, duration and median duration for both hands contact activities are presented on Tables 7a-c. There were no significant differences across US EPA age grouping and both hand activities.
- For mouthing activities, the frequency duration and median duration are presented on Tables 8a-c (EPA age groups) and Table 8d-c (two age groups).
- Age was negatively correlated ($p < 0.05$) with the duration and median duration of mouthing activities for non-dietary objects and total objects (Table 9). Age was also negatively correlated ($p < 0.05$) for with the median duration of mouthing activities for hands (Table 9).
- We found significant differences across US EPA age groupings in *mouthing* hourly contact duration with non-dietary objects and in mouthing median duration with hands, non-dietary, total objects (Table 10; Figure 1a-b).
- There were significant differences between younger (1-5 years old) and older children (6-12 years old) groups for the *mouthing* hourly duration and median duration with non-dietary objects and all objects (Table 11; Figure 1c-d). Also, the *mouthing* median duration was significantly different for hands between these two age groups (Table 11; Figure 1c-d).
- With respect to gender, males had significantly higher hourly contact duration of *both hands* with non-dietary objects than females (Table 12; Figure 2). There were no other significant differences for mouthing events.

2.4.3. Results from playground location only

Right and left hand results are presented on Tables 13a-b, 14a-b, and 15a-b. However, there were no significant differences on the contact frequency, duration or median duration with object/surfaces between right hand and left hand; therefore, both hands combined was summarized (Tables 13c, 14c, 15c) and by age groupings is summarized in Tables 16a-c.

- The median floors contact frequency for *both of the hands* combined was 12.1 events/h with hourly contact duration of 0.4 min/h and a median contact duration of 2 s (Tables 13c, 14c, 15c).

The mouthing frequencies duration, median duration are presented on Tables 13d, 14d, 15d, respectively, and by age groupings on Table 18a-c. The median mouthing frequencies were 9.8 events/h and 10.2 events/h for hands and non-dietary objects, respectively (Table 13d).

- The median hourly mouthing duration was 0.79 min/h with all objects (Table 14d). Median mouthing contact duration was 1 .0 s and 2.0 s for hands and non-dietary objects, respectively (Table 15d).
- We found a correlation with age and mouthing behavior (Table 19). There were significant differences between younger (1-5 years old) and older children (6-12 years old) groups for the mouthing frequency with non-dietary objects and all objects (Table 20; Figure 3) and for the mouthing median duration with non-dietary objects (Figure 4).

2.4.4. Data Translation

Video was translated using a specialized software, VirtualTimingDeviceTM based on the palette shown in Figure 5 (AuYeung et al., 2006).

Demographics

Table 1a. Selected categories for object/surfaces on turf

	Location
Outdoor (Turf)	Yard, Park, Garden
	Objects categories
Grass	Grass
Dietary objects	Water/beverage, sticky food, other food, food container
Non-Dietary objects	Everything, but dietary categories
Hands*	Hands
All objects/surfaces	Wood wall, wood tools, wood toy, vegetation, hard toys, porous plastic toys, fabric toys, plastic tool, plastic wall, paper, pool water, puddle water, metal wall, metal tool, footwear, carpet, wood floor, tile floor, rock floor, sidewalk, dirt

* Only used for mouthing events

Table 1b. Selected categories for object/surfaces on playgrounds

	Location
Outdoor	Yard, Park, Garden, Patio, Street, Garage
Specific location	Playground
	Objects categories
Floors	Dirt, Asphalt, Rock floor, wood floor, tile, carpet/mat
Dietary objects	Water/beverage, sticky food, other food, food container
Non-Dietary objects	Everything, but dietary categories
Hands*	Hands
All objects/surfaces	Wood wall, wood tools, wood toy, vegetation, hard toys, porous plastic toys, fabric toys, plastic tool, plastic wall, paper, pool water, puddle water, metal wall, metal tool, footwear, carpet, wood floor, tile floor, rock floor, sidewalk, dirt

* Only used for mouthing events

Table 2a. Number of children playing on turf grouped by age and gender

Age groups					
1 to <2 years	2 to < 3 years	3 to < 6 years	6 to < 11 years	11 to < 16 years	Total
5	5	7	5	5	27
3	2	10	13	1	29
8	7	17	18	6	56

Table 2b. Number of children playing on playground by age and gender

Gender	Age groups					
	1 to <2 years	2 to < 3 years	3 to < 6 years	6 to < 11 years	11 to < 16 years	Total
Male	3	4	4	0	0	11
Female	2	1	4	6	0	13
Total	5	5	8	6	0	24

Table 2c. Number of children playing on turf grouped by two age groups and gender

Gender	Age Groups		
	1 - 5 years old	6 - 12 years old	Total
Male	17	10	27
Female	15	14	29
Total	32	24	56

Table 2d. Number of children playing on playground grouped by two age groups and gender

Gender	Age Groups		
	1 - 5 years old	6 - 12 years old	Total
Male	11	0	11
Female	7	6	13
Total	18	6	24

Footage time

Table 3a. Total time of footage for all 56 children

	Total footage
Total time in hours	43
Total time in minutes	2548
Median total time (min)	112

Table 3b. Time spent on playground (N = 24)

	Time in View	Time not in view
Total time (minutes)	531.0	38.2
Median time (min) per child	21.0	0.3
Percentage of time spent on playground (%)	20.8	1.5

Table 3c. Time spent on turf (N = 56)

	Total time	Time not in view
Total time (minutes)	1812.0	99.5
Median time (min) per child	84.0	2.5
Percentage of time spent on turf (%)	71.1	3.9

Turf Locations:

Table 4a. Right hand Frequency (event/h) while playing on the turf (n = 56)

	Grass	Dietary	Non-Dietary	All Objects
Mean	7.2	3.1	129.4	132.5
SD	17.5	5.4	54.6	54.3
Min	0.0	0.0	57.3	57.3
Median	0.0	0.0	93.8	95.9
p25	2.2	0.1	112.5	115.7
p75	6.8	3.4	152.2	156.0
p95	25.9	16.4	233.2	233.2
p99	122.3	20.7	372.0	373.4
Max	122.3	20.7	372.0	373.4

Table 4b. Left hand Frequency (event/h) while playing on the turf (n = 56)

	Grass	Dietary	Non-Dietary	All Objects
Mean	7.0	3.1	134.2	137.3
SD	18.2	5.2	68.1	67.4
Min	0.0	0.0	9.6	9.6
Median	0.2	0.0	100.0	103.5
p25	1.7	0.2	118.7	127.2
p75	7.0	4.9	146.9	149.6
p95	31.5	17.9	257.8	257.8
p99	129.5	19.6	393.9	395.0
Max	129.5	19.6	393.9	395.0

Table 4c. Both hands object/surface frequency (event/h) (n = 56)

	Grass	Dietary	Non-Dietary	All Objects
Mean	14.5	54.1	423.7	477.8
SD	35.5	58.1	217.3	237.1
Min	0.0	1.4	157.6	207.0
Median	0.6	23.0	302.1	341.7
p25	4.1	37.4	352.8	402.4
p75	15.4	66.1	504.1	571.8
p95	59.2	123.3	770.4	821.7
p99	251.9	322.4	1528.3	1559.9
Max	251.9	322.4	1528.3	1559.9

Table 4d. Mouth frequency (event/h) while playing on the turf (n = 56)

	Grass	Hands	Dietary	Non-Dietary	All Objects
Mean	0.1	12.4	14.0	20.6	34.6
SD	0.3	12.4	30.6	21.7	38.9
Min	0	0.5	0	0	0
p25	0	5.2	0	7.1	8.7
Median	0	8.1	0.8	11.8	19.0
p75	0	15.2	11.0	25.2	55.8
p95	1.1	33.5	70.8	76.6	92.1
p99	1.5	65.1	194.7	83.3	217.2
Max	1.5	65.1	194.7	83.3	217.2

Table 5a. Right hand Duration (min/h) while playing on the turf (n = 56)

	Grass	Dietary	Non-Dietary	All Objects
Mean	0.4	0.8	16.0	16.8
SD	1.0	1.3	2.0	1.7
Min	0.0	0.0	11.0	12.6
Median	0.0	0.0	14.5	15.7
p25	0.1	0.0	16.1	17.2
p75	0.4	1.2	17.5	18.1
p95	2.4	3.8	18.9	18.9
p99	5.9	5.0	19.3	19.3
Max	5.9	5.0	19.3	19.3

Table 5b. LHD duration (min/h) while playing on the turf (n=56)

	Grass	Dietary	Non-Dietary	All Objects
Mean	0.4	0.7	15.7	16.4
SD	1.0	1.3	3.0	2.9
Min	0.0	0.0	4.9	4.9
Median	0.0	0.0	14.4	15.1
p25	0.1	0.0	15.7	16.6
p75	0.4	0.8	17.4	17.9
p95	2.2	3.8	19.5	19.5
p99	6.1	4.3	26.0	26.8
Max	6.1	4.3	26.0	26.8

Table 5c. Both hands object/surface contact duration while playing on turf (min/h) (n =56)

	Grass	Dietary	Non-Dietary	All Objects
Mean	0.9	5.6	50.7	56.3
SD	2.0	5.0	22.1	22.2
Min	0.0	0.0	14.0	14.8
Median	0.0	1.7	38.5	44.1
p25	0.2	3.5	43.9	49.6
p75	0.7	9.2	51.8	58.4
p95	4.6	14.0	100.6	104.1
p99	12.0	23.3	129.3	138.4
Max	12.0	23.3	129.3	138.4

Table 5d. Mouthing duration (min/h) while playing on the turf (n = 56)

	Grass	Hands	Dietary	Non-Dietary	All Objects
Mean	0	0.5	1.2	2	3
SD	0	0.7	2.7	8.0	8.3
Min	0	0	0	0	0
p25	0	0.1	0	0.1	0.3
Median	0	0.2	0	0.3	0.9
p75	0	0.4	1.2	1.4	3.3
p95	0.1	2.3	6.9	4.0	16.6
p99	0.1	3.2	16.6	58.4	58.4
Max	0.1	3.2	16.6	58.4	58.4

Table 6a. Right hand median duration while playing on the turf (seconds) (n = 56)

	Grass	Dietary	Non-Dietary	All Objects
Mean	1.8	14.4	72.1	86.6
SD	1.7	35.7	57.6	69.6
Min	0.0	0.0	17.5	17.5
Median	0.0	0.0	40.5	47.0
p25	1.8	0.5	60.5	65.5
p75	2.5	19.0	83.0	106.0
p95	5.0	71.5	157.5	175.5
p99	8.0	242.0	415.5	447.5
Max	8.0	242.0	415.5	447.5

Table 6b. Left hand median duration while playing on the turf (seconds) (n = 56)

	Grass	Dietary	Non-Dietary	All Objects
Mean	2.6	8.6	69.0	77.5
SD	3.9	11.7	41.9	45.3
Min	0.0	0.0	19.0	25.5
Median	0.3	0.0	45.3	49.5
p25	2.0	0.5	58.3	60.4
p75	2.8	16.8	79.5	85.5
p95	12.5	30.0	155.0	187.5
p99	20.5	42.5	265.5	265.5
Max	20.5	42.5	265.5	265.5

Table 6c. Both hands median duration while playing on the turf (seconds) (n = 56)

	Grass (n=43)	Dietary (n=56)	Non-Dietary (n=56)	All Objects (n=56)
Mean	2.6	8.6	68.8	77.4
SD	2.1	7.1	64.3	64.7
Min	0.5	1.0	17.5	20.5
Median	2.0	6.0	51.4	63.0
p25	2.0	4.0	40.3	47.8
p75	3.0	11.3	76.8	86.0
p95	5.0	25.0	164.0	175.5
p99	13.0	33.5	437.0	446.0
Max	13.0	33.5	437.0	446.0

Table 6d. Mouthing median duration while playing on turf (seconds)

	Grass (n =4)	Hands (n =49)	Dietary (n = 56)	Non-Dietary (n = 56)	All Objects (n = 56)
Mean	1.4	1.9	6.6	6.3	12.9
SD	0.8	1.9	18.4	6.8	20.7
Min	1	0.5	0	0	0
p25	1.0	1.0	0.0	1.8	4.0
Median	1.0	1.0	1.5	5.0	7.3
p75	1.75	2	6.5	8.5	14
p95	2.5	5	19.5	23	57.5
p99	2.5	12	123	38	124
Max	2.5	12	123	38	124

Table 7a. Both hands frequency (event/h) while playing on turf (n = 56)

Age Group		Grass	Dietary	Non - Dietary	All Objects
< 2	Mean	11.1	43.7	435.6	479.3
	SD	11.8	30.8	75.6	70.5
	Min	0.3	9.5	331.5	394.1
	Median	2.9	22.9	367.8	410.7
	p25	8.5	32.3	441.8	483.5
	p75	14.0	63.3	508.0	544.0
	p95	37.2	103.1	518.1	564.1
	p99	37.2	103.1	518.1	564.1
	Max	37.2	103.1	518.1	564.1
2 to < 3	Mean	5.6	35.1	301.5	336.6
	SD	10.6	15.6	64.0	63.6
	Min	0.0	19.3	178.5	222.5
	Median	0.0	20.7	274.0	298.9
	p25	2.1	30.6	317.7	338.4
	p75	3.2	44.5	344.8	404.4
	p95	29.4	61.6	373.8	406.4
	p99	29.4	61.6	373.8	406.4
	Max	29.4	61.6	373.8	406.4
3 to < 6	Mean	9.8	66.5	497.6	564.2
	SD	17.2	70.7	327.1	350.4
	Min	0.0	17.1	234.9	259.4
	Median	0.0	26.8	296.3	359.3
	p25	2.1	49.5	345.9	379.6
	p75	17.4	73.4	617.8	642.3
	p95	70.0	322.4	1528.3	1559.9
	p99	70.0	322.4	1528.3	1559.9
	Max	70.0	322.4	1528.3	1559.9
6 to < 11	Mean	20.0	56.6	382.0	438.6
	SD	58.2	70.0	159.4	186.4
	Min	0.0	8.2	157.6	207.0
	Median	0.0	19.4	301.3	321.0
	p25	6.4	31.1	354.3	391.9
	p75	11.3	49.4	487.5	586.1
	p95	251.9	300.4	751.4	797.0
	p99	251.9	300.4	751.4	797.0
	Max	251.9	300.4	751.4	797.0
11 to < 16	Mean	26.6	47.3	466.1	513.5
	SD	23.8	39.6	172.6	187.2
	Min	0.3	1.4	295.4	298.6
	Median	2.6	3.3	352.8	354.1
	p25	26.2	53.3	434.2	510.1
	p75	45.0	78.6	510.0	600.4
	p95	59.2	94.1	770.4	807.4
	p99	59.2	94.1	770.4	807.4
	Max	59.2	94.1	770.4	807.4

Table 7b. Both hands duration (min/h) while playing on turf (n = 56)

Age Group		Grass	Dietary	Non - Dietary	All Objects
	Mean	0.9	6.8	47.4	54.2
	SD	1.6	4.8	4.7	6.0
	Min	0.0	0.5	39.0	44.1
	Median	0.1	2.1	45.0	50.4
< 2	p25	0.5	7.5	47.5	54.2
	p75	0.6	10.7	50.5	59.6
	p95	4.8	13.3	54.2	61.2
	p99	4.8	13.3	54.2	61.2
	Max	4.8	13.3	54.2	61.2
	Mean	0.8	5.0	61.3	66.3
	SD	1.7	2.7	25.7	26.2
	Min	0.0	1.6	39.2	43.3
	Median	0.1	3.5	39.7	46.7
2 to < 3	p25	0.2	3.6	47.7	49.5
	p75	0.4	7.5	91.6	100.7
	p95	4.6	9.1	100.5	104.1
	p99	4.6	9.1	100.5	104.1
	Max	4.6	9.1	100.5	104.1
	Mean	0.7	5.5	47.2	52.7
	SD	1.4	4.1	18.4	19.5
	Min	0.0	1.2	33.7	39.2
	Median	0.0	2.0	37.5	43.7
3 to < 6	p25	0.1	4.9	41.6	46.9
	p75	0.4	9.1	47.7	51.9
	p95	4.6	12.8	111.0	122.6
	p99	4.6	12.8	111.0	122.6
	Max	4.6	12.8	111.0	122.6
	Mean	1.1	5.4	48.0	53.4
	SD	2.8	6.6	23.2	21.9
	Min	0.0	0.7	14.0	14.8
	Median	0.1	1.1	34.6	42.2
6 to < 11	p25	0.3	1.9	43.6	48.2
	p75	0.7	9.4	52.7	56.6
	p95	12.0	23.3	100.6	102.6
	p99	12.0	23.3	100.6	102.6
	Max	12.0	23.3	100.6	102.6
	Mean	1.4	5.7	61.0	66.6
	SD	1.8	5.5	35.5	36.7
	Min	0.0	0.0	37.2	37.8
	Median	0.1	0.4	37.7	49.6
11 to < 16	p25	0.6	5.6	46.5	51.7
	p75	3.0	10.1	68.6	70.7
	p95	4.2	12.4	129.3	138.4
	p99	4.2	12.4	129.3	138.4
	Max	4.2	12.4	129.3	138.4

Table 7c. Both hands median duration (seconds) while playing on turf

Age Group		Grass (n=43)	Dietary (n=56)	Non - Dietary (n=56)	All Objects (n=56)
< 2	Mean	2.3	7.8	55.0	62.8
	SD	1.0	8.1	22.4	28.5
	Min	0.8	2.0	29.5	37.0
	Median	2.0	3.0	41.3	45.3
	p25	2.0	5.5	49.0	56.3
	p75	3.0	8.3	64.9	67.6
	p95	4.0	27.0	100.0	127.0
	p99	4.0	27.0	100.0	127.0
	Max	4.0	27.0	100.0	127.0
2 to < 3	Mean	3.5	6.0	82.4	88.4
	SD	1.4	4.1	86.5	86.6
	Min	2.0	1.0	30.5	33.0
	Median	2.5	3.5	32.0	34.0
	p25	3.0	5.0	55.0	68.0
	p75	5.0	8.0	76.5	84.5
	p95	5.0	14.0	275.0	280.0
	p99	5.0	14.0	275.0	280.0
	Max	5.0	14.0	275.0	280.0
3 to < 6	Mean	2.2	8.5	81.5	90.0
	SD	2.1	6.4	93.9	94.3
	Min	0.5	1.0	18.5	23.5
	Median	1.0	3.0	41.5	51.5
	p25	1.5	6.0	62.0	69.5
	p75	3.0	11.0	78.0	88.0
	p95	8.0	22.0	437.0	446.0
	p99	8.0	22.0	437.0	446.0
	Max	8.0	22.0	437.0	446.0
6 to < 11	Mean	2.9	10.4	60.7	71.1
	SD	3.2	8.7	40.5	39.5
	Min	0.5	3.0	17.5	20.5
	Median	2.0	4.3	31.0	48.0
	p25	2.0	6.0	45.1	59.3
	p75	3.0	16.5	78.5	88.0
	p95	13.0	33.5	164.0	175.5
	p99	13.0	33.5	164.0	175.5
	Max	13.0	33.5	164.0	175.5
11 to < 16	Mean	2.3	7.2	60.2	67.4
	SD	0.5	5.4	24.8	29.3
	Min	2.0	1.0	36.0	39.0
	Median	2.0	3.0	47.0	53.0
	p25	2.0	6.0	51.4	54.9
	p75	3.0	13.0	70.0	83.0
	p95	3.0	14.0	105.5	119.5
	p99	3.0	14.0	105.5	119.5
	Max	3.0	14.0	105.5	119.5

Table 7d. Both hands frequency (event/h) while playing on turf (two age groups)

Age Group		Grass	Dietary	Non - Dietary	All Objects
1 - 5 years	Mean	9.2	54.0	439.2	493.2
	SD	14.5	55.1	251.9	271.3
	Min	0.0	9.5	178.5	222.5
	Median				
	n	0.6	24.5	299.6	355.3
	p25	3.2	42.0	345.4	397.8
	p75	14.0	63.3	508.0	544.0
	p95	37.2	105.6	837.9	1160.3
	p99	70.0	322.4	1528.3	1559.9
	Max	70.0	322.4	1528.3	1559.9
6 - 12 years	Mean	21.6	54.3	403.0	457.3
	SD	51.3	63.1	163.2	185.5
	Min	0.0	1.4	157.6	207.0
	Median				
	n	1.1	17.1	305.2	323.8
	p25	6.9	34.5	361.6	417.4
	p75	15.8	74.1	499.3	593.2
	p95	59.2	123.3	751.4	797.0
	p99	251.9	300.4	770.4	807.4
	Max	251.9	300.4	770.4	807.4

Table 7e. Both hands contact duration (min/h) while playing on turf (two age groups)

Age Group		Grass	Dietary	Non - Dietary	All Objects
1 - 5 years	Mean	0.8	5.7	50.3	56.1
	SD	1.5	4.0	18.5	19.2
	Min	0.0	0.5	33.7	39.2
	Median	0.0	2.1	39.4	44.1
	p25	0.2	5.4	43.9	49.5
	p75	0.6	9.1	50.5	59.6
	p95	4.6	12.8	100.5	104.1
	p99	4.8	13.3	111.0	122.6
	Max	4.8	13.3	111.0	122.6
6 - 12 years	Mean	1.2	5.5	51.3	56.7
	SD	2.5	6.3	26.5	26.1
	Min	0.0	0.0	14.0	14.8
	Median	0.1	1.1	36.7	43.2
	p25	0.3	2.0	43.6	50.2
	p75	0.9	9.7	55.0	57.3
	p95	4.2	16.1	100.6	102.6
	p99	12.0	23.3	129.3	138.4
	Max	12.0	23.3	129.3	138.4

Table 7f. Both hands median duration (seconds) while playing on turf

Age Group		Grass (n=43)	Dietary (n=56)	Non - Dietary (n=56)	All Objects (n=56)
1 - 5 years	Mean	2.5	7.8	75.1	82.8
	SD	1.7	6.3	79.0	79.8
	Min	0.5	1.0	18.5	23.5
	Median	1.5	3.0	41.0	47.0
	p25	2.0	5.8	55.3	67.5
	p75	3.0	9.5	76.8	86.0
	p95	5.0	22.0	275.0	280.0
	p99	8.0	27.0	437.0	446.0
	Max	8.0	27.0	437.0	446.0
6 - 12 years	Mean	2.7	9.6	60.5	70.2
	SD	2.6	8.1	36.7	36.7
	Min	0.5	1.0	17.5	20.5
	Median	2.0	4.0	35.0	49.0
	p25	2.0	6.0	47.3	55.5
	p75	3.0	13.5	74.3	85.5
	p95	13.0	25.0	121.5	127.5
	p99	13.0	33.5	164.0	175.5
	Max	13.0	33.5	164.0	175.5

Table 8a. Mouthing frequency (event/h) while playing on turf

Age Group		Grass (n =4)	Hands (n =49)	Dietary (n = 56)	Non-Dietary (n = 56)	All Objects (n = 56)
< 2	Mean	0.3	11.9	2.6	25.8	28.4
	SD	0.6	10.7	4.1	20.2	21.0
	Min	0.0	0.7	0.0	4.6	4.6
	Median	0.0	3.3	0.0	12.2	12.9
	p25	0.0	11.5	0.7	16.6	19.5
	p75	0.5	15.6	3.9	41.2	47.8
	p95	1.5	33.5	11.5	62.0	62.0
	p99	1.5	33.5	11.5	62.0	62.0
	Max	1.5	33.5	11.5	62.0	62.0
2 to < 3	Mean	.	9.9	26.1	15.7	41.8
	SD	.	5.1	33.3	7.7	28.4
	Min	.	3.8	0.0	5.7	13.6
	Median	.	5.2	0.0	8.2	15.2
	p25	.	9.4	2.6	13.6	28.6
	p75	.	14.8	70.8	23.5	76.5
	p95	.	18.2	71.6	26.0	79.8
	p99	.	18.2	71.6	26.0	79.8
	Max	.	18.2	71.6	26.0	79.8
3 to < 6	Mean	0.1	11.0	20.7	23.7	44.5
	SD	0.4	9.4	46.9	25.1	53.0
	Min	0.0	2.0	0.0	0.0	0.7
	Median	0.0	3.4	0.0	9.3	10.5
	p25	0.0	7.3	1.7	12.2	19.1
	p75	0.0	15.5	21.8	34.2	56.0
	p95	1.2	30.2	194.7	83.3	217.2
	p99	1.2	30.2	194.7	83.3	217.2
	Max	1.2	30.2	194.7	83.3	217.2
6 to < 11	Mean	.	8.3	7.1	12.1	19.2
	SD	.	4.5	14.0	17.6	24.3
	Min	.	0.5	0.0	0.0	0.0
	Median	.	5.9	0.0	3.8	7.1
	p25	.	7.5	0.0	7.8	8.7
	p75	.	10.5	8.0	10.1	23.2
	p95	.	18.0	41.4	76.6	76.6
	p99	.	18.0	41.4	76.6	76.6
	Max	.	18.0	41.4	76.6	76.6
11 to < 16	Mean	.	28.5	17.1	35.5	52.6
	SD	.	25.1	22.2	29.0	48.0
	Min	.	1.4	0.0	2.8	5.9
	Median	.	4.0	1.0	5.0	13.4
	p25	.	26.2	9.5	37.7	41.9
	p75	.	48.3	23.7	58.1	81.9
	p95	.	65.1	58.9	71.8	130.7
	p99	.	65.1	58.9	71.8	130.7
	Max	.	65.1	58.9	71.8	130.7

Table 8b. Mouthing contact duration (min/h) while playing on turf

Age Group		Grass (n =4)	Hands (n =49)	Dietary (n = 56)	Non-Dietary (n = 56)	All Objects (n = 56)
< 2	Mean	0.0	1.0	0.6	1.7	2.3
	SD	0.0	1.4	1.2	1.3	1.5
	Min	0.0	0.0	0.0	0.2	0.2
	Median	0.0	0.2	0.0	0.4	1.1
	p25	0.0	0.3	0.0	1.7	2.3
	p75	0.0	2.0	0.5	2.8	3.6
	p95	0.0	3.2	3.5	3.6	4.0
	p99	0.0	3.2	3.5	3.6	4.0
	Max	0.0	3.2	3.5	3.6	4.0
2 to < 3	Mean	.	0.5	0.9	0.6	1.5
	SD	.	0.6	1.2	0.6	1.0
	Min	.	0.1	0.0	0.1	0.5
	Median	.	0.1	0.0	0.2	0.7
	p25	.	0.2	0.3	0.3	1.3
	p75	.	0.5	1.6	1.0	1.9
	p95	.	1.7	3.1	1.9	3.3
	p99	.	1.7	3.1	1.9	3.3
	Max	.	1.7	3.1	1.9	3.3
3 to < 6	Mean	0.0	0.3	1.6	5.0	6.6
	SD	0.0	0.3	2.6	14.2	14.2
	Min	0.0	0.1	0.0	0.0	0.1
	Median	0.0	0.1	0.0	0.2	0.3
	p25	0.0	0.2	0.1	0.4	1.3
	p75	0.1	0.3	1.3	1.5	8.0
	p95	0.1	1.2	7.2	58.4	58.4
	p99	0.1	1.2	7.2	58.4	58.4
	Max	0.1	1.2	7.2	58.4	58.4
6 to < 11	Mean	.	0.2	1.3	0.4	1.7
	SD	.	0.1	3.9	0.9	4.0
	Min	.	0.0	0.0	0.0	0.0
	Median	.	0.1	0.0	0.0	0.1
	p25	.	0.2	0.0	0.1	0.2
	p75	.	0.3	0.2	0.3	0.9
	p95	.	0.5	16.6	4.0	16.6
	p99	.	0.5	16.6	4.0	16.6
	Max	.	0.5	16.6	4.0	16.6
11 to < 16	Mean	.	0.9	1.1	1.1	2.2
	SD	.	0.9	1.5	1.0	2.2
	Min	.	0.0	0.0	0.1	0.4
	Median	.	0.2	0.2	0.2	0.6
	p25	.	0.8	0.6	0.9	1.2
	p75	.	1.4	1.1	1.7	3.8
	p95	.	2.3	4.1	2.8	5.7
	p99	.	2.3	4.1	2.8	5.7
	Max	.	2.3	4.1	2.8	5.7

Table 8c. Mouthing median duration (seconds) while playing on turf

Age Group		Grass (n =4)	Hands (n =49)	Dietary (n = 56)	Non-Dietary (n = 56)	All Objects (n = 56)
< 2	Mean	1.0	3.7	3.9	9.4	13.3
	SD	0.0	3.8	5.5	4.9	7.2
	Min	1.0	1.0	0.0	3.0	3.0
	Median	1.0	1.0	0.0	7.0	7.8
	p25	1.0	2.5	0.5	9.0	13.5
	p75	1.0	4.8	8.3	10.0	19.0
	p95	1.0	12.0	14.0	20.0	23.0
	p99	1.0	12.0	14.0	20.0	23.0
	Max	1.0	12.0	14.0	20.0	23.0
2 to < 3	Mean		1.7	4.1	5.3	9.4
	SD	.	0.9	3.5	1.9	2.5
	Min	.	1.0	0.0	3.0	6.5
	Median	.	1.0	0.0	3.5	7.0
	p25	.	1.5	3.5	5.0	8.5
	p75	.	2.0	8.0	7.0	11.0
	p95	.	3.5	9.0	8.5	13.5
	p99	.	3.5	9.0	8.5	13.5
	Max	.	3.5	9.0	8.5	13.5
3 to < 6	Mean	1.8	1.6	6.7	9.5	16.1
	SD	1.1	1.1	16.0	10.2	23.1
	Min	1.0	0.5	0.0	0.0	0.5
	Median	1.0	1.0	0.0	3.5	4.0
	p25	1.8	1.0	2.0	5.5	7.0
	p75	2.5	2.0	4.0	10.0	15.5
	p95	2.5	5.0	66.0	38.0	89.0
	p99	2.5	5.0	66.0	38.0	89.0
	Max	2.5	5.0	66.0	38.0	89.0
6 to < 11	Mean	.	1.3	8.6	2.8	11.3
	SD	.	1.1	28.7	3.3	28.7
	Min	.	1.0	0.0	0.0	0.0
	Median	.	1.0	0.0	1.0	1.0
	p25	.	1.0	0.0	1.0	3.5
	p75	.	1.0	3.0	5.0	7.5
	p95	.	5.0	123.0	11.0	124.0
	p99	.	5.0	123.0	11.0	124.0
	Max	.	5.0	123.0	11.0	124.0
11 to < 16	Mean	.	1.5	6.7	5.3	11.9
	SD	.	0.5	4.8	2.7	7.1
	Min	.	1.0	0.0	3.0	4.0
	Median	.	1.0	3.0	4.0	7.0
	p25	.	1.5	7.3	4.5	11.3
	p75	.	2.0	9.0	5.0	14.0
	p95	.	2.0	13.5	10.5	24.0
	p99	.	2.0	13.5	10.5	24.0
	Max	.	2.0	13.5	10.5	24.0

Table 8d. Mouthing frequency (event/h) while playing on turf (two age groups)

Age Group		Grass (n =4)	Hands (n =49)	Dietary (n = 56)	Non-Dietary (n = 56)	All Objects (n = 56)
1 - 5 years	Mean	0.1	11.0	17.4	22.5	39.9
	SD	0.4	8.7	37.8	21.0	41.9
	Min	0.0	0.7	0.0	0.0	0.7
	Median	0.0	5.2	0.0	9.5	12.9
	p25	0.0	8.1	1.8	14.2	21.8
	p75	0.0	15.0	16.6	30.1	55.8
	p95	1.2	30.2	71.6	82.2	92.1
	p99	1.5	33.5	194.7	83.3	217.2
	Max	1.5	33.5	194.7	83.3	217.2
6 - 12 years	Mean	0.0	14.3	9.6	18.0	27.6
	SD	0.0	16.4	16.5	22.8	34.0
	Min	0.0	0.5	0.0	0.0	0.0
	Median	0.0	5.1	0.0	4.4	7.1
	p25	0.0	8.0	0.3	8.3	9.8
	p75	0.0	16.6	9.8	22.2	49.2
	p95	0.0	56.7	41.4	71.8	81.9
	p99	0.0	65.1	58.9	76.6	130.7
	Max	0.0	65.1	58.9	76.6	130.7

Table 8e. Mouthing contact duration (min/h) while playing on turf (two age groups)

Age Group		Grass (n =4)	Hands (n =49)	Dietary (n = 56)	Non-Dietary (n = 56)	All Objects (n = 56)
1 - 5 years	Mean	0.0	0.5	1.2	3.2	4.4
	SD	0.0	0.8	2.1	10.4	10.5
	Min	0.0	0.0	0.0	0.0	0.1
	Median	0.0	0.1	0.0	0.2	0.4
	p25	0.0	0.3	0.1	0.5	1.8
	p75	0.0	0.4	1.3	1.8	3.4
	p95	0.1	3.2	6.9	15.5	17.7
	p99	0.1	3.2	7.2	58.4	58.4
	Max	0.1	3.2	7.2	58.4	58.4
6 - 12 years	Mean	.	0.4	1.2	0.6	1.8
	SD	.	0.6	3.4	1.0	3.6
	Min	.	0.0	0.0	0.0	0.0
	Median	.	0.1	0.0	0.1	0.1
	p25	.	0.2	0.0	0.2	0.3
	p75	.	0.4	0.8	0.7	2.0
	p95	.	1.9	4.1	2.8	5.7
	p99	.	2.3	16.6	4.0	16.6
	Max	.	2.3	16.6	4.0	16.6

Table 8f. Mouthing median duration (seconds) while playing on turf (two age groups)

Age Group		Grass (n =4)	Hands (n =49)	Dietary (n = 56)	Non-Dietary (n = 56)	All Objects (n = 56)
1 - 5 years	Mean	1.4	2.2	5.4	8.5	14.0
	SD	0.8	2.3	12.0	7.9	17.2
	Min	1.0	0.5	0.0	0.0	0.5
	Median	1.0	1.0	0.0	3.8	5.5
	p25	1.0	1.5	2.5	6.5	9.5
	p75	1.8	2.0	6.0	9.3	16.0
	p95	2.5	6.5	19.5	23.0	57.5
	p99	2.5	12.0	66.0	38.0	89.0
	Max	2.5	12.0	66.0	38.0	89.0
6 - 12 years	Mean	.	1.4	8.1	3.4	11.5
	SD	.	0.9	24.8	3.3	24.9
	Min	.	1.0	0.0	0.0	0.0
	Median	.	1.0	0.0	1.0	1.0
	p25	.	1.0	0.5	2.5	4.5
	p75	.	1.0	7.5	5.0	12.5
	p95	.	3.5	13.5	10.5	24.0
	p99	.	5.0	123.0	11.0	124.0
	Max	.	5.0	123.0	11.0	124.0

Table 9. Age correlation with mouthing events.

Mouth contact frequency (event/h) correlation with age (n = 56)

	Spearman Rho	P-value
Grass	-0.221	0.101
Hands	0.071	0.630
Non-Dietary	-0.197	0.146
Dietary	-0.052	0.705
Total Objects	-0.199	0.140

Mouth contact duration (min/h) correlation with age (n = 56)

	Spearman Rho	P-value
Grass	0.272	0.728
Hands	-0.128	0.381
Non-Dietary*	-0.336	0.011
Dietary	-0.062	0.651
Total Objects*	-0.298	0.025

Mouth median duration (sec) correlation with age (n = 56)

	Spearman Rho	P-value
Grass (n = 4)	0.272	0.728
Hands* (n=49)	-0.357	0.012
Non-Dietary* (n =56)	-0.466	<0.001
Dietary (n = 56)	-0.043	0.755
Total Objects* (n=56)	-0.331	0.013

* Significant ($p < 0.05$) correlation with age (Spearman's rank correlation).

Table 10. Mouthing events in relation to EPA age groups

Mouth contact frequency (event/h) by 5 age groups (n = 56)

	Median	Range	P-value
Grass	0.0	0-1.5	0.156
Hands	8.1	15.2-65.1	0.601
Non-Dietary	11.8	25.2-83.3	0.075
Dietary	0.8	11.0-194.7	0.198
Total objects	19.0	55.8-217.2	0.057

Mouth contact duration (min/h) by 5 age groups (n = 56)

	Median	Range	P-value
Grass	0	0-0.1	0.317
Hands	0.2	0-3.23	0.214
Non-Dietary*	0.3	0-58.4	0.011
Dietary	0	0-16.5	0.361
Total objects	0.9	0-58.4	0.058

Mouth contact median duration (s) by 5 age groups

	Median	Range	P-value
Grass (n = 4)	1.0	1-2.5	0.317
Hands (n = 49)*	1.0	0.5-12	0.080
Non-Dietary* (n=56)	5.0	0-38	0.004
Dietary (n = 56)	1.5	0-123	0.296
Total objects* (n=56)	7.3	0-124	0.045

* Significant ($p < 0.05$) correlation with age (Kruskal-Wallis test)

Table 11. Mouthing events in relation to two age groups (children <6 and 6-12 years old)

Mouth contact duration (min/h) by 2 age groups (n = 56)

	Median	Range	P-value
Grass	0	0.0	-
Hands	0.2	0-3.23	0.476
Non-Dietary*	0.3	0-58.4	0.006
Dietary	0	0-16.5	0.430
Total objects*	0.9	0-58.4	0.025

Mouth median duration (seconds) by 2 age groups

	Median	Range	P-value
Grass (n = 4)	1.0	1-2.5	-
Hands (n = 49)*	1.0	0.5-12	0.047
Non-Dietary* (n=56)	5.0	0-38	0.001
Dietary (n = 56)	1.5	0-123	0.735
Total objects* (n=56)	7.3	0-124	0.037

* Wilcoxon Sum-rank test for children <6 and 6-12 years old

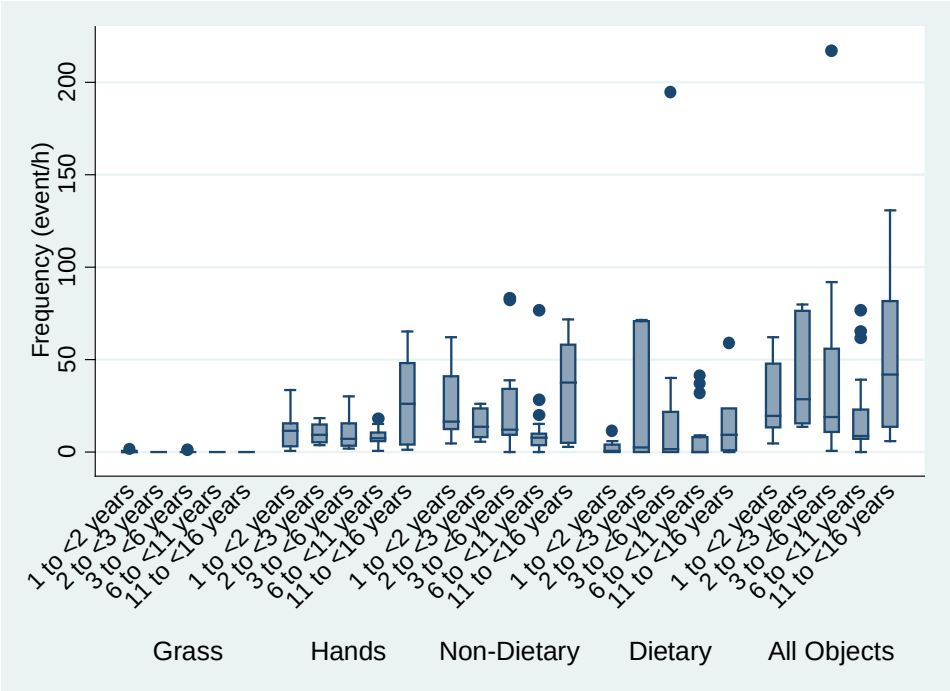

Figure 1a. Mouthing frequency (event/h) grouped by age groups playing on Turf

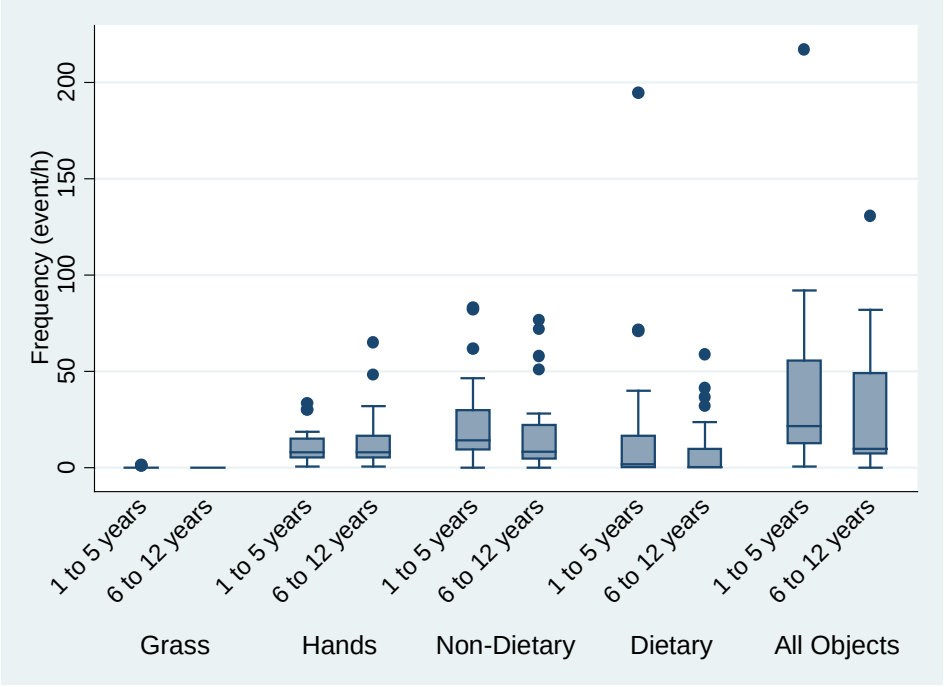

Figure 1b. Mouthing frequency (event/h) grouped by two age groups playing on Turf

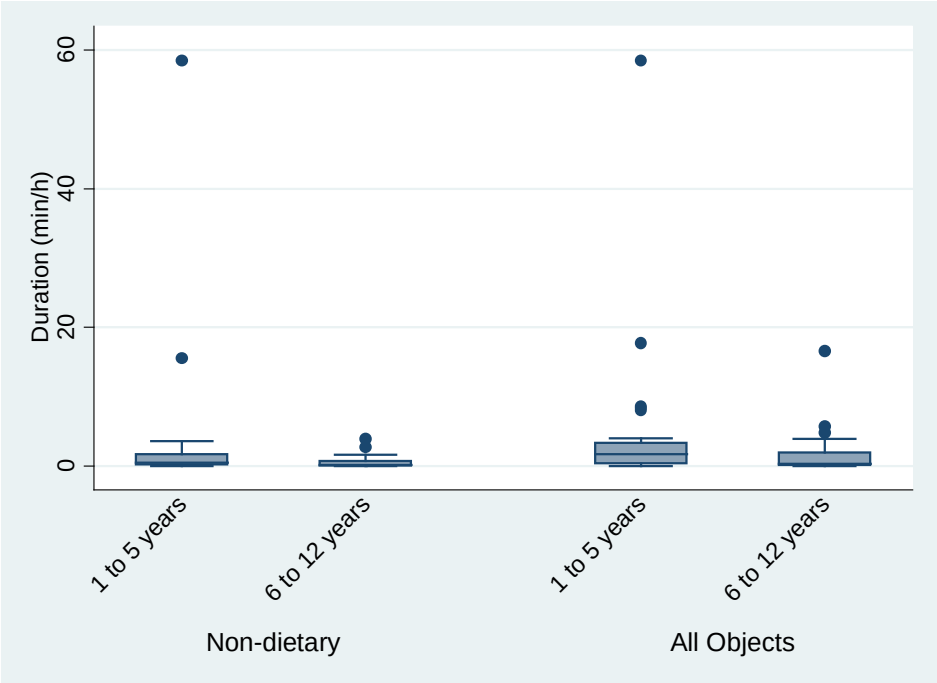

Figure 1c. Mouth contact duration (min/h) with non-dietary and all objects on turf (n = 56)

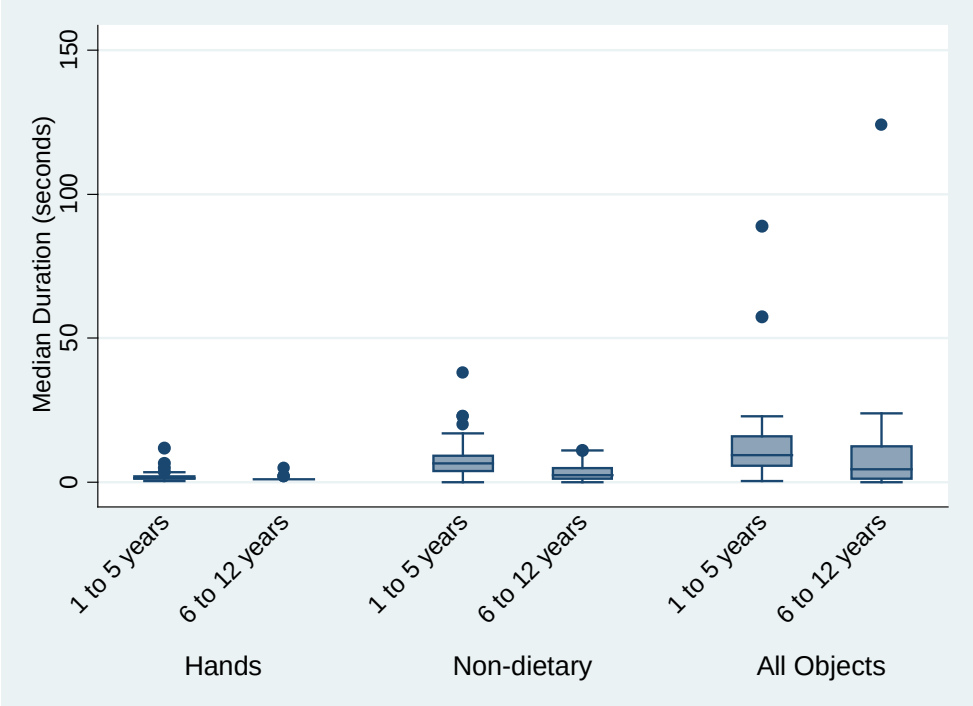

Figure 1d. Mouth contact median duration (seconds) with hands, non-dietary, and all objects on turf (n = 56)

Table 12. Both hands contact duration (min/h) by gender (n = 56) while playing on turf

	Median	Range	P-value
Grass	0.2	0.5-13	0.059
Dietary	3.5	1-33.5	0.954
Non-Dietary*	43.9	17.5-437	0.017
Total objects	49.6	20.5-446	0.078

* Significant ($p < 0.05$) difference by gender (Wilcoxon rank-sum test).

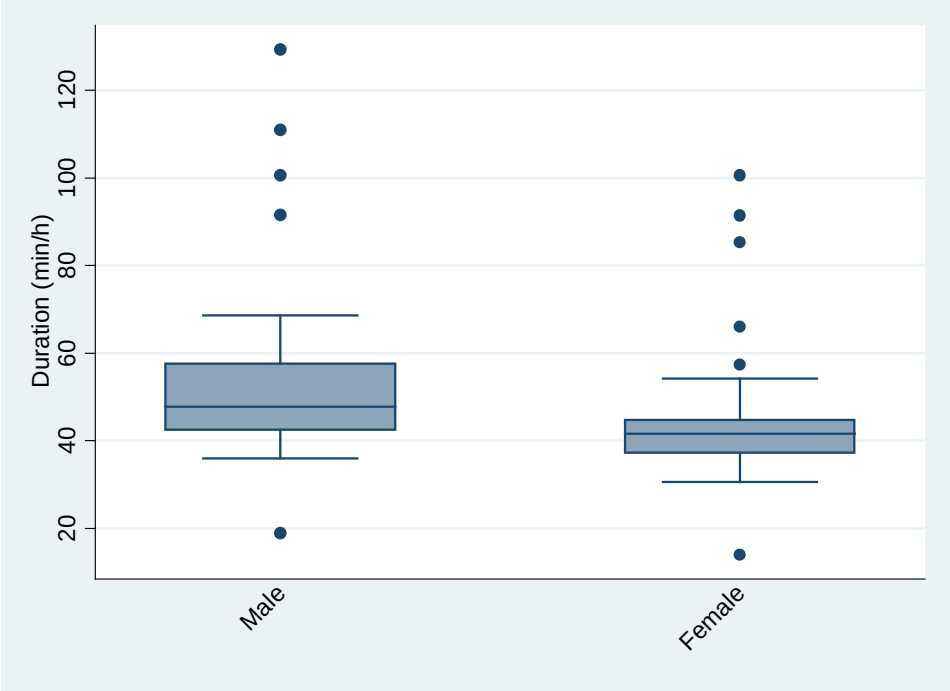

Figure 2. Both hands contact duration (min/h) with non-dietary objects grouped by gender on turf

Playground Locations

Table 13a. RHD frequency while playing on the Playground (n = 24)

	Floors	Dietary	Non-Dietary	All Objects
Mean	30.3	0.6	162.7	163.3
SD	100.9	1.7	123.3	123.2
Min	0.0	0.0	15.9	15.9
Median	0.0	0.0	97.5	99.4
p25	4.8	0.0	128.1	128.1
p75	13.5	0.0	193.3	193.3
p95	69.2	3.7	342.9	342.9
p99	497.7	7.0	585.4	585.4
Max	497.7	7.0	585.4	585.4

Table 13b. LHD frequency while playing on the Playground (n = 24)

	Floors	Dietary	Non-Dietary	All Objects
Mean	23.9	1.0	154.5	155.5
SD	59.6	2.8	95.5	95.1
Min	0.0	0.0	10.7	10.7
Median	0.0	0.0	95.6	95.6
p25	5.7	0.0	143.6	145.8
p75	15.5	0.0	189.2	189.8
p95	72.0	8.9	338.0	338.0
p99	288.8	10.8	406.3	406.3
Max	288.8	10.8	406.3	406.3

Table 13c. Both hands object/surface frequency (event/h) (n = 24)

	Floors	Dietary	Non-Dietary	All Objects
Mean	54.2	1.6	317.3	318.8
SD	159.3	3.9	214.3	213.9
Min	0.0	0.0	30.6	30.6
Median	0.0	0.0	198.4	204.2
p25	12.1	0.0	261.4	262.3
p75	36.3	0.6	401.0	401.6
p95	141.2	10.8	634.2	634.2
p99	786.6	15.9	991.7	991.7
Max	786.6	15.9	991.7	991.7

Table 13d. Mouth frequency (event/h) while playing on the Playground (n = 24)

	Floors	Hands	Dietary	Non-Dietary	All Objects
Mean	0.1	19.6	43.1	28.2	71.3
SD	0.5	20.3	112.3	46.8	114.3
Min	0.0	1.4	0.0	0.0	0.0
Median	0.0	4.3	0.0	2.9	4.0
p25	0.0	9.8	0.0	10.2	20.4
p75	0.0	25.4	3.2	30.3	66.0
p95	0.0	67.5	313.4	82.5	335.0
p99	2.3	67.5	379.0	218.2	379.0
Max	2.3	67.5	379.0	218.2	379.0

Table 14a. RHD duration (min/h) while playing on the Playground (n = 24)

	Floors	Dietary	Non-Dietary	All Objects
Mean	1.0	0.2	16.5	16.7
SD	1.8	1.0	3.3	3.3
Min	0.0	0.0	3.6	3.6
Median	0.0	0.0	15.5	15.9
p25	0.2	0.0	17.2	17.5
p75	1.2	0.0	18.6	18.6
p95	6.1	0.8	19.2	19.2
p99	6.3	5.0	19.9	19.9
Max	6.3	5.0	19.9	19.9

Table 14b. LHD duration (min/h) while playing on the Playground (n = 24)

	Floors	Dietary	Non-Dietary	All Objects
Mean	0.8	1.1	16.5	17.6
SD	1.2	4.6	3.4	6.5
Min	0.0	0.0	4.4	4.4
Median	0.0	0.0	15.2	15.4
p25	0.2	0.0	17.2	17.2
p75	1.3	0.0	18.2	18.3
p95	3.5	3.9	20.0	20.0
p99	3.8	22.2	21.9	44.1
Max	3.8	22.2	21.9	44.1

Table 14c. Both hands duration (min/h) while playing on the Playground (n = 24)

	Floors	Dietary	Non-Dietary	All Objects
Mean	1.9	1.4	33.0	34.3
SD	3.0	4.6	4.2	6.9
Min	0.0	0.0	23.0	23.0
Median	0.0	0.0	31.7	31.8
p25	0.4	0.0	33.4	34.1
p75	2.3	0.1	36.5	36.7
p95	9.7	5.0	38.6	39.7
p99	10.1	22.2	39.7	59.6
Max	10.1	22.2	39.7	59.6

Table 14d. Mouth duration (min/h) while playing on the Playground (n = 24)

	Floors (n = 1)	Hands	Dietary	Non-Dietary	All Objects
Mean	0.0	1.0	1.5	1.7	3.2
SD	0.0	1.6	4.1	4.1	5.5
Min	0.0	0.0	0.0	0.0	0.0
Median	0.0	0.1	0.0	0.0	0.0
p25	0.0	0.3	0.0	0.3	0.8
p75	0.0	0.7	0.2	1.3	3.8
p95	0.0	5.0	11.4	5.0	16.6

Table 15a. RHD median duration (sec) while playing on the Playground (n =24)

	Floors (n = 15)	Dietary (n =3)	Non-Dietary	All Objects
Mean	2.9	4.4	56.8	61.2
SD	3.4	18.0	51.4	53.5
Min	0.0	0.0	1.0	1.0
Median	0.0	0.0	25.3	25.3
p25	2.3	0.0	40.0	41.0
p75	4.5	0.0	70.5	86.8
p95	10.0	16.0	150.5	150.5
p99	11.5	87.5	222.0	222.0
Max	11.5	87.5	222.0	222.0

Table 15b. LHD median duration (sec) while playing on the Playground (n = 24)

	Floors (n = 17)	Dietary (n = 4)	Non-Dietary	All Objects
Mean	3.4	1.1	55.9	57.0
SD	3.9	3.2	54.9	55.0
Min	0.0	0.0	5.0	5.0
Median	0.0	0.0	29.8	29.8
p25	2.5	0.0	46.0	46.8
p75	5.0	0.0	62.8	68.5
p95	13.0	7.5	109.5	109.5
p99	14.0	14.0	286.0	286.0
Max	14.0	14.0	286.0	286.0

Table 15c. Both hands object/surface median duration (sec) (n = 24)

	Floors (n = 17)	Dietary (n =6)	Non-Dietary	All Objects
Mean	1.9	1.4	33.0	34.3
SD	3.0	4.6	4.2	6.9
Min	0.0	0.0	23.0	23.0
Median	0.0	0.0	31.7	31.8
p25	0.4	0.0	33.4	34.1
p75	2.3	0.1	36.5	36.7
p95	9.7	5.0	38.6	39.7
p99	10.1	22.2	39.7	59.6
Max	10.1	22.2	39.7	59.6

Table 15d. Mouth median duration (Sec) while playing on the Playground (n = 24)

	Floors	Hands	Dietary	Non-Dietary	All Objects
Mean	0.0	2.1	6.5	3.0	9.6
SD	0.2	1.9	29.7	3.2	29.5
Min	0.0	1.0	0.0	0.0	0.0
Median	0.0	1.0	0.0	0.5	0.8
p25	0.0	1.0	0.0	2.0	3.0
p75	0.0	2.0	0.3	5.3	6.0
p95	0.0	6.5	4.0	6.5	13.5
p99	1.0	6.5	146.0	13.5	147.0
Max	1.0	6.5	146.0	13.5	147.0

Table 16a. Both hands Frequency (event/h) in Playground (n = 24)

Age Group		Floors	Dietary	Non-Dietary	All Objects
< 2	Mean	40.0	0.2	426.6	426.8
	SD	27.8	0.5	184.5	184.4
	Min	0.7	0.0	205.9	205.9
	Median	20.3	0.0	336.2	336.2
	p25	58.1	0.0	354.3	355.5
	p75	58.4	0.0	602.5	602.5
	p95	62.4	1.2	634.2	634.2
	p99	62.4	1.2	634.2	634.2
	Max	62.4	1.2	634.2	634.2
2 to < 3	Mean	10.0	2.7	166.5	169.2
	SD	10.4	4.7	107.3	108.6
	Min	0.0	0.0	30.6	30.6
	Median	0.0	0.0	80.6	80.6
	p25	8.7	0.0	191.7	202.5
	p75	19.5	2.8	253.7	256.5
	p95	21.8	10.8	275.9	275.9
	p99	21.8	10.8	275.9	275.9
	Max	21.8	10.8	275.9	275.9
3 to < 6	Mean	125.5	2.0	404.2	406.2
	SD	271.4	5.6	291.2	290.3
	Min	0.0	0.0	37.6	37.6
	Median	0.0	0.0	222.6	222.6
	p25	12.6	0.0	368.0	375.9
	p75	96.0	0.0	511.6	511.6
	p95	786.6	15.9	991.7	991.7
	p99	786.6	15.9	991.7	991.7
	Max	786.6	15.9	991.7	991.7
6 to < 11	Mean	8.0	1.2	235.8	237.1
	SD	7.1	1.9	38.4	38.3
	Min	0.0	0.0	171.5	171.5
	Median	0.0	0.0	205.1	208.8
	p25	8.6	0.0	256.6	257.5
	p75	13.2	3.6	260.0	261.8
	p95	17.3	3.7	265.2	265.2
	p99	17.3	3.7	265.2	265.2
	Max	17.3	3.7	265.2	265.2

Table 16b. Both hands duration (min/h) in Playground (n = 24)

Age Group		Floors	Dietary	Non-Dietary	All Objects
< 2	Mean	2.8	4.4	32.2	36.7
	SD	4.3	9.9	3.8	13.1
	Min	0.0	0.0	26.9	26.9
	Median	0.0	0.0	31.6	31.6
	p25	0.8	0.0	31.9	31.9
	p75	3.3	0.0	33.5	33.5
	p95	10.1	22.2	37.4	59.6
	p99	10.1	22.2	37.4	59.6
	Max	10.1	22.2	37.4	59.6
2 to < 3	Mean	0.5	0.8	31.9	32.7
	SD	0.7	1.7	5.3	5.8
	Min	0.0	0.0	23.0	23.0
	Median	0.0	0.0	31.9	31.9
	p25	0.3	0.0	33.3	34.5
	p75	0.3	0.1	34.4	36.8
	p95	1.8	3.9	36.8	37.2
	p99	1.8	3.9	36.8	37.2
	Max	1.8	3.9	36.8	37.2
3 to < 6	Mean	3.1	0.1	32.6	32.8
	SD	3.7	0.4	4.9	5.0
	Min	0.0	0.0	23.6	23.6
	Median	0.0	0.0	30.2	30.2
	p25	1.6	0.0	33.2	33.4
	p75	5.9	0.0	35.4	35.9
	p95	9.7	1.2	39.7	39.7
	p99	9.7	1.2	39.7	39.7
	Max	9.7	1.2	39.7	39.7
6 to < 11	Mean	0.7	0.9	34.9	35.8
	SD	0.7	2.0	2.9	2.5
	Min	0.0	0.0	31.7	31.8
	Median	0.0	0.0	31.8	33.8
	p25	0.6	0.0	35.2	36.6
	p75	1.1	0.1	37.1	37.2
	p95	1.7	5.0	38.6	38.6
	p99	1.7	5.0	38.6	38.6
	Max	1.7	5.0	38.6	38.6

Table 16c. Both hands median duration (seconds) in Playground (n = 24)

Age Group		Floors (n = 17)	Dietary (n = 6)	Non-Dietary	All Objects
< 2	Mean	5.6	0.2	33.4	33.6
	SD	3.9	0.4	12.3	12.6
	Min	1.0	0.0	14.0	14.0
	Median	2.0	0.0	33.5	33.5
	p25	7.0	0.0	35.0	35.0
	p75	8.0	0.0	36.5	36.5
	p95	10.0	1.0	48.0	49.0
	p99	10.0	1.0	48.0	49.0
	Max	10.0	1.0	48.0	49.0
2 to < 3	Mean	2.1	3.2	141.4	144.6
	SD	1.9	6.1	158.4	156.2
	Min	0.0	0.0	52.0	58.0
	Median	0.0	0.0	56.0	66.0
	p25	3.0	0.0	84.0	84.0
	p75	3.5	2.0	92.0	92.0
	p95	4.0	14.0	423.0	423.0
	p99	4.0	14.0	423.0	423.0
	Max	4.0	14.0	423.0	423.0
3 to < 6	Mean	3.7	1.6	45.5	47.0
	SD	5.3	4.4	36.1	37.0
	Min	0.0	0.0	1.0	1.0
	Median	0.0	0.0	19.8	19.8
	p25	1.8	0.0	39.4	39.4
	p75	6.3	0.0	64.5	70.8
	p95	13.5	12.5	115.5	115.5
	p99	13.5	12.5	115.5	115.5
	Max	13.5	12.5	115.5	115.5
6 to < 11	Mean	2.2	15.3	61.1	76.3
	SD	2.0	35.4	31.6	47.4
	Min	0.0	0.0	32.5	32.5
	Median	0.0	0.0	37.5	37.5
	p25	2.0	0.0	57.0	58.8
	p75	4.0	4.0	61.5	125.0
	p95	5.0	87.5	121.0	145.5
	p99	5.0	87.5	121.0	145.5
	Max	5.0	87.5	121.0	145.5

Table 17a. Mouthing Frequency (event/h) in Playground (n = 24)

Age Group		Floors	Hands	Dietary	Non-Dietary	All Objects
< 2	Mean	0.5	26.6	6.4	27.2	33.6
	SD	1.0	18.6	9.3	14.8	18.9
	Min	0.0	9.2	0.0	5.0	5.0
	Median	0.0	9.2	0.0	24.4	24.4
	p25	0.0	24.4	0.0	30.0	41.5
	p75	0.0	46.2	11.5	30.7	46.2
	p95	2.3	46.2	20.5	46.2	51.1
	p99	2.3	46.2	20.5	46.2	51.1
	Max	2.3	46.2	20.5	46.2	51.1
2 to < 3	Mean	0.0	34.4	60.7	47.1	107.8
	SD	0.0	27.8	135.8	34.4	114.7
	Min	0.0	7.1	0.0	4.4	16.5
	Median	0.0	11.7	0.0	16.5	65.2
	p25	0.0	31.6	0.0	65.2	66.9
	p75	0.0	57.2	0.0	66.9	82.5
	p95	0.0	67.5	303.7	82.5	308.1
	p99	0.0	67.5	303.7	82.5	308.1
	Max	0.0	67.5	303.7	82.5	308.1
3 to < 6	Mean	0.0	10.8	86.5	34.8	121.4
	SD	0.0	10.3	161.2	74.8	163.2
	Min	0.0	2.9	0.0	0.0	0.0
	Median	0.0	3.6	0.0	0.0	1.5
	p25	0.0	7.3	0.0	6.7	17.9
	p75	0.0	17.9	156.7	23.5	276.6
	p95	0.0	25.4	379.0	218.2	379.0
	p99	0.0	25.4	379.0	218.2	379.0
	Max	0.0	25.4	379.0	218.2	379.0
6 to < 11	Mean	0.0	4.8	1.1	4.3	5.4
	SD	0.0	3.9	2.6	4.4	5.0
	Min	0.0	1.4	0.0	0.0	0.0
	Median	0.0	1.4	0.0	0.0	0.0
	p25	0.0	3.9	0.0	3.3	5.9
	p75	0.0	9.1	0.0	9.1	10.0
	p95	0.0	9.1	6.4	10.0	10.3
	p99	0.0	9.1	6.4	10.0	10.3
	Max	0.0	9.1	6.4	10.0	10.3

Table 17b. Mouthing hourly duration (min/h) on Playground (n = 24)

Age Group		Floors	Hands	Dietary	Non-Dietary	All Objects
< 2	Mean	0.0	3.1	0.3	2.7	2.9
	SD	0.0	2.6	0.4	2.0	1.9
	Min	0.0	0.1	0.0	0.3	0.3
	Median	0.0	0.1	0.0	0.8	1.7
	p25	0.0	4.1	0.0	3.1	3.4
	p75	0.0	5.0	0.3	4.1	4.1
	p95	0.0	5.0	1.0	5.0	5.0
	p99	0.0	5.0	1.0	5.0	5.0
	Max	0.0	5.0	1.0	5.0	5.0
2 to < 3	Mean	0.0	0.7	0.9	0.9	1.9
	SD	0.0	0.7	2.1	0.6	1.7
	Min	0.0	0.3	0.0	0.2	0.6
	Median	0.0	0.3	0.0	0.6	1.0
	p25	0.0	0.5	0.0	1.0	1.1
	p75	0.0	1.2	0.0	1.1	1.9
	p95	0.0	1.8	4.6	1.9	4.8
	p99	0.0	1.8	4.6	1.9	4.8
	Max	0.0	1.8	4.6	1.9	4.8
3 to < 6	Mean	0.0	0.3	1.8	2.8	4.6
	SD	0.0	0.2	4.0	7.0	7.6
	Min	0.0	0.1	0.0	0.0	0.0
	Median	0.0	0.2	0.0	0.0	0.0
	p25	0.0	0.3	0.0	0.2	0.4
	p75	0.0	0.4	1.6	1.0	8.1
	p95	0.0	0.5	11.4	20.0	20.0
	p99	0.0	0.5	11.4	20.0	20.0
	Max	0.0	0.5	11.4	20.0	20.0
6 to < 11	Mean	0.0	0.1	2.8	0.1	2.8
	SD	0.0	0.1	6.7	0.1	6.7
	Min	0.0	0.0	0.0	0.0	0.0
	Median	0.0	0.0	0.0	0.0	0.0
	p25	0.0	0.1	0.0	0.0	0.0
	p75	0.0	0.3	0.0	0.1	0.3
	p95	0.0	0.3	16.5	0.3	16.6
	p99	0.0	0.3	16.5	0.3	16.6
	Max	0.0	0.3	16.5	0.3	16.6

Table 17c. Mouthing median duration (seconds) on Playground (n = 24)

Age Group		Floors	Hands	Dietary	Non-Dietary	All Objects
< 2	Mean	0.2	4.5	0.8	5.5	6.3
	SD	0.4	3.0	1.3	1.0	1.8
	Min	0.0	1.0	0.0	4.0	4.0
	Median	0.0	1.0	0.0	5.0	6.0
	p25	0.0	6.0	0.0	6.0	6.0
	p75	0.0	6.5	1.0	6.0	6.5
	p95	1.0	6.5	3.0	6.5	9.0
	p99	1.0	6.5	3.0	6.5	9.0
	Max	1.0	6.5	3.0	6.5	9.0
2 to < 3	Mean	0.0	1.3	0.4	2.7	3.1
	SD	0.0	0.5	0.9	1.2	1.2
	Min	0.0	1.0	0.0	1.5	1.5
	Median	0.0	1.0	0.0	2.0	2.0
	p25	0.0	1.0	0.0	2.0	4.0
	p75	0.0	1.5	0.0	4.0	4.0
	p95	0.0	2.0	2.0	4.0	4.0
	p99	0.0	2.0	2.0	4.0	4.0
	Max	0.0	2.0	2.0	4.0	4.0
3 to < 6	Mean	0.0	1.8	0.6	2.9	3.5
	SD	0.0	1.0	1.4	4.7	5.2
	Min	0.0	1.0	0.0	0.0	0.0
	Median	0.0	1.0	0.0	0.0	0.3
	p25	0.0	1.5	0.0	1.0	1.0
	p75	0.0	2.5	0.3	4.0	6.0
	p95	0.0	3.0	4.0	13.5	13.5
	p99	0.0	3.0	4.0	13.5	13.5
	Max	0.0	3.0	4.0	13.5	13.5
6 to < 11	Mean	0.0	1.2	24.3	1.4	25.8
	SD	0.0	0.3	59.6	2.2	59.4
	Min	0.0	1.0	0.0	0.0	0.0
	Median	0.0	1.0	0.0	0.0	0.0
	p25	0.0	1.0	0.0	0.5	1.0
	p75	0.0	1.5	0.0	2.0	5.5
	p95	0.0	1.5	146.0	5.5	147.0
	p99	0.0	1.5	146.0	5.5	147.0
	Max	0.0	1.5	146.0	5.5	147.0

Table 18a. Mouthing Frequency (event/h) on Playground (n = 24) by two age groups

Age Group		Floors	Hands	Dietary	Non-Dietary	All Objects
1 - 5 years	Mean	0.1	23.7	57.1	36.1	93.2
	SD	0.5	21.2	127.4	51.9	125.0
	Min	0.0	2.9	0.0	0.0	0.0
	Median	0.0	7.1	0.0	4.4	10.4
	p25	0.0	16.3	0.0	23.0	43.8
	p75	0.0	46.2	11.5	46.2	82.5
	p95	2.3	67.5	379.0	218.2	379.0
	p99	2.3	67.5	379.0	218.2	379.0
	Max	2.3	67.5	379.0	218.2	379.0
6 - 12 years	Mean	0.0	4.8	1.1	4.3	5.4
	SD	0.0	3.9	2.6	4.4	5.0
	Min	0.0	1.4	0.0	0.0	0.0
	Median	0.0	1.4	0.0	0.0	0.0
	p25	0.0	3.9	0.0	3.3	5.9
	p75	0.0	9.1	0.0	9.1	10.0
	p95	0.0	9.1	6.4	10.0	10.3
	p99	0.0	9.1	6.4	10.0	10.3
	Max	0.0	9.1	6.4	10.0	10.3

Table 18b. Mouthing duration (min/h) on Playground (n = 24) by two age groups

Age Group		Floors	Hands	Dietary	Non-Dietary	All Objects
1 - 5 years	Mean	0.0	1.2	1.1	2.2	3.4
	SD	0.0	1.7	2.9	4.7	5.2
	Min	0.0	0.1	0.0	0.0	0.0
	Median	0.0	0.3	0.0	0.2	0.3
	p25	0.0	0.3	0.0	0.7	1.4
	p75	0.0	1.8	0.3	1.9	4.1
	p95	0.0	5.0	11.4	20.0	20.0
	p99	0.0	5.0	11.4	20.0	20.0
	Max	0.0	5.0	11.4	20.0	20.0
6 - 12 years	Mean	0.0	0.1	2.8	0.1	2.8
	SD	0.0	0.1	6.7	0.1	6.7
	Min	0.0	0.0	0.0	0.0	0.0
	Median	0.0	0.0	0.0	0.0	0.0
	p25	0.0	0.1	0.0	0.0	0.0
	p75	0.0	0.3	0.0	0.1	0.3
	p95	0.0	0.3	16.5	0.3	16.6
	p99	0.0	0.3	16.5	0.3	16.6
	Max	0.0	0.3	16.5	0.3	16.6

Table 18c. Mouthing median duration (seconds) on Playground (n = 24) by two age groups

Age Group		Floors	Hands	Dietary	Non-Dietary	All Objects
1 - 5 years	Mean	0.1	2.3	0.6	3.6	4.2
	SD	0.2	2.1	1.2	3.3	3.8
	Min	0.0	1.0	0.0	0.0	0.0
	Median	0.0	1.0	0.0	1.0	1.0
	p25	0.0	1.0	0.0	3.0	4.0
	p75	0.0	3.0	0.5	6.0	6.0
	p95	1.0	6.5	4.0	13.5	13.5
	p99	1.0	6.5	4.0	13.5	13.5
	Max	1.0	6.5	4.0	13.5	13.5
6 - 12 years	Mean	0.0	1.2	24.3	1.4	25.8
	SD	0.0	0.3	59.6	2.2	59.4
	Min	0.0	1.0	0.0	0.0	0.0
	Median	0.0	1.0	0.0	0.0	0.0
	p25	0.0	1.0	0.0	0.5	1.0
	p75	0.0	1.5	0.0	2.0	5.5
	p95	0.0	1.5	146.0	5.5	147.0
	p99	0.0	1.5	146.0	5.5	147.0
	Max	0.0	1.5	146.0	5.5	147.0

Table 19. Age correlation with mouthing events--Mouth contact frequency (event/h) correlation with age (n = 24)

	Spearman Rho	P-value
Floors	-0.289	0.170
Hands*	-0.631	0.016
Non-Dietary	0.378	0.705
Dietary	-0.163	0.448
Total Objects*	-0.459	0.024

Mouth contact duration (min/h) correlation with age (n = 24)

	Spearman Rho	P-value
Floors	-0.289	0.170
Hands*	-0.593	0.025
Non-Dietary*	-0.624	0.011
Dietary	-0.095	0.657
Total Objects*	-0.025	0.025

Mouth median duration (sec) correlation with age (n = 24)

	Spearman Rho	P-value
Floors	-0.289	0.169
Hands	-0.322	0.261
Non-Dietary*	-0.555	0.005
Dietary	-0.122	0.570
Total Objects*	-0.418	0.042

* Significant ($p < 0.05$) correlation with age (Spearman's rank correlation).

Table 20. Mouthing frequency (event/h) in relation to two age groups (children <6 and 6-12 years old)

	Median	Range	P-value
Floors	0	0	-
Hands	4.3	1.4-67.5	0.052
Non-Dietary*	2.9	0-218.2	0.032
Dietary	0	0-379.0	0.456
Total objects*	4.0	0-379.0	0.011

*Significant difference ($p < 0.05$) using Wilcoxon rank sum test.

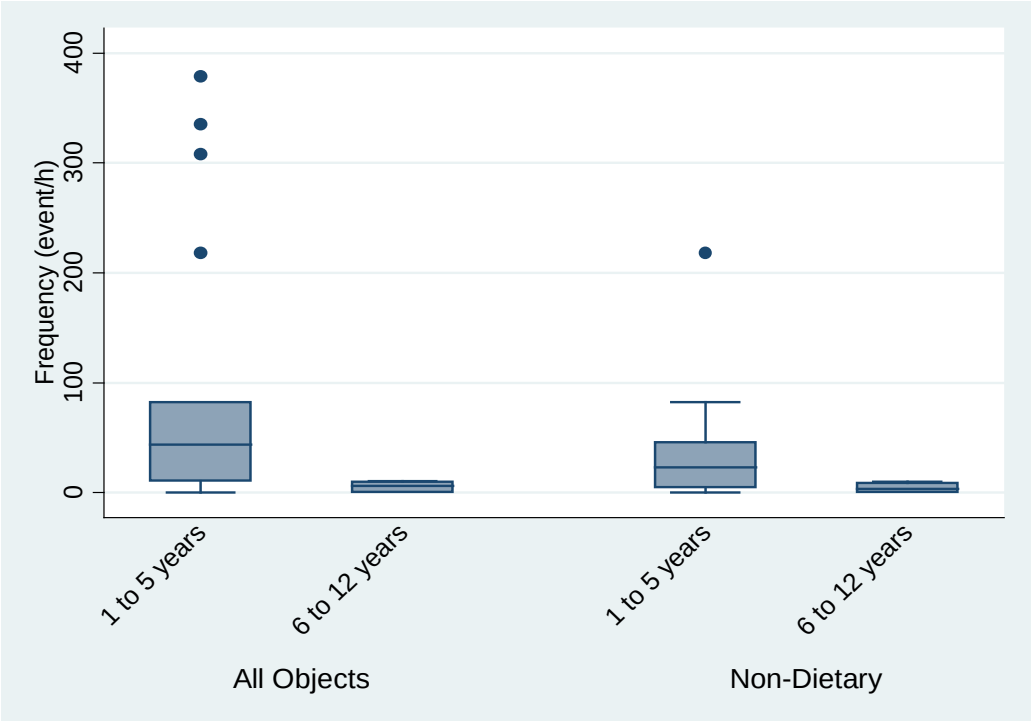

Figure 3. Mouthing significant difference (p<0.05) of frequency (event/h) grouped by age while playing on Playground (Wilcoxon rank-sum test)

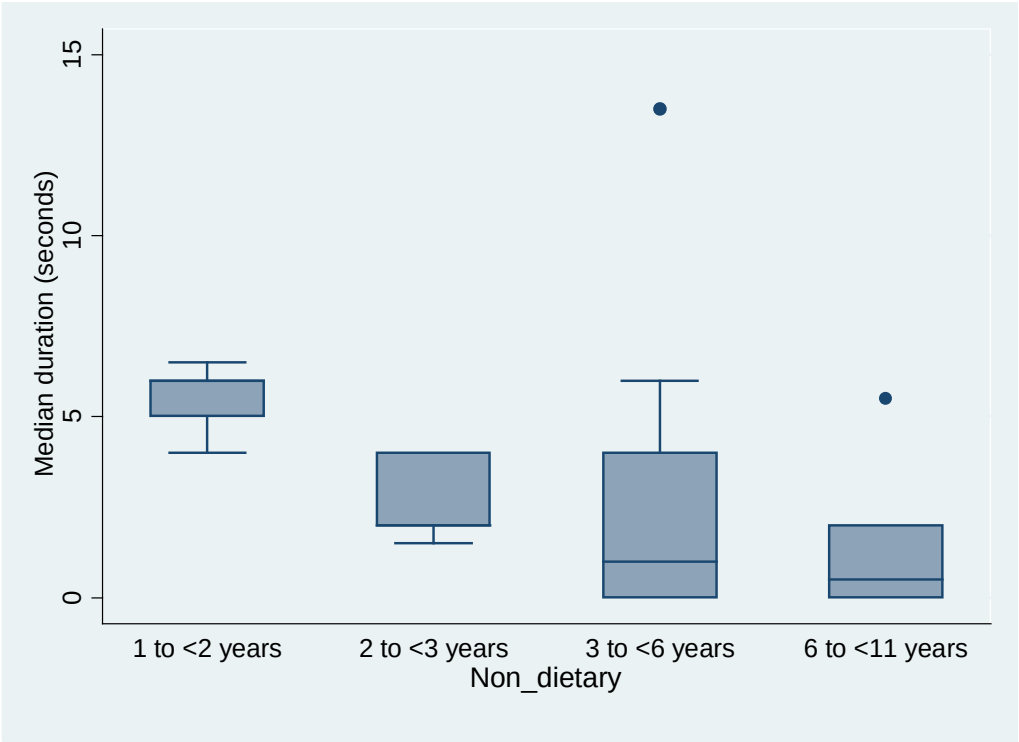

Figure 4. Mouthing significant difference (p< 0.05) for median duration (seconds) in relation to age groups while children are playing on Playground (Kruskal Wallis test).

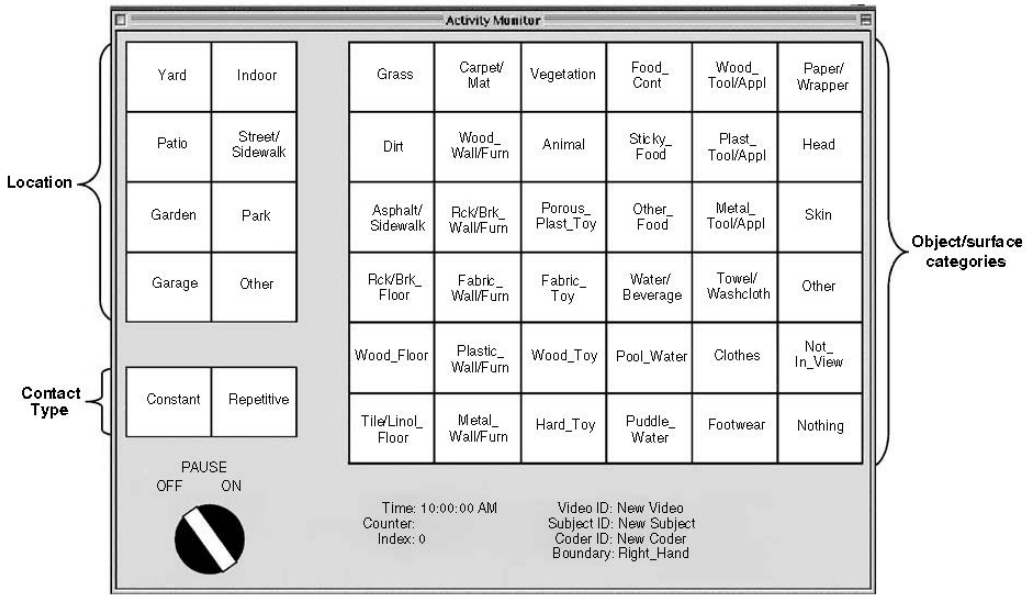

Figure 5. Video Palette for Children's Hand-to-Mouth Micro-Level Activity. This palette (AuYeung *et al.*, 2006) is used to transcribe micro-level activity from archived video footage of children to model hand-to-mouth behavior on playgrounds.

5. References

AuYeung W, Canales R, Beamer P*, et al.* (2006). Young children's hand contact activities: An observational study via videotaping in primarily outdoor residential settings. *J Expo Sci Environ Epidemiol* **16**: 434-446.

AuYeung W, Canales RA, Beamer P*, et al.* (2004). Young children's mouthing behavior: An observational study via videotaping in a primarily outdoor residential setting. *Journal of Children's Health* **2**(3-4): 271-295.

Ferguson A, Canales R, Beamer P*, et al.* (2006). Video methods in the quantification of children's exposures. *J Expos Sci Environ Epidemiol* **16**(3): 287-298.

Appendix 1
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** served 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 served 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 2

A Handy Guide to

The Bagley-Keene Act 2004 (http://ag.ca.gov/publications/bagleykeene2004_ada.pdf)