Appendix B

OEHHA Synthetic Turf Study

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Appendix B. OEHHA Synthetic Turf Study Exposure and Risk Assessment Parameters and Methods

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LIST OF ABBREVIATIONS

ABS	Skin absorption factor
A_{chem}	Inhalation absorption factor of a chemical
$AD_{(inh\ or\ der\ or\ ing)\text{-}DART\text{-}field}$	Average one-day exposure dose for a DART (for inhalation, dermal, or ingestion exposure) for an individual field
$ADD_{(inh\ or\ der\ or\ ing)}$	Average daily exposure dose for a general chemical or carcinogen (for inhalation, dermal, or ingestion exposure)
$AET_{(DART)}$	Annual event time (for a DART)
AF_i	Crumb rubber adherence factor for a specific body part
$AF_{inh\ (inh\text{-}DART\ or\ inh\text{-}sensory)}$	Adjustment factor for inhalation exposure or a general chemical (or a DART or sensory irritant)
AF_{obj}	Adherence factor of crumb rubber for an object
ASF	Age sensitivity factor
AT	Averaging time of a lifetime exposure
BR	Breathing rate
BR_{TW}	Time-weighed one-hour breathing rate
BW	Bodyweight
$BW_{default\text{-}adult}$	Default adult body weight
$C_{air\text{-}avg}$	Average concentration of a chemical in air across 35 fields
$C_{air\text{-}field}$	Average concentration of a chemical in air for an individual field
$C_{air\text{-}max}$	Maximum one-hour concentration of a chemical in air
$C_{(der\ or\ GI)\text{-}crumb\ rubber}$	Average dermal or GI bioaccessible concentration in crumb rubber across 35 fields of a general chemical
$C_{(der\ or\ GI)\text{-}crumb\ rubber\text{-}field}$	Average dermal or GI bioaccessible concentration in crumb rubber for an individual field of a DART
CDC	Centers for Disease Control and Prevention
CF	Conversion factor, units vary based on use
$C_{inh\ (inh\text{-}DART\text{-}field\ or\ inh\text{-}sensory)}$	Exposure concentration for a general chemical (or a DART or a sensory irritant)
$CSF_{inh\ (or\ oral)}$	Cancer slope factor for inhalation or (oral) exposure
DART	Developmental and reproductive toxicant (or toxicity)
DL	Dermal load
ED	Exposure duration
$EF_{(practice\ or\ game)}$	Exposure frequency (of practices or games)
EFH	United States Environmental Protection Agency Exposure Factors Handbook
EL	Exertion level

ET_{DART}	Exposure time of practices or games for a DART
$ET_{practice\ or\ game}$	Exposure time (of practices or games)
EV_{DART}	Event frequency for a DART chemical
$EV_{(practice\ or\ game)}$	Event frequency (of practices or games)
$f_{HTM\ or\ HTOTM\ or\ OTM}$	Hand-to-mouth, hand-to-object-to-mouth, or object-to-mouth contact frequency
$FTSA_i$	Fraction of total body surface area for a body part, i
GI	Gastrointestinal
GRAF	Gastrointestinal relative absorption factor
$HI_{(DART\ or\ sensory)}$	Hazard index for general chemicals (or for DARTs or sensory irritants)
$HQ_{der\ (or\ ing\ or\ inh)}$	Hazard quotient for a general chemical for dermal (or ingestion or inhalation) exposure
$HQ_{der\ (or\ ing\ of\ inh)\text{-}DART}$	Hazard quotient for dermal (or ingestion or inhalation) exposure for a DART
$HQ_{inh\text{-}sensory}$	Hazard quotient for inhalation exposure to a sensory irritant
$HQ_{der\ (or\ ing\ or\ inh)\text{-}sum}$	Hazard quotient for the dermal (or ingestion or inhalation) route for all chemicals
$HQ_{der\ (or\ ing\ or\ inh)\text{-}DART\text{-}sum}$	Hazard quotient for the dermal (or ingestion or inhalation) route for all DARTs
$HQ_{inh\text{-}sensory\text{-}sum}$	Hazard quotient for the inhalation exposure route for all sensory irritants
HTM	Hand-to-mouth
HTOTM	Hand-to-object-to-mouth
IR_{daily}	Daily crumb rubber ingestion rate for a general chemical
IR_{DART}	One-day crumb rubber ingestion rate for a DART
$IR_{direct\ (or\ indirect)}$	Ingestion rate from direct (or indirect) ingestion routes
$IR_{HTM\ or\ HTOTM\ or\ OTM}$	Hand-to-mouth, hand-to-object-to-mouth, or object-to-mouth ingestion rate
$LADD_{der\ (or\ ing\ or\ inh)}$	Lifetime average daily exposure dose of a chemical for dermal (or ingestion or inhalation) exposure
LBNL	Lawrence Berkeley National Laboratory
MLATS	Micro-level activity time series
NHANES	National Health and Nutrition Examination Survey
OEHHA	Office of Environmental Health Hazard Assessment
ORETF	Outdoor Residential Exposure Task Force
OTM	Object-to-mouth
P_i	Adjustment factor for partial exposure of a specified body part

$PM_{2.5}$	Particles with an aerodynamic diameter equal to or less than 2.5 microns
PM_{10}	Particles with an aerodynamic diameter equal to or less than 10 microns
$Risk_{field}$	Lifetime incremental cancer risk of chemicals through multiroute exposures
$Risk_{der\text{-}sum\ (or\ ing\text{-}sum\ or\ inh\text{-}sum)}$	Total lifetime incremental cancer risk of chemicals from dermal (or ingestion or inhalation) exposure
$Risk_{der\ (or\ ing\ or\ inh)\text{-}sum\text{-}field}$	Total lifetime incremental cancer risk of chemicals from dermal (or ingestion or inhalation) exposure for a specific field
RIVM	National Institute for Public Health and the Environment
SA_{HTM}	Mean surface area of the part of the hands in direct contact with the mouth
SA_{HTOTM}	Mean surface area of the part of the hand in contact with an object reaching the mouth
SA_i	Skin surface area of a specific body part, i
SA_{obj}	Mean surface area of the part of the object in contact with the mouth
SAP	Synthetic Turf Scientific Advisory Panel
SA_{total}	Total body skin surface area
SVOC	Semi-volatile organic chemical
TAS	Time-Activity Study
$TC_{(der\ or\ ing\ or\ inh)}$	Toxicity criteria (for dermal or ingestion or inhalation toxicity)
TF_{HTM}	Fraction of crumb rubber transferred from the part of the hands in contact with the mouth
TF_{HTOTM}	Fraction of crumb rubber transferred from the hands to an object then into the mouth
TF_{loss}	Fraction of crumb rubber lost from the hand prior to transfer into the mouth
TF_{obj}	Fraction of the amount of crumb rubber transferred from an object into the mouth
TSD	Technical Support Document
USEPA	United States Environmental Protection Agency
$V_{default\text{-}adult}$	Default adult daily inhalation volume
V_{event}	Average volume of air inhaled during a soccer event
VOC	Volatile organic chemical

B.1. Introduction

B.1.1. Purpose of this Technical Support Document

The Office of Environmental Health Hazard Assessment (OEHHA) prepared this Technical Support Document (TSD) for Synthetic Turf Exposure and Risk Assessment to supplement the Main Report of the OEHHA Synthetic Turf Study (the Main Report). We designed this TSD to define and describe the development of exposure parameters and outline the methodologies used to estimate and assess the exposure, non-cancer hazard, and cancer risk of chemicals that a receptor category (i.e., athletes, coaches, referees, and spectators) may be exposed to on a synthetic turf field in California.

The full details of the OEHHA Synthetic Turf Study (the Study) are provided in the Main Report. Briefly, OEHHA and the Lawrence Berkeley National Laboratory (LBNL) collected samples from the air and crumb rubber on 35 randomly selected synthetic turf fields in California. The concentrations of the chemicals detected in the samples were used to evaluate the exposure concentration and/or exposure dose of a chemical a receptor category may be exposed to on a field through inhalation, dermal, and ingestion routes. The Study focused on a soccer player scenario due to the popularity of the sport among all genders and ages in California. As such, athletes (i.e., soccer players), coaches and referees (i.e., team leaders, trainers, and moderators), and spectators (i.e., family, friends and observers of field activities) are the four receptor category groups of this study. Through collaborations with the University of California, Berkeley and the University of Arizona, OEHHA conducted three California-centered Time-Activity Studies (TAS, details in Appendix Sections F.1, F.2 and F.3) to gather information about the activity patterns of soccer athletes in a survey, obtain field observations and video recordings of soccer behaviors during games and practice on synthetic turf fields, and analyze archived video footage of young children playing outdoors on natural turf. These data were used to estimate receptor- and pathway-specific parameters relevant to soccer-related activities at synthetic turf fields in California. Where no data was available for non-athlete receptor categories, data for athletes, if the data was applicable, or values from the literature were used to estimate parameter values.

This TSD provides an overview of parameter development and the exposure and risk assessment methods used in the Study. The sections describe:

i. the selection and estimation of the age- and receptor-specific parameters used in assessing exposures on synthetic turf fields (Section B.2)
ii. the selection and estimation of the exposure pathway-specific parameters and adjustment factors used to estimate the levels of chemical exposure on synthetic turf fields (Section B.3, Section B.4, and Section B.5)
iii. the methodologies used in the derivation of human health cancer risk and non-cancer hazard estimates (Section B.6)

B.1.2. Development of Receptor-Specific Parameters

Section B.2 of this TSD discusses the development of age- and receptor-specific exposure parameters. These parameters (and the pathway-specific parameters discussed below) are used to estimate the exposure concentration (for the inhalation pathway) and/or dose (for all exposure routes) of chemicals that a receptor category is exposed to on a synthetic turf field. They are used in the evaluation of the three routes of exposure—inhalation, dermal, and ingestion.

The age-specific bodyweights (BW) used in the Study are described, including discussion of how the Study age groups are selected and the analysis of the selected BW data. This section also defines the parameters used to describe the frequency and length of exposures and discussion of their estimation. The event frequency (EV) and event time (ET) describe the number of events and hours per week that a receptor is on a synthetic turf field. The annual event time (AET) and exposure duration (ED) describe the total number of hours in a year and that total number of years a receptor may spend on the field. These parameters are variable based on both age and receptor category and were estimated using the collected TAS Survey data (Appendix Section F.1).

Over 1,000 participants responded to the TAS Survey. OEHHA included all the participants in the data analysis for parameter development except where participants' response precluded use of their data in the development of a specific parameter as follows:

i. Bodyweight (BW, kilograms) – participants left weight “Blank” (24 out of a total of 1069 survey participants)

ii. Gender-Specific Parameters – participants left “Blank” the gender question or chose "Prefer not to identify” for their gender. The number of participants who did not specify a gender (8 out of a total of 1069 survey participants) is too small for developing a separate set of gender-specific exposure parameters. Note that participants who left “Blank” or chose “Prefer not to identify” on gender were included in the analysis of combined-gender parameters.

iii. Event-Type Related Parameters (i.e., practice time and frequency versus game time and frequency) – participants entered “Zero”, “Don't know”, or “Prefer not to answer” for the percent of practices and/or games on synthetic turf fields.

iv. Exposure Frequency (EF, events per week, used to estimate EV and AET) –

- participants entered “Zero” or left “Blank” for EF in all seasons
- participants entered “Zero” or left “Blank” for EF in some seasons, excluded the participant data only for those seasons.

v. Exposure Time (ET, hours per event, used to estimate AET) –

- participants entered “Zero” or left “Blank” for all seasons

- participants entered “Zero” or left “Blank” for ET in some seasons, excluded the participant data only for those seasons
- participants provided at least one season with ET greater than 16 hours per day, the participants excluded from all analyses of ET due to uncertainty in the responses. It is not reasonable that an athlete participates in a practice or a game for more than 16 hours per day.

vi. Soccer-Type Parameters (Soccer History and Exposure Duration, ED, years) – participants indicated ‘Don't know’ or ‘Prefer not to answer’ for soccer type (i.e., competitive, recreational, or both).

B.1.3. Development of Pathway-Specific Parameters to Estimate Exposure Levels

Sections B.3 to B.5 each outline the pathway-specific parameters and mathematical models used to evaluate exposure via the inhalation (Section B.3), dermal (Section B.4), and ingestion (Section B.5) routes. OEHHA used established models (OEHHA, 2012; OEHHA, 2015; USEPA, 1989) to calculate the exposure concentration and/or exposure dose of chemicals for each pathway. In each section, we define and present the development of the pathway-related parameters used in a specific pathway exposure model and outline any assumptions OEHHA applied.

Section B.3 focuses on the estimation of exposure concentration (used to assess non-cancer hazard) and exposure dose (used to assess cancer risk) for the inhalation pathway. The section largely discusses the development of the time-weighted breathing rates (BR_{TW}) for each age group and receptor category, which is a significant parameter in determining inhalation exposures. We describe the exertion level (EL) TAS Survey data and literature breathing rates used to estimate BR_{TW}. Another focus of the section is discussion of the modification of chemical concentrations for inhalation exposures to assess non-cancer hazard and the factors used to do the adjustment (AF_{inh}). This section also describes the inhalation absorption factor (A_{chem}).

Section B.4 primarily focuses on the development of dermal load (DL), the primary parameter used to assess exposure dose (used for non-cancer hazard and cancer risk) via the dermal pathway. We discuss the selection and analysis of TAS Survey and literature data to estimate DL, including BW, height, skin surface area (SA_i) and crumb rubber adherence factors (AF_i). This section also describes the chemical skin absorption factor (ABS).

Section B.5 focuses on the development of daily ingestion rates (IR_{daily}) used to estimate the exposure dose (used for non-cancer hazard and cancer risk) of chemicals on synthetic turf fields via the ingestion pathway. Ingestion rates for direct (IR_{direct}; e.g. accidental or incidental ingestion) and indirect ($IR_{indirect}$; e.g. hand-to-mouth (HTM), object-to-mouth (OTM), and hand-to-object-to-mouth (HTOTM) ingestion) ingestion routes, the drivers of ingestion exposure, are estimated for each age group and receptor

category. The section describes the selection and analysis of the three TAS and literature data to estimate IRs, including crumb rubber adherence factors (AF_i), surface area of hands and objects (SA_i), crumb rubber transfer fractions (TF), and hand, objects, and mouth contact frequencies (f). This section also describes the gastrointestinal relative absorption factor (GRAF).

Similar to the use of TAS data in the development of age- and receptor-specific parameters, we included all participants in the data analysis for pathway-specific parameter development except where a participant's response precluded as follows:

i. Gender-Specific Parameters – participants left “Blank” the gender question or chose "Prefer not to identify”’ for their gender. The number of participants who did not specify a gender (8 out of a total of 1069 survey participants) is too small for developing a separate set of gender-specific exposure parameters. Note that participants who left “Blank” or chose “Prefer not to identify” on gender were included in the analysis of combined-gender parameters.

ii. Event-Type Related Parameters (e.g., practice time and frequency and game time and frequency) – participants entered “Zero”, “Don't know”, or “Prefer not to answer” for the percent of practices or games on synthetic turf fields.

iii. Exertion level (EL) – participants entered “Zero” or left “Blank” for EL for all activity levels.

iv. Surface area (SA_i) – participants left either or both BW and height responses “Blank”. SA_i is a function of BW and height, so a participant is excluded from all SA_i analyses if their BW and height dataset is incomplete.

B.1.4. Overview of Non-Cancer Hazard and Risk Assessment Methods

Section B.6 describes the methods and models used to estimate human non-cancer hazard and cancer risk for potential multiroute exposures on synthetic turf fields. To evaluate the non-cancer hazard and lifetime cancer risk for chemical exposures, we applied the OEHHA Risk Assessment Guidelines (2012; 2015) and the USEPA Risk Assessment Guidelines for Superfund Site, Part A (1989). We incorporated the chemical concentrations measured from field samples, the developed age-, receptor- and pathway-specific exposure parameters, and the available toxicity criteria (Main Report Chapter 4) into these models to estimate the non-cancer hazard index and lifetime cancer risk for human exposures on synthetic turf fields.

B.1.5. References

OEHHA (2012). Air Toxics Hot Spots Program Risk Assessment Guidelines: Technical Support Document for Exposure Assessment and Stochastic Analysis. Sacramento, CA, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

OEHHA (2015). Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spot Program Guidance Manual for Preparation of Health Risk Assessments. Sacramento, CA, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

USEPA (1989). Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A). Washington D.C., Office of Emergency and Remedial Response, U.S. Environmental Protection Agency.

B.2. Receptor-Specific Exposure Parameters

This section provides details on the estimations of receptor-specific exposure parameters for the Synthetic Turf Study (the Study). OEHHA designated athletes, coaches, referees, and spectators to be the primary exposure receptor categories of our Synthetic Turf Field Study (Main Report Section 5.2.2). The parameters described in this section are bodyweight (BW), event frequency (EV), event time (ET), annual event time (AET), and exposure duration (ED). The OEHHA Time-Activity Studies (TAS) Survey (individual participant data obtained from the survey of soccer athletes in CA) are the main data sources of estimates for athletes. Due to the lack of non-athlete data in the literature or our TAS, OEHHA estimated the parameter values for coaches, referees, and spectators based on values of the athletes. Additionally, we applied data of BW gain during pregnancy from the United States Environmental Protection Agency Exposure Factor Handbook, EFH, (USEPA, 2011) to estimate the BW of pregnant women. Considering these receptor-specific parameters are also age-specific (details described in this section), we, therefore, established an age grouping scheme specific for our Study. By combining the chemical concentrations reported from Main Report Chapter 3 , receptor-specific parameter estimates (this section and Main Report Chapter 5), and exposure-specific parameter estimates (described in Sections B.3 to B.5 of this TSD and Main Report Chapter 5), we derived the doses of chemicals exposed via each pathway for each receptor (Main Report Chapter 5).

B.2.1. Age Group

Among the primary receptor categories, the athletes and spectators contain individuals from a wide range of ages—from young children to seniors.

Young children are different from adults in activities, behaviors, breathing rates, and other physiological characteristics that can lead to higher levels of exposure to environmental pollutants. Also, since they go through many developmental processes that are susceptible to disruption, young children are inherently more vulnerable to the toxic effects of exposure of environmental chemicals (Faustman *et al.*, 2000). These differences between children and adults are important to consider in exposure assessments. As a result, OEHHA included the sensitivity of this subpopulation in estimating the risk (Main Report Section 5.4.5 and Section B.6). This section discusses the impacts of these age-related intrinsic factors and behavior patterns to exposures on synthetic turf fields.

Traditionally, OEHHA recommends the evaluation of the following age groups for risk assessments: third trimester fetus, 0<2, 2<9, 9<16, and 16-70 years (OEHHA, 2012; OEHHA, 2015). For the Study, OEHHA and the Synthetic Turf Scientific Advisory Panel (SAP) shared concerns that the default age ranges in some groups might be too wide to appropriately address differences in the physiology, activity patterns, and lifestyle patterns among the age groups of the receptor categories. Therefore, OEHHA decided

to apply the following age groups for this Study: third trimester fetus, 0<2, 2<6, 6<11, 11<16, 16<30, 30<40, 40<50, and 50<70 years. These age ranges can be interpreted as “from X years of age to less than Y years of age”, where if a person is Y years old, they would not be evaluated in this age group, but in the age group with the next higher range. For example, a 6-year-old child would be included in the 6<11 years age group and not the 2<6 years. Table B-1 presents the age groups of each receptor category considered in the exposure assessments.

Table B-1. Age Groups of Each Receptor Category Considered in the Exposure Assessment

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester fetus	No	No	No	Yes
0<2 years	No	No	No	Yes
2<6 years	Yes	No	No	Yes
6<11 years	Yes	No	No	Yes
11<16 years	Yes	No	No	Yes
16<30 years	Yes	Yes	Yes	Yes
30<40 years	Yes	Yes	Yes	Yes
40<50 years	Yes	Yes	Yes	Yes
50<70 years	Yes	Yes	Yes	Yes

B.2.1.1. Physiology

The two life stages of particular concern in terms chemical exposure are those of young children and adults at reproductive ages (16 years or older). Physiological development starts early in gestation. During this time, a fetus undergoes periods of rapid growth and development of various organ systems. After birth, the bodies of infants continue to grow and mature. Increases in BW and height occur rapidly during early childhood and continue through adolescence. The organ systems of children are continuously developing and maturing. For example, in assessing inhalation exposure, it is important to consider that the lungs continue to grow from early in life and mature in young adulthood (Schittny, 2017). Due to differences in lung size and structure, breathing patterns and inhalation rates vary with age. In adulthood, BW generally stabilizes although weight changes may occur depending on many factors including health status (for example pregnancy) and activity level.

The peak reproductive period for humans typically occurs from 16 to 50 years of age. Exposure to chemicals during these years has been shown to have adverse effects on female and male reproductive capabilities (e.g., infertility, poor pregnancy outcomes) as well as interfere with proper development during gestation and into childhood (e.g., physical deformities, altered growth, developmental delays)(Gynecologists, 2021; Segal and Giudice, 2019). Some mechanisms by which chemicals exert such toxicity include endocrine or hormone disruption and improper functioning of reproductive organs (Dubey *et al.*, 2022; Kelley *et al.*, 2019; Makhadumsab *et al.*, 2022; Rattan *et al.*, 2017). It is unknown what the link is between the timing and duration of exposure to the

development of adverse effects, so it is important to give special attention to chemical exposures during this sensitive period.

To account for the physiological differences associated with various life stages OEHHA used the groupings of third trimester fetus, 0<2, 2<6, 6<11, and 11<16 years of age to represent developing fetus, infancy, early childhood, middle childhood, and adolescence (ODPHP, 2020). The 16<30 and 30<40 years age groups represent the childbearing years for females, while the 16<30, 30<40, and 40<50 age groups cover the reproductive age for males.

B.2.1.2. Activity Patterns

Young children have different activity and behavior patterns than adolescents and adults that can influence exposures on synthetic turf fields. For example, young children tend to put their hands, toys, or other non-food objects into their mouths. This type of mouthing activity has been found to decrease with age in a study of children aged 7 to 36 months (Tsou *et al.*, 2015). Young children also spend more time close to the ground than pre-adolescents and adults. The 2<6, 6<11, and 11<16 years groupings represent the approximate years of pre-kindergarten/kindergarten, elementary school, and middle/high school, respectively, which this Study used to address differences in activity patterns (details in TAS Observational Study, Appendix F.3).

B.2.1.3. Lifestyle Patterns

The adult groupings, 16<30, 30<40, 40<50, and 50<70 years, represent stages from young to mature adulthood. During these periods, lifestyle, including education, careers, social patterns, and family life, may affect the amount of time a person spends at a synthetic turf field.

The 16<30 years age group encompasses high school, college, and professional athletes. These individuals tend to be highly competitive and may spend a substantial amount of time on synthetic turf fields. The 30<40 years group is also important to consider for professional athletes. A recent study (Kalén *et al.*, 2019) of aging trends and market values found that the performance of professional soccer players peaks around 25-27 years of age. After 35 years of age, the market value of players is at its lowest and the number of professional players is extremely low.

Family life is a consideration for individuals in the 16<50 years groups. These groups generally include women of childbearing age (16<40 years) and men of reproductive age (16<50 years), where reproductive and developmental toxicity are important considerations as discussed above. Individuals in these age groups, especially 30<50 years, may spend more time to take care of family members. This may impact the amount of time spend (e.g., EV and ET) or change their roles (e.g., athletes versus spectators) on synthetic turf fields.

B.2.2. Bodyweight

Measurements of BW for individuals of all ages are available in the literature. Both OEHHA (2012) and the EFH used measured BW data reported in the National Health and Nutrition Examination Survey (NHANES) to calculate and recommend BW values for various age groups. While the NHANES data are direct measurements of BW from a large sample of individuals designed to represent the general population of the United States, the data are neither California specific nor specific for athletes.

For BW values in this Study, OEHHA used a combination of data collected from the TAS Survey (Appendix F) on soccer players in California, NHANES, and the USEPA. The BW values from the TAS Survey are self-reported and considered estimates as they were not verified. However, they are specific for California soccer athletes, who are the primary receptors in our Study. Data gaps in our BW estimates are filled using data available from NHANES and the EFH. Table B-2 shows the BW value for each age group used in our Study. Data are presented for combined gender, females, and males. Combined gender values include data for females, males, and, when applicable, data for study participants who did not specify a gender. These values are used for all receptor categories following the assumption that coaches, referees, and spectators may be former or current players themselves and therefore would have a similar BW as the athletes. For the BW of third trimester pregnant women, OEHHA added an estimated 13.3 kilograms weight gain by 33 weeks pregnant (USEPA, 2011) to the mean BW for 16<40 year old women from the TAS Survey. For comparison to the Study-specific BW, BW data from the individual sources are shown in Table B-3 (NHANES 1999-2006 in OEHHA, 2012), Table B-4 (NHANES 1999-2006 in USEPA, 2011), Table B-5 (NHANES 2011-2014 in Fryar et al., 2016), and Table B-6 (OEHHA TAS Survey). A comparison of NHANES BW data from different years is presented in Table B-7.

Table B-2. Synthetic Turf Study Specific Mean Bodyweight (BW, kilograms)

Age Group	Combined Gender	Female	Male	Source
Third Trimester Pregnant Women[a]	Not applicable	75.6	Not applicable	TAS Survey and EFH
0<2 years[b]	9.4	9.2	9.6	NHANES 2011-2014 data (Fryar *et al.*, 2016)
2<6 years[c]	20.5	20.5	20.5	TAS Survey
6<11 years	32.0	31.6	32.2	TAS Survey
11<16 years	48.7	48.3	49.0	TAS Survey
16<30 years	65.8	60.9	72.3	TAS Survey
30<40 years	75.3	67.9	86.4	TAS Survey
40<50 years	74.5	65.2	84.8	TAS Survey
50<70 years	74.3	58.0	78.9	TAS Survey

[a] Third trimester pregnant women BW equals the sum of the mean survey BW for female athletes aged 16<40 years, and the total average BW gains in the first trimester, second trimester, and first seven weeks of the third trimester from the USEPA Exposure Factors Handbook (USEPA, 2011).
[b] The TAS Survey did not recruit participants in the 0<2 years group. Mean BW values for this age group were derived from the NHANES 2011-2014 data (Fryar *et al.*, 2016).
[c] The TAS Survey was unable to recruit any 2<6 year-old females. BW of the single 2<6 year-old male survey participant (20.5 kilograms) was used as a surrogate value for the mean BW of all the 2<6 years age groups.

B.2.2.1. National Health and Nutrition Examination Surveys 1999-2006

OEHHA (2012) derived the recommended BW values of combined gender for 0<2, 2<9, 2<16, 16<30 years, and 16-70 years age groups using the NHANES 1999-2006 data (Table B-3). The wide age range groupings make these values less than ideal for use in this Study.

Table B-3. OEHHA Recommended Combined Gender Bodyweight (BW, kilograms) Point Estimates Based on Analysis of NHANES 1999-2006 (OEHHA, 2012)

Age Group	Mean	50th Percentile
0<2 years	9.7	9.9
2<9 years	21.9	20.3
2<16 years	37	32.1
16<30 years	75.9	72.1
16-70 years	80	77.4

The EFH provides recommendations on the mean BW for children and adults derived from the NHANES 1999-2006 data. The age groups presented in the EFH are different from those used in our Study, so OEHHA combined the USEPA age groups to match the Synthetic Turf Study groupings. We calculated time-weighted BW values for each group (e.g., for the 0<2 years group, NHANES 1999-2006 1 to <3 months group data is

given a weight of 2 months per 24 months)[1]. Table B-4 shows the mean, 25th percentile, and 50th percentile BW values for combined gender.

Table B-4. USEPA Recommended Combined Gender Bodyweight (BW, kilograms) Derived from NHANES 1999-2006 (USEPA, 2011)

Age Group	Mean	25th Percentile	50th Percentile
0<2 years[a]	9.6	8.7	9.5
2<6 years[a]	17.4	15.0	16.8
6<11 years	31.8	24.4	29.3
11<16 years	56.8	45.0	54.2
16<30 years[a]	76.0	61.6	72.5
30<40 years	80.8	66.1	77.9
40<50 years	83.6	68.3	81.4
50<70 years[a]	83.0	69.1	80.7

[a] Time-weighted values due to the combining age groups. For example, data from the birth<1 month, 1<3 months, 3< 6 months, 6<12 months and 1<2 years groups were combined to estimate the BW of the 0<2 years group (see example in footnote 1).

B.2.2.2. National Health and Nutrition Examination Surveys 2011-2014

Recently, the Centers for Disease Control and Prevention (CDC) reported a more recent NHANES dataset, collected from 2011 to 2014 (Fryar *et al.*, 2016). Using the updated data, OEHHA derived BW values for combined gender, females, and males (Table B-5) and in 0<2, 2<6, 6<11, 11<16, 16<30, 30<40, 40<50, and 50<70 years age groupings. We applied the same time-weight average calculation method to derive BW values of several age groups. Table B-5 summarizes BW values for the mean, 25th, and 50th percentiles for combined gender. There is less than a five percent difference between the mean values derived using NHANES 1999-2006 (Table B-4) and NHANES 2011-2014 (Table B-5).

[1] To combine age group data from the EFH into a time-weighted mean value for a Synthetic Turf Study defined age group, USEPA data values are multiplied by weighted factors (a factor of one for each year of age over the number of years in the Synthetic Turf Study age group) and summed together.

For example, for the combined gender BW for the Synthetic Turf Study 2<6 years age group (Table B-6), data for the combined gender 2<3 years and 3<6 years age groups from Table 8-3 of the EFH are used to calculate the time-weighted mean value. For the 2<3 years and 3<6 years age groups, the USEPA values for the mean BW are given weights of 1/4 and 3/4, respectively.

To calculate the time-weighted mean BW for 2<6 years, the mean body weight for 2<3 years and 3<6 years are multiplied by their respective weights and the values are summed together: (13.8 kilograms times 1/4) + (18.6 kilograms times 3/4) = 17.4 kilograms.

Table B-5. Combined Gender Bodyweight (BW, kilograms) Derived from NHANES 2011-2014 (Fryar *et al.*, 2016)

Age Group	Mean	25th Percentile	50th Percentile
0<2 years[a]	9.4	8.4	9.3
2<6 years	17.2	15.4	16.7
6<11 years	31.9	26.0	29.5
11<16 years	58.0	46.8	53.5
16<30 years[a]	77.1	62.3	72.2
30<40 years	84.3	69.4	79.7
40<50 years	85.0	70.5	81.8
50<70 years[a]	84.2	70.3	82.0

[a] Time-weighted values due to the combining of age groups. For example, data from the birth<1 month, 1<3 months, 3< 6 months, 6<12 months and 1<2 years groups were combined to estimate the BW of the 0<2 years group.

B.2.2.3. Time-Activity Studies Survey Data

OEHHA collected self-reported data on the BW of soccer players in our TAS Survey. Table B-6 summarizes the mean BW data according to age and gender. The TAS Survey focused on collecting activity data from soccer athletes and hence we did not recruit participants younger than two years. Additionally, OEHHA was unable to recruit any female, but just one male, younger than six years to participate in the TAS Survey.

Table B-6. Bodyweight (BW, kilograms) Derived from Time-Activity Study Survey Data

Age Group	No. of Combined Gender	Combined Gender—Mean (Standard Deviation)	No. of Female	Female Mean (Standard Deviation)	No. of Male	Male Mean (Standard Deviation)
2<6 years	1	20.5[a]	0	No data	1	20.5[a]
6<11 years	112	32.0 (6.6)	35	31.6 (6.5)	76	32.2 (6.7)
11<16 years	495	48.7 (10.5)	243	48.3 (9.3)	248	49.0 (11.7)
16<30 years	260	65.8 (10.5)	148	60.9 (7.8)	112	72.3 (10.2)
30<40 years	61	75.3 (13.3)	35	67.9 (8.8)	25	86.4 (10.4)
40<50 years	84	74.5 (14.2)	44	65.2 (9.2)	40	84.8 (11.4)
50<70 years	32	74.3 (11.5)	7	58.0 (7.5)	25	78.9 (7.5)

[a] Not a mean value. Value represents data from one male individual in the 2<6 years group. OEHHA did not estimate the standard deviation.

For younger athletes (2<11 years), our TAS Survey data-derived mean BW values for combined gender are similar to or slightly greater than the mean value of the NHANES 1999-2006 and 2011-2014 data sets for combined gender (Table B-7). For athletes over 11 years of age, our Study mean BW values are lower than the mean values and fall between the 25th and 50th percentile values derived from the NHANES data. These same patterns exist for female or male mean BW (data not shown). This supports our assumption that athletes tend to be physically fit and leaner than the average individual

and that the TAS Survey data is the most appropriate dataset to use in our Study, especially for older athletes. The higher BW values (combined gender) recommended in the OEHHA (OEHHA, 2012) and USEPA (USEPA, 2011) guidance documents may result in underestimating exposures if used in our risk assessment. On the other hand, the similarity of mean combined gender BW values of our TAS Survey data with the NHANES supports the use NHANES to fill in the data gaps for younger athletes.

Table B-7. Comparison of Bodyweight (BW, kilograms) Derived from TAS Survey and NHANES Datasets — Combined Gender

Age Group	TAS Survey Mean	NHANES 1999-2006 Mean	NHANES 1999-2006 25th Percentile	NHANES 1999-2006 50th Percentile	NHANES 2011-2014 Mean	NHANES 2011-2014 25th Percentile	NHANES 2011-2014 50th Percentile
2<6 years	20.5	17.4	15.0	16.8	17.2	15.4	16.7
6<11 years	32.0	31.8	24.4	29.3	31.9	26.0	29.5
11<16 years	48.7	56.8	45.0	54.2	58.0	46.8	53.5
16<30 years	65.8	76.0	61.6	72.5	77.1	62.3	72.2
30<40 years	75.3	80.8	66.1	77.9	84.3	69.4	79.7
40<50 years	74.5	83.6	68.3	81.4	85.0	70.5	81.8
50<70 years	74.3	83.0	69.1	80.7	84.2	70.3	82.0

NHANES: National Health and Nutrition Examination Surveys; TAS: Time-Activity Studies

B.2.2.4. Third Trimester Bodyweight Estimate

For this Study, OEHHA reviewed several BW values for the pregnant women. OEHHA (2012) guidelines recommend a mean BW value of 80.0 kilograms for 16<70 year old, which includes the age group of child-bearing age women. For the California Proposition 65 program, OEHHA calculates the safe harbor levels for reproductive and developmental toxicants using a value of 58.0 kilograms (mandated in the law, Title 22, California Code of Regulations, section 12803(b)). The TAS Survey data showed a higher BW of 62.3 kilograms for 16<40 year-old females.

The EFH recommends a mean value of 80 kilograms for pregnant women in the third trimester, derived from the NHANES 1999-2006. Additionally, the EFH provides the distribution of weight gain during pregnancy by trimester. By the midway point of the third trimester, around 33 weeks, USEPA estimated a mean weight gain of 13.3 kilograms. OEHHA added this weight gain value to the mean BW of a female of child-bearing age (16<40 years, 62.3 kilograms) obtained from the TAS Survey to estimate the mean BW value of 75.6 kilograms for third trimester pregnant women (Table B-2).

B.2.3. Event Frequency

The event frequency (EV, events per year) describes the number of field events that a receptor participates in during a single year. A field event may be a practice, a game, or multiple games in a tournament. The number of events per week may differ between practices and games, by seasons, and across age groups.

B.2.3.1. Athletes

The TAS Survey self-reported data suggest that some highly devoted athletes might have a practice and a game on the same day. When every practice and game are counted as individual events, this results in an event frequency (EV) of greater than 365 events per year for those individual athletes.

OEHHA calculated EV values of each event type for athletes (i.e., practice EV and game EV) from exposure frequency data (EF, the number of events per week an athlete participated in practices or games in each season) collected in our TAS Survey. We calculated the EV of an event type for an individual athlete using the equation below:

$$EV_{event\ type} = \sum_{k=season} EF_{event\ type,k} \times CF \qquad \text{Equation B-1}$$

where,

$EV_{event\ type}$ = event frequency, the annual frequency that an individual participated in a particular type of field event, events per year

$EF_{event\ type,k}$ = exposure frequency, the weekly frequency an individual participated in a particular event type in a particular season of the year, events per week

CF = conversion factor, 13 weeks per season

k = a specific season of the year (i.e., spring, summer, fall, and winter)

Considering there are 13 weeks in a season and 4 seasons (spring, summer, fall, and winter) in a year, OEHHA used each participant's EF for a season to calculate their individual EV for the year. We derived values of EV for practices, games, as well as combined practice and game for each individual athlete. Table B-8 to Table B-10 summarize the descriptive statistics of the combined practice and game EVs for TAS Survey participants (athletes). Additionally, below are the data distribution for practice (Table B-11 to Table B-13) and game (Table B-14 to Table B-16) of athletes.

Table B-8. Combined Practice and Game Event Frequency (EV, Events Per Year) – Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (3)[a]	139	39	Not applicable	Not applicable	Not applicable	221
6<11 years (119)	121 (70)	13	104	208	248	312
11<16 years (487)	149 (83)	13	143	260	295	481
16<30 years (258)	215 (89)[b]	13	208	312	366	494
30<40 years (58)	163 (86)	26	156	260	277	468
40<50 years (84)	137 (96)	26	104	286	338	416
50<70 years (32)	138 (97)	52	104	233	247	559

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency. TAS Survey data of three 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of three 6-year-old participants' TAS Survey data. OEHHA did not estimate the standard deviation, or percentile values for this age group.
[b] Value also used for the EV of coaches (Section B.2.3.2).

Table B-9. Combined Practice and Game Event Frequency (EV, Events Per Year) – Female Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (1)[a]	39	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (38)	99 (59)	13	98	168	208	247
11<16 years (238)	156 (84)	13	150	260	312	481
16<30 years (147)	207 (88)	13	208	312	364	494
30<40 years (34)	131 (75)	26	104	243	252	273
40<50 years (44)	120 (84)	26	104	208	278	364
50<70 years (7)	93 (32)	52	104	120	131	143

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] No female younger than six years old participated in the TAS Survey. OEHHA used TAS Survey data of the only 6-year-old female participant as a surrogate for the female 2<6 years age group. The mean value represents the TAS Survey data of the 6-year-old female participant. OEHHA did not estimate the minimum, maximum, mean, standard deviation, or percentile values for this age group.

Table B-10. Combined Practice and Game Event Frequency (EV, Events Per Year) – Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	189	156	Not applicable	Not applicable	Not applicable	221
6<11 years (79)	131 (71)	13	117	221	261	312
11<16 years (244)	143 (80)	13	130	260	273	364
16<30 years (111)	225 (88)	13	234	312	371	442
30<40 years (23)	206 (84)	52	195	294	311	468
40<50 years (40)	156 (105)	26	1450	315	364	416
50<70 years (25)	151 (106)	52	117	242	247	559

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One male participant in the 2<6 age group completed a TAS Survey but he did not provide responses for exposure frequency. Survey data of two 6-year-old male participants were used as surrogate for the 2<6 years male age group. The mean value represents the average of the two 6-year-old male participants' TAS Survey data. OEHHA did not estimate the standard deviation or percentile values for this age group.

Table B-11. Practice Event Frequency (EV, Events Per Year) – Combined Gender Athletes

Age Group (Number of Participants	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (3)[a]	95	39	Not applicable	Not applicable	Not applicable	143
6<11 years (105)	75 (42)[b]	13	65	130	156	169
11<16 years (432)	101 (55)	13	104	169	201	325
16<30 years (240)	145 (63)	26	143	222	260	338
30<40 years (41)	112 (61)	13	104	182	195	312
40<50 years (44)	101 (57)	26	104	182	204	221
50<70 years (22)	92 (72)	26	72	176	194	351

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency. OEHHA used Survey data of three 6-year-old participants as surrogate for the 2<6 years age group. The mean value represents the average of three 6-year-old participants' TAS Survey data. OEHHA did not estimate the standard deviation, or percentile values for this age group.
[b] We used this value as the EV of all spectators at practice events.

Table B-12. Practice Event Frequency (EV, Events Per Year) – Female Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (1)[a]	39	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (32)	64 (34)	13	65	104	117	143
11<16 years (215)	102 (56)	13	104	169	195	325
16<30 years (132)	137 (59)	26	130	208	234	325
30<40 years (19)	85 (52)	13	65	146	159	182
40<50 years (16)	97 (54)	26	104	169	182	182
50<70 years (4)	62 (29)	39	52	88	96	104

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] No female younger than six years old participated in the TAS Survey. OEHHA used the Survey data of one female 6-year-old participant as surrogate for the 2<6 years age group. The mean value represents the TAS Survey data one 6-year-old female participant. OEHHA did not estimate the minimum, maximum, standard deviation, or percentile values for this age group.

Table B-13. Practice Event Frequency (EV, Events Per Year) – Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	124	104	Not applicable	Not applicable	Not applicable	143
6<11 years (71)	80 (44)	13	78	143	156	169
11<16 years (213)	100 (54)	13	104	169	200	260
16<30 years (108)	155 (67)	26	156	234	260	338
30<40 years (21)	134 (59)	52	130	195	208	312
40<50 years (28)	104 (60)	26	104	190	208	221
50<70 years (18)	98 (77)	26	78	186	218	351

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One male participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency. OEHHA used the Survey data of two male 6-year-old participants as surrogate for the 2<6 years age group. The mean value represents the average of the two 6-year-old male participants' TAS Survey data. OEHHA did not estimate the standard deviation or percentile values for this age group.

Table B-14. Game Event Frequency for (EV, Events Per Year) – Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	65	52	Not applicable	Not applicable	Not applicable	78
6<11 years (110)	59 (39)	13	52	117	150	195
11<16 years (464)	62 (38)	13	52	104	141	273
16<30 years (249)	83 (43)	13	78	130	164	286
30<40 years (56)	86 (42)[b]	13	78	143	156	208
40<50 years (83)	86 (48)[b]	26	78	156	168	221
50<70 years (30)	80 (49)	26	52	144	185	208

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency. Survey data of two 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of two 6-year-old participants' TAS Survey data. OEHHA did not estimate the standard deviation, or percentile values for this age group.
[b] Value used for the EV of referees and for all spectators at game events (Sections B.2.3.3 and B.2.3.4).

Table B-15. Game Event Frequency (EV, Events Per Year) – Female Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (0)[a]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (36)	47 (32)	13	39	98	111	130
11<16 years (227)	67 (40)	13	52	109	152	273
16<30 years (144)	86 (46)	13	78	156	202	286
30<40 years (33)	86 (45)	13	78	130	169	208
40<50 years (44)	85 (47)	26	78	156	156	208
50<70 years (7)	58 (21)	39	52	73	88	104

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] No female younger than six years old participated in the TAS Survey. One six year-old female provided no response or a response of zero for the number of games per week for all four seasons.

Table B-16. Game Event Frequency (EV, Events Per Year) – Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	65	52	Not applicable	Not applicable	Not applicable	78
6<11 years (72)	65 (40)	13	52	117	156	195
11<16 years (232)	58 (36)	13	52	104	130	208
16<30 years (105)	78 (38)	13	65	117	140	247
30<40 years (22)	87 (40)	52	72	143	155	156
40<50 years (39)	86 (50)	26	78	156	173	221
50<70 years (23)	87 (54)	26	65	153	203	208

Table values are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One male participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency. OEHHA used the Survey data of two male 6-year-old participants as surrogate for the 2<6 years age group. The mean value represents the average of the two 6-year-old male participants TAS Survey data and OEHHA did not estimate the standard deviation or percentile values for this age group.

B.2.3.2. Coaches

OEHHA assumed that soccer coaches are on the field every time, when athletes are present, to provide supervision, training, and instruction. As a result, we applied the values of EV for athletes–combined practice and game—to estimate the value of EV for the coaches. Coaches may lead one team or multiple teams (females and males) during the same season. To consider the number of possible teams a coach may have and since the TAS Survey did not collect data on coaching activities, OEHHA considered the data for athletes six years and older, combined gender and combined practice and game in Table B-8 to estimate a single value for coach's EV. Due to uncertainty in the 2<6 year-old group data because of its small sample size and incomplete data collected, OEHHA excluded values from this group in determining the EV of the coach receptor category. OEHHA selected a value of 215 events per year (Table B-17), the highest mean EV, as the EV for coaches, from the estimate for 16<30 years group.

Table B-17. Event Frequency (EV, Events Per Year) – Combined Gender Coaches, Referees, and Spectators

Receptor	Combined Practice and Game	Practice	Game
Coach	215		
Referee	Not applicable	Not applicable	86
Spectator	161	75	86

B.2.3.3. Referees

Referees are on the field for games and may have the same game EV as athletes. The TAS Survey did not collect data on the activities of referees. Similar to coaches, referees may officiate multiples age groups and teams consisting of athletes of both genders. OEHHA considered the game data for athletes six years and older and

combined gender in Table B-14 to estimate a single value for referee's EV. The selected single EV value for referees is 86 events per year (Table B-17), from the 30<40 years and 40<50 years age groups, Table B-14, as the parameter value for this receptor category. This value is the highest estimate of the mean of EV for games of athletes.

B.2.3.4. Spectators

OEHHA assumed spectators to be at the practices of athletes less than 11 years old. Child spectators may be present at the field because their siblings have practices and adult spectators may be present to observe their children (2<11 years old) on the field or on the sidelines. We considered that children and parents were less likely to be at the practices of teenage or adult soccer athletes. OEHHA considered the practice data for combined gender athletes 6<11 years old in Table B-11 to estimate the practice EV of the spectator receptor category. Due to uncertainty in the 2<6 year-old group data because of its small sample size and incomplete data collected, we excluded data from this age group in the estimation. We selected the highest estimate of the mean practice EV of athletes 6<11 years old, a value of 75 events per year (Table B-17), for this receptor category.

Additionally, spectators may be present at the games of athletes of any ages. OEHHA chose the highest estimate among the mean game EV for combined gender athletes from Table B-14, 86 events per year from the 30<40 years and 40<50 years age groups, as the game EV for the spectators in Table B-17.

As stated above, OEHHA considered that spectators (children and parents) were less likely to be at the practices of teenage or adult soccer athletes (≥11 years old) but they may be present at the games of athletes of any ages. Considering spectators may have multiple soccer athletes in their families, they may attend practices of young soccer athletes and games of athletes of any ages. The mean value of combined practice and game EV for combined gender athletes in an individual age group may not be suitable to estimate the values of EV for spectators. OEHHA, therefore, calculated the combined practice and game EV by adding the practice EV and game EV for this receptor category, a value of 161 events per year (Table B-17). This calculated value is higher than mean values of combined practice and game for combined gender athletes at age of 2<6 and 6<11 years (139 and 121 events per year, respectively, in Table B-8).

B.2.4. Event Time

Event time (ET, hours per event) is the amount of time spent on or near the synthetic turf field during an event. As with EF, it may differ between practices and games, seasons, age groups, and receptor categories. OEHHA used the TAS Survey data on ET from athletes to develop this parameter for each receptor category. We applied statistical analysis on the reported maximum ET among all the seasons by each individual survey participant. The descriptive statistics of those values for the athletes are in Table B-18 (practice, combined gender), Table B-19 (practice, females), Table

B-20 (practice, males), Table B-21 (game, combined gender), Table B-22 (game, females), and Table B-23 (game, males).

OEHHA applied the same assumptions used in evaluating the EV to estimate the ET for coaches, referees, and spectators (Table B-24). For coaches, we adopted a value of 3.1 hours per event (Table B-18, for 30<40 years old) as the practice ET. For spectators, we selected a value of 2.1 hours per event (Table B-18, for 6<11 years old) for this receptor group attending practices. For games, we chose a value of 3.1 hours per event (Table B-21, for 16<30 years old) for coaches, referees, and spectators.

Table B-18. Practice Event Time (ET, Hours Per Event) – Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (3)[a]	1.5	1.0	Not applicable	Not applicable	Not applicable	2.0
6<11 years (102)	2.1 (1.9)[b]	0.1	1.8	3.0	4.5	15.0
11<16 years (430)	2.3 (1.7)	0.2	2.0	4.0	5.0	16.0
16<30 years (232)	2.8 (2.1)	1.0	2.0	5.0	8.0	12.0
30<40 years (41)	3.1 (2.2)[c]	1.0	2.0	5.0	6.0	12.0
40<50 years (41)	2.5 (2.0)	0.3	2.0	6.0	6.0	10.0
50<70 years (22)	2.3 (3.1)	0.3	2.0	2.9	3.0	16.0

[a] One participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure time. Survey data of three 6-year-old participants were used as surrogate for the 2<6 years age group. The mean data value represents the average of TAS Survey data of three 6-year-old participants and was used as surrogate for the 2<6 years age group. No standard deviation or percentiles were calculated.
[b] Value used for the practice ET of spectators.
[c] Value used for the practice ET of coaches.
Max: maximum and Min: minimum

Table B-19. Practice Event Time (ET, Hours Per Event) – Female Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (1)[a]	2.0	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (31)	1.8 (1.0)	0.1	1.5	3.0	3.8	5.0
11<16 years (213)	2.1 (1.1)	0.4	2.0	3.0	4.0	10.0
16<30 years (130)	2.9 (2.3)	1.0	2.0	5.1	10.0	12.0
30<40 years (19)	3.3 (3.1)	1.0	2.0	6.8	10.2	12.0
40<50 years (12)	2.6 (2.0)	0.3	2.0	5.8	6.0	6.0
50<70 years (4)	2.0 (0.7)	1.5	n/a	n/a	n/a	3.0

[a] No female younger than six years old participated in the TAS Survey. Survey data of one 6-year-old female participant were used as surrogate for the 2<6 years age group. The mean value represents the TAS Survey data of one 6-year-old female participant. OEHHA did not estimate the minimum, maximum, standard deviation, or percentile values for this age group.
Max: maximum and Min: minimum

Table B-20. Practice Event Time (ET, Hours Per Event) – Male Athletes

Age Group (Number of Participant)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	1.3	1.0	Not applicable	Not applicable	Not applicable	1.5
6<11 years (69)	2.3 (2.2)	0.1	2.0	4.0	5.2	15.0
11<16 years (213)	2.5 (2.2)	0.2	2.0	4.0	6.0	16.0
16<30 years (102)	2.8 (1.0)	1.0	2.0	5.0	6.0	12.0
30<40 years (21)	2.7 (0.9)	1.0	3.0	4.0	4.0	5.0
40<50 years (29)	2.5 (2.0)	0.5	2.0	4.4	6.6	10.0
50<70 years (18)	2.4 (3.5)	0.3	2.0	2.3	4.9	16.0

[a] One male participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure time. Survey data of two 6-year-old male participants were used as surrogate for the 2<6 years age group. The mean value represents the average of the two 6-year-old male participants' TAS Survey data and OEHHA did not estimate the standard deviation or percentile values for this age group.
Max: maximum and Min: minimum

Table B-21. Game Event Time (ET, Hours Per Event) – Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (3)[a]	4.3	1.0	Not applicable	Not applicable	Not applicable	10.0
6<11 years (103)	2.3 (2.5)	0.001	1.5	4.0	7.3	15.0
11<16 years (422)	2.2 (1.9)	0.02	2.0	4.0	5.0	15.0
16<30 years (235)	3.1 (2.4)[b]	0.5	2.0	5.8	6.6	15.0
30<40 years (55)	2.1 (1.2)	0.2	2.0	4.0	4.0	6.0
40<50 years (74)	2.4 (2.1)	0.2	2.0	4.0	6.0	15.0
50<70 years (26)	2.6 (2.9)	0.1	2.0	4.5	5.8	15.0

[a] One participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure time. Survey data of three 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of survey data of three 6-year-old participants and was used as surrogate for the 2<6 years age group. No standard deviation, or percentiles were calculated.
[b] Value used for the game ET of coaches, referees, and spectators.
Max: maximum and Min: minimum

Table B-22. Game Event Time (ET, Hours Per Event) – Female Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (1)[a]	10.0	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (34)	2.6 (3.4)	0.001	1.0	5.7	10.7	15.0
11<16 years (212)	2.3 (2.0)	0.1	2.0	4.0	4.0	15.0
16<30 years (134)	3.0 (2.5)	0.5	2.0	5.0	6.0	15.0
30<40 years (32)	2.0 (1.3)	0.2	1.8	4.0	4.0	5.0
40<50 years (38)	2.3 (2.6)	0.2	1.8	4.0	5.5	15.0
50<70 years (7)	2.1 (1.1)	1.0	1.5	3.4	3.7	4.0

[a] No female younger than six years old participated in the TAS Survey. Survey data of one female 6-year-old participant were used as surrogate for the 2<6 years age group. The mean value represents the TAS Survey data one 6-year-old female participant and was used as surrogate for the 2<6 years age group. OEHHA did not estimate the minimum, maximum, standard deviation, or percentile values for this age group.
Max: maximum and Min: minimum

Table B-23. Game Event Time (ET, Hours Per Event) – Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	1.5	1.0	Not applicable	Not applicable	Not applicable	2.0
6<11 years (67)	2.3 (2.0)	0.1	2.0	4.0	4.7	12.0
11<16 years (206)	2.2 (1.9)	0.02	2.0	4.0	5.0	13.0
16<30 years (101)	3.2 (2.4)	1.0	2.0	6.0	8.0	15.0
30<40 years (22)	2.2 (0.7)	1.0	2.0	3.0	3.5	4.0
40<50 years (36)	2.4 (1.6)	0.3	2.0	4.0	6.0	7.0
50<70 years (19)	2.8 (3.4)	0.1	2.0	5.2	6.9	15.0

[a] One male participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure time. Survey data of two male 6-year-old participants were used as surrogate for the 2<6 years age group. The mean data value represents the average of two 6-year-old male TAS Survey participants' data and was used as surrogate for the 2<6 years male age group. No standard deviation, or percentiles were calculated for this age group.
Max: maximum and Min: minimum

Table B-24. Event Time (ET, Hours Per Event) – Combined Gender Coaches, Referees, and Spectators

Receptor	Practice	Game
Coach	3.1	3.1
Referee	Not applicable	3.1
Spectator	2.1	3.1

B.2.5. Annual Event Time

The annual event time (AET, hours per year) is the total amount of time a receptor spends on the field in a year. This includes time spent for both practices and games, and a sum of the four seasons. OEHHA calculated the AET of individual TAS Survey participants by first multiplying the individual's EF (events per week) and ET (hours per event) for an event type in each season and then converting the product to events per season (applying a conversion factor of 13 weeks per season), followed by summing the hours for both practice and games in the four seasons, as below:

$$AET_i = \sum_{k=season} \left[\left(\left(EF_{i,practice,k} \times ET_{i,practice,k} \right) + \left(EF_{i,game,k} \times ET_{i,game,k} \right) \right) \times CF \right]$$ Equation B-2

Where,

AET_i = annual event time, total practice and game time over the four seasons, of an individual survey participant spent on synthetic turf field, hours per year

$EF_{i,practice,k}$ = exposure frequency of practices in a season, of an individual survey participant, events per week

$ET_{i,practice,k}$ = event time of practices in a season, of an individual survey participant, hours per event

$EF_{i,game,k}$ = exposure frequency of games in a season, of an individual survey participant, events per week

$ET_{i,game,k}$ = event time of games in a season, of an individual survey participant, hours per event

CF = conversion factor, 13 weeks per season

i = designates an individual survey participant

k = a specific season of the year (i.e., spring, summer, fall, and winter)

OEHHA calculated AET for individual TAS Survey participants to capture each of their unique activity patterns. Athletes may or may not play all year-round and their time spent on field can vary by season. Therefore, the EF and ET for a season are treated as paired data and calculated on an individual basis for athletes.

Table B-25, Table B-26, and Table B-27 summarize the descriptive statistics of combined practice and game AET, respectively, for combined gender, female, and male athletes. For coaches and spectators, based on the assumptions made for EV and ET, we estimated their combined practice and game AET as 549 events per year (Table B-25, 16<30 years group) for coaches and 259 events per year (Table B-25, 6<11 years group) for spectators.

Table B-28, Table B-29, and Table B-30 show the descriptive statistics for practice AET values of combined gender, female, and male athletes, respectively. Table B-31, Table B-32, and Table B-33 summarize the descriptive statistics of game AET, respectively, for combined gender, female, and male athletes. For coaches, referees, and spectators, we applied the same assumptions made for EV (Section B2.3) and ET (Section B2.4) and estimated their AET as 354 practice hours per year (Table B-28, 16<30 years group), 241 game hours per year (Table B-31, 16<30 years group), and 549 combined practice and game hours per year (Table B-25, 16<30 years group) for coaches; 241 game hours per year for referees (Table B-31, 16<30 years group); and 156 practice hours per year (Table B-28, 6<11 years group), 241 game hours per year (Table B-31, 16<30 years group), and 397 combined practice and game hours per year for spectators.

Table B-25. Combined Practice and Game Annual Event Time (AET, Hours Per Year) – Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (3)[a]	195	78	Not applicable	Not applicable	Not applicable	299
6<11 years (114)	259 (269)[b]	2.7	169	597	729	1820
11<16 years (467)	316 (272)	0.9	247	624	780	2860
16<30 years (249)	549 (421)[c]	26	442	980	1193	2912
30<40 years (58)	395 (352)	10	312	736	979	1872
40<50 years (78)	335 (454)	9.8	156	832	989	2912
50<70 years (29)	350 (466)	7.3	208	673	1284	2145

Table values less than 10 are rounded to the nearest whole integer. Max: maximum and Min: minimum

[a] One participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency or exposure time. Survey data of three 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of three 6-year-old TAS Survey participants' data and was used as surrogate for the 2<6 years male age group. No standard deviation, or percentiles were calculated for this age group.

[b] Values used for the combined practice and game AET of spectators.

[c] Value used for the combined practice and game AET of coaches.

Table B-26. Combined Practice and Game Annual Event Time (AET, Hours Per Year) – Female Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (1)[a]	78	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (36)	193 (232)	2.7	130	429	598	1196
11<16 years (229)	322 (248)	20	260	624	784	1456
16<30 years (143)	521 (408)	26	429	901	1205	2912
30<40 years (34)	328 (386)	10	208	681	994	1872
40<50 years (38)	280 (401)	20	150	705	1012	2054
50<70 years (7)	181 (80)	52	195	250	281	312

Table values less than 10 are rounded to the nearest whole integer. Max: maximum and Min: minimum

[a] No female younger than six years old participated in the TAS Survey. Survey data of one 6-year-old female participant were used as surrogate for the 2<6 years age group. The mean value represents the TAS Survey data one 6-year-old female participant. OEHHA did not estimate the minimum, maximum, standard deviation, or percentile values for this age group.

Table B-27. Combined Practice and Game Annual Event Time (AET, Hours Per Year) – Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	254	208	Not applicable	Not applicable	Not applicable	299
6<11 years (76)	291 (283)	10	208	624	757	1820
11<16 years (233)	313 (296)	0.9	234	634	780	2860
16<30 years (106	586 (436)	52.0	494	1014	1162	2834
30<40 years (23)	470 (269)	91.0	468	707	751	1404
40<50 years (40)	387 (498)	9.8	260	836	943	2912
50<70 years (22)	403 (525)	7.3	221	846	1526	2145

Table values less than 10 are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One male participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency or exposure time. Survey data of two male 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of two 6-year-old male TAS Survey participants' data and was used as surrogate for the 2<6 years male age group. No standard deviation, or percentiles were calculated for this age group.

Table B-28. Practice Annual Event Time (AET, Hours Per Year) – Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (3)[a]	126	78	Not applicable	Not applicable	Not applicable	156
6<11 years (100)	156 (205)[b]	2.6	104	260	431	1820
11<16 years (422)	223 (224)	3.9	176	416	545	2860
16<30 years (229)	354 (254)[c]	26	312	650	796	1872
30<40 years (40)	343 (336)	26	260	653	813	1872
40<50 years (40)	256 (295)	15	130	506	825	1456
50<70 years (21)	187 (266)	13	104	364	390	1248

Table values less than 10 are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency or exposure time. Survey data of three 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of TAS Survey data of three 6-year-old participants and was used as surrogate for the 2<6 years age group. No standard deviation, or percentiles were calculated.
[b] Values used for the practice AET of spectators.
[c] Value used for the practice AET of coaches.

Table B-29. Practice Annual Event Time (AET, Hours Per Year) – Female Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (1)[a]	78	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (29)	109 (87)	2.6	91	198	224	429
11<16 years (210)	210 (162)	13	156	390	468	1118
16<30 years (127)	331 (247)	26	273	608	754	1768
30<40 years (19)	323 (442)	26	156	681	913	1872
40<50 years (12)	260 (295)	15	130	697	822	936
50<70 years (4)	114 (43)	59	120.3	150	153	156

Table values less than 10 are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] No female younger than six years old participated in the TAS Survey. Survey data of one 6-year-old female participant were used as surrogate for the 2<6 years age group. The mean value represents the TAS Survey data one 6-year-old female participant. OEHHA did not estimate the minimum, maximum, standard deviation, or percentile values for this age group.

Table B-30. Practice Annual Event Time (AET, Hours Per Year) – Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	150	143	Not applicable	Not applicable	Not applicable	156
6<11 years (69)	177 (238)	5.2	104	287	468	1820
11<16 years (208)	238 (272)	3.9	189	450	624	2860
16<30 years (102)	382 (260)	52	351	685	843	1872
30<40 years (20)	350 (209)	104	299	629	689	936
40<50 years (28)	255 (300)	26	130	481	701	1456
50<70 years (17)	204 (294)	13	104	374	5612	1248

Table values less than 10 are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One male participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency or exposure time. Survey data of two male 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of the two 6-year-old male participants TAS Survey data and OEHHA did not estimate the standard deviation or percentile values for this age group.

Table B-31. Game Annual Event Time (AET, Hours Per Year) – Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	104	52	Not applicable	Not applicable	Not applicable	156
6<11 years (102)	137 (172)	0.1	68	390	493	988
11<16 years (414)	129 (135)	0.3	91	260	338	1170
16<30 years (231)	241 (312)[b]	22	156	390	641	2912
30<40 years (55)	167 (116)	10	104	312	432	481
40<50 years (74)	214 (266)	9.8	126	494	750	1456
50<70 years (26)	239 (354)	6.5	104	689	861	1560

Table values less than 10 are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] One participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure frequency or exposure time. Survey data of two 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of two 6-year-old male TAS Survey participants' data and was used as surrogate for the 2<6 years male age group. No standard deviation or percentiles were calculated for this age group.
[b] Value used for the AET of coaches, referees, and spectators.

Table B-32. Game Annual Event Time (AET, Hours Per Year) – Female Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (0)[a]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (33)	115 (192)	0.1	39	265	432	988
11<16 years (208)	143 (149)	3.9	104	316	389	1170
16<30 years (133)	244 (342)	22	156	359	638	2912
30<40 years (32)	157 (124)	10	104	312	439	481
40<50 years (38)	198 (248)	11	104	494	699	1118
50<70 years (7)	116 (59)	52	104	177	192	208

Table values less than 10 are rounded to the nearest whole integer. Max: maximum and Min: minimum.
[a] No female younger than six years old participated in the TAS Survey. The Survey was unable to recruit a female 6-year-old participant who provided game data to use as a surrogate for the 2<6 years age group.

Table B-33. Game Annual Event Time (AET, Hours Per Year) – Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	104	52	Not applicable	Not applicable	Not applicable	156
6<11 years (67)	148 (164)	4.6	78	416	516	728
11<16 years (202	116 (117)	0.3	78	234	312	936
16<30 years (98)	237 (269)	26	163	398	640	1950
30<40 years (22)	174 (101)	52	130	283	311	468
40<50 years (36)	232 (286)	9.8	156	494	673	1456
50<70 years (19)	284 (406)	6.5	104	783	963	1560

Table values less than 10 are rounded to the nearest whole integer.

[a] One male participant in the 2<6 age group completed a TAS Survey but did not provide responses for exposure time. Survey data of two male 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of two 6-year-old male TAS Survey participants' data and was used as surrogate for the 2<6 years male age group. No standard deviation or percentiles were calculated for this age group.

Table B-34. Annual Event Time (AET, Hours Per Year) – Combined Gender Coaches, Referees, and Spectators

Receptor	Combined Practice and Game	Practice	Game
Coach	549	354	241
Referee	Not applicable	Not applicable	241
Spectator	397	156	241

B.2.6. Exposure Duration

Exposure duration (ED, years) is the length of exposure within each age group for a receptor category. Table B-35 presents the duration values for each age group. OEHHA qualitatively analyzed soccer history data collected in the TAS Survey, including what type (recreational versus competitive), how long, and at what ages they played soccer (Section B.2.6.1). The results suggest that athletes start playing soccer as young children and continue throughout grade school. For those that continue playing in college, it appears common for them to continue throughout adulthood. Based on this information, we considered a lifelong exposure for athletes. Athletes may also be coaches and referees. Anecdotal evidence (communications with soccer athletes and parents during TAS) suggests that these additional coaching and refereeing exposures may start at 16 years of age. Spectator exposure may occur at any point in a lifetime.

Table B-35. Exposure Duration (ED, years) According to Age Groups – Combined Gender

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	0.25
0<2 years	Not applicable	Not applicable	Not applicable	2
2<6 years	4	Not applicable	Not applicable	4
6<11 years	5	Not applicable	Not applicable	5
11<16 years	5	Not applicable	Not applicable	5
16<30 years	14	14	14	14
30<40 years	10	10	10	10
40<50 years	10	10	10	10
50<70 years	20	20	20	20

B.2.6.1. Time-Activity Studies Survey Player History Data

The TAS Survey included soccer playing history questions about how long and at what ages the participants played soccer. OEHHA qualitatively analyzed these data, by age group and soccer type—competitive, recreational, and both types (expressed as comp+rec, for players who play both competitive and recreational soccer), to estimate the duration of an athlete's exposure on synthetic turf fields. Competitive soccer typically requires higher commitment times (i.e., more frequent practices for longer periods of times) and longer, more intense training/practice sessions than recreational soccer, thus soccer type may affect an athletes time spent on the field and the intensity in which they play. Also, competitive soccer players may travel more within the state than recreational players, especially for tournaments.

The age of survey participants who provided responses to questions about their soccer playing history ranges from 4 to 71 years, with the median age being 15 years old. Table B-36 to Table B-38 summarize the range of age starting soccer for various age groups. By soccer-type, the median starting age ranges from 5-8 years old for competitive players (Table B-36), 5-13 years old for recreational players (Table B-37), and 5-21 for players who play both types (Table B-38). Most participants indicated that they had played soccer for approximately half their lives or more. For the purposes of estimating the values of exposure duration, OEHHA assumed that soccer playing was continuous year after year. Survey data about the number of years playing soccer did not specify whether a participant had taken a break at any time during their soccer history, which anecdotal evidence suggests occurs. If a participant took a break, our analysis could underestimate a player's starting age. The median starting age increases with the age of participants and was the highest among participants aged 41-71 for recreational and both (recreational and competitive) players. These participants represent the group most likely to have taken a break from the sport. If these years were not accounted for, their starting ages for soccer might be earlier than the data suggested and more similar to those seen in the other age groups.

Table B-36. Years Played and Starting Age for Competitive Players – Combined Gender

Age of Participant, Years Old (Number of Participants)	Range of Starting Age (Years Old)	Mean Starting Age (Years Old)	Median Starting Age (Years Old)	Mean Number of Years Played (Years)	Median Number of Years Played (Years)
4-10 (105)	2-7	5	5	4	5
11-20 (646)	1-12	6	5	9	8
21-30 (18)	3-21	7	5	17	18
31-40 (17)	2-10	7	7	29	30
41-50 (18)	2-19	8	7	36	36
51-71 (4)	5-44	8	8	48	48

Table B-37. Years Played and Starting Age for Recreational Players – Combined Gender

Age of Participant, Years Old (Number of Participants)	Range of Starting Age (Years Old)	Mean Starting Age (Years Old)	Median Starting Age (Years Old)	Mean Number of Years Played (Years)	Median Number of Years Played (Years)
4-10 (6)	3-8	5	5	2	2
11-20 (17)	3-18	7	6	7	8
21-30 (14)	3-23	8	6	19	22
31-40 (26)	3-29	10	6	27	30
41-50 (40)	3-49	18	14	28	35
51-71 (11)	5-44	17	13	38	40

Table B-38. Years Played and Starting Age for Comp+Rec Players – Combined Gender

Age of Participant, Years Old (Number of Participants)	Range of Starting Age (Years Old)	Mean Starting Age (Years Old)	Median Starting Age (Years Old)	Mean Number of Years Played (Years)	Median Number of Years Played (Years)
4-10 (11)	3-6	5	5	5	5
11-20 (47)	4-17	6	5	9	10
21-30 (23)	3-19	7	6	19	20
31-40 (20)	4-33	9	7	27	29
41-50 (23)	3-24	10	9	35	37
51-71 (8)	8-41	23	21	33	31

The TAS Survey data suggest that the number of competitive players decreases, whereas the number of recreational and comp+rec players increase, as the age of

participants increase (Table B-39). In all age groups, the majority of comp+rec (Table B-40) and competitive (Table B-41) players played soccer year-round. On the contrary, the number of recreational players (Table B-42) who played soccer year-round increases as the age of participants increases.

Table B-39. Percent Soccer Type by Age of Participants – Combined Gender

Age of Participant (Years)	Number of Participants	Percent Competitive Players	Percent Recreational Players	Percent Comp+Rec Players
4-10	126	86	5	10
11-20	714	91	2	7
21-30	56	34	25	41
31-40	63	27	41	32
41-50	63	22	50	28
51-71	23	17	48	35

Table B-40. Year-Round Soccer Play for Comp+Rec Players – Combined Gender

Age (Years)	Number of Participants	Percent That Play Year-Round
4-10	12	83
11-20	48	73
21-30	23	91
31-40	20	90
41-50	23	91
51-71	8	88

Table B-41. Year-Round Soccer Play for Competitive Players – Combined Gender

Age of Participant (Years)	Number of Participants	Percent That Play Year-Round
4-10	108	94
11-20	648	91
21-30	19	84
31-40	17	88
41-50	18	100
51-71	4	100

Table B-42. Year-Round Soccer Play for Recreational Players – Combined Gender

Age of Participant (Years)	Number of Participants	Percent That Play Year-Round
4-10	6	17
11-20	17	29
21-30	14	79
31-40	26	88
41-50	41	83
51-71	11	91

B.2.6.1.1. Youth Soccer Players

OEHHA designated youth soccer players as individual survey participants at 4≤18 years old, who were attending school up to and including 12th grade. Among these participants, independent of the soccer type, almost all of them play/played between the ages of 4-12. There was only a slightly reduction in the number of participants at age 13-17 years old (Table B-43). This age period represents the middle school and high school years, where players might switch to different sports or other activities and hence resulting in the decreased percentages shown by the data.

Table B-43. Youth Players Soccer Playing History – Combined Gender

Soccer Type	Percent of Participants Who Play/Played Between 4-8 Years Old (Number of Participants)	Percent of Participants Who Play/Played Between 9-12 Years Old (Number of Participants)	Percent of Participants Who Play/Played Between 13-17 Years Old (Number of Participants)
All Soccer Types	95 (728)	94 (713)	83 (404)
Competitive	95 (666)	94 (656)	84 (373)
Recreational	95 (19)	94 (15)	70 (7)
Comp+Rec	86 (43)	88 (42)	77 (24)

Youth players are 4- to 18-year-old children attending grade school.

The Survey also collected data on soccer activity past-two-year history of each participant. Most of the youth players did not switch between soccer types, especially for recreational players (Table B-44).

Table B-44. Soccer Type Played in the Past Two Years – Combined Gender Youth Players (4- to 18-Years-Old TAS Survey Participants)

Soccer Type	Played Competitively (Number of Participants)	Played Recreationally (Number of Participants)
Competitive	94% (722)	16% (715)
Recreational	0% (20)	85% (20)
Comp+Rec	87% (51)	73% (51)

Overall, our analysis of the Survey data from youth players suggests that it is typical for the majority of individuals who started playing soccer as young children to continue playing throughout high school. This pattern is evident among each of the three soccer-types. Players are not likely to switch from one soccer type to another during this young age period of 4-18 years.

B.2.6.1.2. Adult Soccer Players

OEHHA designated adult soccer players as individuals older than 18 years and not currently attending high school. Among the adult players, a majority of individuals in this

group played soccer before high school and played for longer than seven years before attending high school (Table B-45 and Table B-46).

Table B-45. Soccer Play Before High School – Combined Gender Adult Players

Soccer Type	Number of Participants	Percent Played before High School
All Soccer Types	253	87
Competitive	79	95
Recreational	95	80
Comp+Rec	79	86

Table B-46. Years of Soccer Play Before Attending High School – Combined Gender Adult Players

Years of Soccer Play	Percent of All Adult Players (Number of Participants = 212)	Percent of Competitive Players (Number of Participants = 65)	Percent of Recreational Players (Number of Participants = 80)	Percent of Comp+Rec Players (Number of Participants = 67)
1	2	0	5	0
2	2	2	5	0
3	3	2	4	4
4	6	5	8	4
5	9	5	10	12
6	7	8	5	9
7+	68	75	61	69

Additionally, irrespective to the soccer types, most of the adult players played soccer in high school with a high percentage in this group playing all four years (Table B-47 and Table B-48).

Table B-47. Soccer Play in High School— Combined Gender Adult Players

Soccer Type	Number of Participants	Percent Played in High School
All Soccer Types	240	89
Competitive	68	96
Recreational	95	83
Comp+Rec	77	90

Table B-48. Years of Soccer Play in High School — Combined Gender Adult Players

Years of Soccer Play	Percent of All Adult Players (Number of Participants = 213)	Percent of Competitive Players (Number of Participants = 65)	Percent of Recreational Players (Number of Participants = 79)	Percent of Comp+Rec Players (Number of Participants = 69)
1	2	0	4	1
2	7	3	8	9
3	10	3	16	10
4	79	94	70	77

Although the percentage of participants who played soccer in college is slightly lower than in high school for all soccer types (89% versus 78%) and Comp+Rec (90% versus 87%), the percentage of competitive players are almost unchanged (95% in high school versus 94% in college), comparing data in Table B-47 (played in high school) and Table B-49 (played in college). On the other hand, the percentage of recreational players drops (83% in high school versus 60% in college, data in Table B-47 versus Table B-49). Taken together, these data suggests that during college some players may stop or take a break from soccer play. However, for players who played soccer in college, nearly half indicated that they played for four years (Table B-50).

Table B-49. Soccer Play in College — Combined Gender Adult Players

Soccer type	Number of Participants	Percent Played in College
All Soccer Types	240	78
Competitive	68	94
Recreational	95	60
Comp+Rec	77	87

Table B-50. Years of Soccer Play in College — Combined Gender Adult Players

Years of Soccer Play	Percent of All Adult Players (Number of Participants = 188)	Percent of Competitive Players (Number of Participants = 64)	Percent of Recreational Players (Number of Participants = 57)	Percent of Comp+Rec Players (Number of Participants = 67)
1	16	19	14	15
2	18	22	18	16
3	13	13	16	10
4	49	42	49	55

As stated in Section B.2.6.1.1, the TAS Survey included question of soccer type played in the past two years. Irrespective to the soccer types, almost all the adult participants kept their soccer types in the past two years. There were low percentages of competitive players and recreational players either switched between soccer types or played both competitively and recreationally (Table B-51).

Table B-51.Soccer Type Played in the Past Two Years — Combined Gender Adult Players

Soccer Type	Number of Participants	Played Competitively	Played Recreationally
Competitive	84	94%	27%
Recreational	95	13%	93%
Comp+Rec	80	89%	91%

Analysis of data provided by adult players suggests that, like youth players, soccer is a lifelong activity for many. Players started well before high school and a high percentage continued into college. Responses about the number of years participants have played soccer further suggest that soccer play continued for many years after college as well. Additionally, the data suggests that although participants didn't explicitly identify as players who play both competitive and recreational soccer, this is in fact the case for a small portion of individuals who considered themselves to be either competitive or recreational players.

B.2.6.1.3. Player History Data Summary

OEHHA performed qualitative analysis of collected player history data from the TAS Survey to develop the exposure duration for soccer players. The results show that soccer is a sport that there are athletes who start playing as young children and continue throughout grade school, into in college, and continuing into adulthood. Switching between competitive and recreational play does occur, but it does not appear to be common. Based on these results, OEHHA assumes an exposure duration from ages 2<70 years for athletes in assessing risk from exposure to chemicals from synthetic turf fields (Table B-1, Table B-35). In comparison, the exposure duration for spectators is for a lifetime, from third trimester to <70 years old.

B.2.7. References

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B.3. Inhalation Exposure Concentrations, Exposure Dose and Route-Specific Parameters

B.3.1. Inhalation Exposure Concentration

Inhalation exposure occurs when field receptors (e.g., athletes, coaches, referees, and spectators) breathe the air that contains chemical vapors and airborne fine particulate matter released from the field. Depending on local meteorological conditions, elevated temperature or high wind speed can enhance the evaporation of volatile organic compounds (VOCs) or semi-volatile organic compounds (SVOCs) from the fields into the air.

Following evaporation, VOCs in vapor form, can easily be inhaled into the deep lung. SVOCs may exist in vapor form or more likely redistribute and adsorb onto various particle surfaces such as crumb rubber dust. These particles can vary greatly in size. Through inhalation, the human nose may remove coarse particles (particles with an aerodynamic diameter equal to or less than 10 microns, PM_{10}). However, most of the fine particles (particles with an aerodynamic diameter equal to or less than 2.5 microns, $PM_{2.5}$) can reach the deeper lung areas. OEHHA assumed that all vapor and extractable chemicals from the $PM_{2.5}$ sampled from on- or off-field locations (part of the SVOC sample trains, Main Report Section 3.4.6) were available for absorption upon inhalation.

OEHHA, in collaboration with the LBNL, analyzed the chemical composition of vapor (VOCs and SVOCs) and solvent extracts of $PM_{2.5}$ (adhered SVOCs) sampled from the air on the synthetic turf fields. Main Report Section 3.4 describes the air sampling protocols. For each chemical with established an acute one-hour toxicity criterion (Acute TC_{inh}), we calculated a maximum inhalation exposure concentration (Acute C_{inh})—equal to the maximum one-hour concentration of a VOC in air on or off any of the 35 fields, maximum three-hour concentration of SVOC in air on or off any of the 35 fields, or the maximum (one- to three-hour) concentration of a carbonyl in air on any of the 35 fields ($C_{air\text{-}max}$). Additionally, for each chemical, OEHHA calculated each individual field's mean air concentration ($C_{air\text{-}field}$) and the mean of the 35 individual field average air concentrations of a chemical ($C_{air\text{-}avg}$) for on- or off-field locations. On an individual field basis, the average concentration of a VOC is the average detected concentration in air samples collected during the second to fourth hours at each on-field location or at an off-field location of a field. The average concentration of a SVOC for an individual field is the average detected concentration in the solvent extract of a sample train (combined extracts of the vapor phase and the $PM_{2.5}$) collected at each on-field location or the detected concentration in the solvent extract of a sample train collected at an off-field location of a field.

OEHHA used the $C_{air\text{-}max}$ of the selected chemicals to evaluate the non-cancer hazard for acute exposure via the inhalation pathway (Section B.3.4.1). We used the $C_{air\text{-}field}$,

reflecting an average one-day exposure on a field, to derive the one-day inhalation exposure concentration for chemicals with developmental and reproductive effects (DART; $C_{inh\text{-}DART\text{-}field}$) as a critical endpoint (Section B.3.4.2). We used the $C_{air\text{-}avg}$ of each chemical, reflecting the mean of all 35 fields, to derive the chronic inhalation exposure concentration (Chronic $C_{inh\text{-}sensory}$ and Chronic C_{inh}, respectively; Section B.3.4.3) and the average daily inhalation dose (ADD_{inh}, Section B.3.5) for chemicals with cancer endpoints. When necessary, we incorporated an adjustment factor or exposure parameters, respectively, in the calculation Chronic C_{inh} or ADD_{inh} of a chemical to account for the augmented breathing rate of athletes and non-continuous exposures of the field users on or off the fields.

B.3.2. Time-Weighted Breathing Rate

While at the field, synthetic turf field receptors (particularly athletes, coaches, and referees) engage in activities of various levels of intensity, including rest (sitting or standing), light (walking), moderate (jogging), and high (running). The two key parameters determining the inhalation uptake of chemicals into the body are breathing rate (BR) and exertion level (EL). Breathing rate is the volume of air inhaled per unit of time (i.e., cubic meters per day or cubic meters per hour). OEHHA defined ventilation rate as the volume of air inhaled per minute (i.e., milliliters per minute) and breathing frequency as the number of breaths taken per minute.

OEHHA derived a time-weighted breathing rate (BR_{TW}) for each receptor category in an age group (Table B-52 to Table B-57 for athletes, Table B-58 for coaches and referees, and Table B-59 for spectators). The BR_{TW} is based on the values of one-hour BR (of athletes or non-athletes) reported in the literature (Table B-60) and self-reported EL data obtained in the Time-Activity Studies (TAS) Survey of soccer athletes. The self-reported individual EL values were used for athletes, while assumed EL values were used for other receptor categories (Table B-61 to Table B-63). Descriptions of the literature studies (Section B.3.2.2.2) and data used to compile the values of one-hour BR in Table B-60 are presented Table B-66 to Table B-69. If no literature value was available for an age group at a specific activity level, an OEHHA (2012) guidance recommended value was used. We applied the pathway- and receptor-specific BR_{TW} to adjust the chronic inhalation exposure concentrations of chemicals (Section B.3.4.3) and calculate the inhalation exposure doses of chemicals (Section B.3.5) in air, for each receptor category, on synthetic turf fields.

OEHHA estimated values of BR_{TW} for each receptor category and age group using the following equation:

$$BR_{TW} = \sum_{k=1}^{4} EL_k \times BR_k \qquad \text{Equation B-3}$$

where,

BR_{TW} = Time-weighed one-hour breathing rate of a receptor category in an age group (cubic meters per hour)

EL_k = Self-reported relative duration engaging in activities at an exertion level (percentage), during soccer games or practices, by an individual soccer player, k=1 for resting, k=2 for lightly active, k=3 for moderately active, k=4 for highly active; relative duration engaging in activities at an exertion level (percentage) during soccer games or practices for coaches and referees (assumed values in Table B-61), and spectators (assumed values in Table B-62 and Table B-63)

BR_k= One-hour breathing rate (cubic meters per hour) of a receptor category in an age group under a specific activity level: k=1 for resting, k=2 for lightly active, k=3 for moderately active, k=4 for highly active (see Table B-60)

Table B-52. Time-Weighted Practice Breathing Rates (BR_{TW}, cubic meters per hour)—Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (3)[a]	1.4	1.2	Not applicable	Not applicable	Not applicable	1.7
6<11 years (103)	2.3 (0.6)	1.0	2.2	3.1	3.3	3.9
11<16 years (420)	2.8 (0.9)	0.6	2.7	4.0	4.3	4.9
16<30 years (232)	4.2 (1.3)	1.9	3.9	5.8	6.7	8.3
30<40 years (39)	3.6 (1.1)	2.0	3.2	5.1	5.1	6.4
40<50 years (45)	3.9 (1.3)	1.7	3.7	5.6	6.0	6.4
50<70 years (20)	4.1 (1.4)	2.2	4.2	5.3	6.4	7.8

[a] One participant in the 2<6 age group completed a survey, but did not provide responses for exertion levels. TAS Survey data of three 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of the three 6-year-old participants' TAS Survey data. OEHHA did not estimate the standard deviation, or percentile values for this age group.
Values are rounded to one decimal place.
Max: maximum and Min: minimum

Table B-53. Time-Weighted Practice Breathing Rates (BR_{TW}, cubic meters per hour)—Female Athletes

Age Group[a]	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (1)[b]	1.4	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (35)	2.1 (0.5)	1.0	2.2	2.6	2.8	3.3
11<16 years (208)	2.8 (0.9)	0.6	2.8	4.1	4.3	4.9
16<30 years (129)	4.2 (1.2)	1.9	3.9	5.7	6.4	8.3
30<40 years (18)	3.8 (1.1)	2.1	3.7	5.1	5.4	6.4
40<50 years (17)	4.2 (1.2)	2.6	3.7	5.9	6.1	6.4
50<70 years (4)	4.2 (1.1)	2.5	4.6	5.0	5.0	5.1

[a] Numbers in parathesis are the number of participants in each age group.
[b] No female younger than six years old participated in the TAS Survey. OEHHA used TAS Survey data of the only 6-year-old female participant as a surrogate for the female 2<6 years age group. The mean value represents the TAS Survey data of the one 6-year-old female participant. OEHHA did not estimate the minimum, maximum, standard deviation, or percentile values for this age group.
Values are rounded to one decimal place.
Max: maximum and Min: minimum

Table B-54. Time-Weighted Practice Breathing Rates (BR_{TW}, cubic meters per hour)—Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	1.5	1.2	Not applicable	Not applicable	Not applicable	1.7
6<11 years (88)	2.3 (0.6)	1.1	2.2	3.2	3.3	3.9
11<16 years (212)	2.7 (0.8)	0.9	2.6	3.7	4.2	4.9
16<30 years (103)	4.2 (1.4)	2.1	3.9	5.8	6.8	7.6
30<40 years (21)	3.4 (1.0)	2.0	3.1	4.9	5.1	5.1
40<50 years (28)	3.7 (1.3)	1.7	3.4	5.2	5.5	6.4
50<70 years (16)	4.1 (1.5)	2.2	4.0	5.7	6.7	7.8

[a] One male participant in the 2<6 age group completed a survey, but did not provide responses for exertion levels. TAS Survey data of two male 6-year-old participants were used as surrogate for the 2<6 years age group. The mean value represents the average of the two 6-year-old male participants' TAS Survey data. OEHHA did not estimate the standard deviation or percentile values for this age group.
Values are rounded to one decimal place.
Max: maximum and Min: minimum

Table B-55. Time-Weighted Game Breathing Rates (BR_{TW}, cubic meters per hour)—Combined Gender Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (3)[a]	1.5	1.5	Not applicable	Not applicable	Not applicable	1.6
6<11 years (107)	2.3 (0.6)	1.0	2.2	3.1	3.3	3.9
11<16 years (460)	2.9 (1.0)	0.5	2.8	4.2	4.5	5.4
16<30 years (246)	4.4 (1.5)	1.1	4.3	6.5	7.1	8.4
30<40 years (52)	4.0 (1.2)	2.1	3.7	5.8	6.1	7.1
40<50 years (78)	4.0 (1.3)	1.2	3.6	6.0	6.5	7.1
50<70 years (28)	4.4 (1.5)	2.2	4.3	6.4	6.8	7.8

[a] One participant in the 2<6 age group completed a survey, but did not provide responses for exertion levels. TAS Survey data of three 6-year-old participants were used as surrogate for the 2<6 years age group. This mean value represents the average of three 6-year-old participants' TAS Survey data. OEHHA did not estimate the standard deviation, or percentile values for this age group.
Values are rounded to one decimal place.
Max: maximum and Min: minimum

Table B-56. Time-Weighted Game Breathing Rates (BR_{TW}, cubic meters per hour)—Female Athletes

Age Group[a]	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (1)[b]	1.6	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
6<11 years (36)	2.2 (0.6)	1.0	2.2	3.0	3.1	3.6
11<16 years (228)	2.9 (1.0)	0.5	2.8	4.3	4.5	5.4
16<30 years (140)	4.4 (1.5)	1.1	4.4	6.5	7.1	8.3
30<40 years (32)	4.1 (1.1)	2.7	3.8	5.8	6.1	7.1
40<50 years (44)	4.1 (1.3)	2.1	3.7	6.1	6.4	6.5
50<70 years (7)	4.1 (1.4)	2.4	4.3	5.7	5.8	5.8

[a] Numbers in parathesis are the number of participants in each age group.
[b] No female younger than six years old participated in the TAS Survey. OEHHA used TAS Survey data of the only 6-year-old female participant as a surrogate for the female 2<6 years age group. The mean value represents the TAS Survey data of the one 6-year-old female participant. OEHHA did not estimate the minimum, maximum, standard deviation, or percentile values for this age group.
Values are rounded to one decimal place.

Max: maximum and Min: minimum

Table B-57. Time-Weighted Game Breathing Rates (BR_{TW}, cubic meters per hour)—Male Athletes

Age Group (Number of Participants)	Mean (Standard Deviation)	Min	50th Percentile	90th Percentile	95th Percentile	Max
2<6 years (2)[a]	1.4	1.2	Not applicable	Not applicable	Not applicable	1.5
6<11 years (71)	2.3 (0.6)	1.1	2.2	3.1	3.3	3.9
11<16 years (232)	2.8 (0.9)	0.5	2.8	4.1	4.4	4.9
16<30 years (106)	4.3 (1.6)	1.2	4.1	6.6	7.1	8.4
30<40 years (20)	3.8 (1.4)	2.1	3.4	5.3	6.1	7.1
40<50 years (34)	3.8 (1.4)	1.2	3.3	5.7	6.2	7.1
50<70 years (21)	4.4 (1.5)	2.2	4.2	6.7	6.9	7.8

[a] One male participant in the 2<6 age group completed a survey, but did not provide responses for exertion levels. TAS Survey data of two male 6-year-old participants are used as surrogate for the 2<6 years age group. The mean value represents the average of the two 6-year-old male participants' TAS Survey data. OEHHA did not estimate the standard deviation or percentile values for this age group.
Values are rounded to one decimal place.
Max: maximum and Min: minimum

Table B-58. Time-Weighted Practice and Game Breathing Rates (BR_{TW}, cubic meters per hour)—Combined Gender Coaches and Referees[a]

Age Group	Practice Breathing Rate	Game Breathing Rate
16<30 years	1.9	1.6
30<40 years	1.9	1.6
40<50 years	1.9	1.6
50<70 years	1.9	1.6

[a] Game breathing rates only are used for referees.
Values are rounded to one decimal place.

Table B-59. Time-Weighted Practice and Game Breathing Rates (BR_{TW}, cubic meters per hour)—Combined Gender Spectators

Age Group	Practice and Game Breathing Rate
Third trimester fetus[a]	0.4
0<2 years	0.4
2<6 years	0.5
6<11 years	0.7
11<16 years	0.5
16<30 years	0.4
30<40 years	0.4
40<50 years	0.4
50<70 years	0.4

[a] Third trimester fetus age group represents unborn fetus in pregnant spectators, and the mean value of the 16 to <40 years old females.
Values are rounded to one decimal place.

The Synthetic Turf Study specific mean one-hour BR derived from literature studies (Section B.3.2.2.2) are presented in Table B-60. A comparison of these mean values and the OEHHA (2012) recommended mean and 95th percentile one-hour breathing rates (Section B.3.2.2.1) showed that most of the Study-specific mean BR are the same or within the mean and 95th percentile range of the OEHHA recommended values. The exceptions are the much higher Study-specific mean BRs for high activity of the 11<16 and 16<70 years old groups because they were derived from the studies (Bongers *et al.*, 2014; Guenette *et al.*, 2007) designed to measure BR at maximal exercise tests (Section B.3.2.2.2).

Table B-60. Synthetic Turf Study Specific Mean One-Hour Breathing Rates (cubic meters per hour)

Age Group	Breathing Rate for Resting Activity	Breathing Rate for Light Activity	Breathing Rate for Moderate Activity	Breathing Rate for High Activity
0<2 years	0.23[a]	0.58[a]	1.06[a]	Not applicable[b]
2<6 years	0.26	0.68	1.25[a]	2.24[a]
6<11 years	0.37	1.04	1.49	3.87
11<16 years	0.46	0.96	1.26	5.37
16<70 years	0.41	1.38	2.35	8.43

[a] No literature value was identified. OEHHA (2012) one-hour breathing rate is used.
[b] Individuals in the 0<2 years age group were not anticipated to engage in high intensity activities (OEHHA, 2012).
Values are rounded to two decimal places.

B.3.2.1. Exertion Level

The exertion level (EL) represents the percentage of event time spent on the field when a receptor performs activity at a specific intensity level. The intensity levels are rest

(sitting or standing), light (walking), moderate (jogging), and high activity (running). Receptor category, event type (game, practice), soccer type (competitive, recreational), gender, and age may affect the relative amount of time performing at each activity level.

The TAS consisted of two parts for athletes: Survey of Soccer Players (TAS Survey; in-person and on-line) and Observational Study of Soccer Activities (TAS Observation Study). In the TAS Observation Study, OEHHA observed and videotaped soccer events of 40 players to categorize and determine the duration of intensity levels (i.e., rest, light, moderate, and high) of activities such as sitting, walking, and running. Appendix F.3 and Main Report Section 5.3.1.2 describes details of the TAS Observation Study. For each recorded player, OEHHA estimated their EL dataset (i.e., each player's EL for each intensity level) from the recorded soccer event. These players also participated in the in-person Survey, which they self-reported ELs during typical practices and games. An additional study group of 852 TAS Survey participants (1,029 on-line total participants, no accompanied video data) provided data on their ELs during practices and games.

Analysis of the EL datasets from video of the 40 participants showed no differences in the amount of time spent performing at each intensity level with regards to age, gender, or event type. When compared to EL dataset values collected in the TAS Survey, the Wilcoxon Rank Sum Test (non-parametric equivalent of the paired t-test) performed using RStudio (RStudio Team, 2018), shows that the ELs measured in the TAS Observation Study are significantly different from the self-reported TAS Survey responses ($p<0.05$). Differences in the observed versus self-reported ELs may be due to response bias in the TAS Survey and/or the TAS Observation Study. There might be differences in interpretation of the terms used in the survey; for example, an individual's definition of jogging versus running might differ from that of other participants. Furthermore, participants were videotaped for only one practice or game, which might not represent a typical event for them. Participants were aware of the videotaping that they might consciously or subconsciously modify their behaviors at the game or practice. Since the video data present a snapshot of each participant's time on the field and there are only 40 participants, OEHHA selected the self-reported EL values from the TAS Survey to estimate the BR_{TW} of athletes. Each individual's self-reported EL dataset corresponds to the relative amount of time at each intensity level for a typical event. As such, the data must be used as a corresponding set when calculating a BR_{TW} to avoid underestimating or overestimating the breathing rate.

Our TAS did not capture exertion data for coaches, referees, or spectators. Additionally, there are no such data in the literature. OEHHA, therefore, applied the following assumed values of EL for coaches, referees, and spectators.

Coaches spend half the time walking and the other half jogging during practice. They are less active during game time. We assumed referees have the same ELs as coaches during game time, and do not participate in practices. Child spectators walk around and play for half of the time spent at the field, and sit and rest on the turf for the other half of

the time. For adult spectators, they spend the entire time at the field sitting. Observations made on the field and anecdotal evidence from parents suggest that parents observe their young children playing from their seats by the field. The values for EL are shown in Table B-61 (Coaches and Referees), Table B-62 (Child Spectators), and Table B-63 (Adult Spectators).

Table B-61. Exertion Level (EL, Percent)—Coaches and Referees[a]

Activity Intensity	Practice	Game
Rest	Not applicable	25
Light	50	25
Moderate	50	50
High	Not applicable	Not applicable

[a] Game exertion levels only are used for referees.

Table B-62. Exertion Level (EL, Percent)—Child Spectators

Activity Intensity	Practice	Game
Rest	50	50
Light	50	50
Moderate	Not applicable	Not applicable
High	Not applicable	Not applicable

Table B-63. Exertion Level (EL, Percent)—Adult Spectators

Activity Intensity	Practice	Game
Rest	100	100
Light	Not applicable	Not applicable
Moderate	Not applicable	Not applicable
High	Not applicable	Not applicable

B.3.2.2. Breathing Rates of Receptor Categories

B.3.2.2.1. OEHHA Recommended One-Hour Breathing Rates

The OEHHA Risk Assessment Guidelines (OEHHA, 2012) and the USEPA Exposure Factors Handbooks (USEPA, 2008; USEPA, 2011) provide in-depth analyses and recommended values of BR of various age groups at different activity levels. USEPA (2009) applied a metabolic equivalent approach to estimate minute BRs at various activity levels, in multiple age groups (birth to over 81 years old), and for both genders. Based on these USEPA values, OEHHA (2012) derived the one-hour (ventilation rate multiplied 60 minute per hour) and eight-hour BRs (ventilation rate multiplied 8 hours multiplied 60 minute per hour). Additionally, OEHHA (2012) calculated long-term daily average BRs based on two sets of energy expenditure data.

OEHHA (2012) recommends application of the following BRs in assessing human health risk under the specified inhalation exposure scenarios:

1. Short-term one-hour BRs – exposure at school during physical education classes, after school sports, and training that require high energy output
2. Eight-hour BRs – workers at worksite, students and teachers at school or residents long-term and repeated exposure to non-continuous emission sources
3. Long-term daily BRs – long-term daily continuous exposure of residents

The USEPA- and OEHHA-derived daily BRs are average BRs over a 24-hour period under normal daily activities, including resting and sleeping. The OEHHA eight-hour breathing rates are suitable for assessment involving general activities of students and teachers at school or adult workers at worksite. However, these long-term BRs underrepresent the breathing conditions of athletes while conducting in sport activities. Athletes predominantly engage in rigorous physical activities during their time spent on synthetic turf field. During exercise, their ventilation rates (liters per minute) increase by increasing tidal volume (liters per breath) and breathing frequency, (breaths per minute), in order to provide the elevated demands for oxygenation.

The OEHHA Risk Assessment Guidelines (2012) recommend the use of one-hour BRs (high-intensity activities) for after school sports and trainings. The mean and 95th percentile of the one-hour BRs range from 2.24 to 3.01 cubic meters per hour and 2.98 to 4.39 cubic meters per hour, respectively, for age groups of 2 to 70 years old (Table B-64 and Table B-65). However, these rates were obtained from simulation data of the general population. Use of these one-hour BRs for high intensity activities may underestimate inhalation exposure of athletes on synthetic turf fields, especially the acclimated and highly competitive soccer players.

Table B-64. OEHHA Risk Assessment Guidelines (2012) Recommended Mean Short-Term One-Hour Breathing Rates in cubic meters per hour

Age Group	Sedentary and Passive Breathing Rate	Light Intensity Activity Breathing Rate	Moderate Intensity Activity Breathing Rate	High Intensity Activity Breathing Rate
0<2 years	0.23	0.58	1.06	Not applicable[a]
2<6 years	0.27	0.68	1.25	2.24
6<11 years	0.29	0.68	1.30	2.49
11<16 years	0.33	0.76	1.50	2.92
16<70 years	0.32	0.75	1.62	3.01

[a] Individuals in the 0<2 years age group are not anticipated to engage in high intensity activities (OEHHA, 2012).

Table B-65. OEHHA Risk Assessment Guidelines (2012) Recommended 95th Percentile Short-Term One-Hour Breathing Rates in cubic meters per hour

Age Group	Sedentary and Passive Breathing Rate	Light Intensity Activity Breathing Rate	Moderate Intensity Activity Breathing Rate	High Intensity Activity Breathing Rate
0<2 years	0.34	0.81	1.54	Not applicable[a]
2<6 years	0.36	0.86	1.63	2.98
6<11 years	0.39	0.91	1.73	3.51
11<16 years	0.45	1.03	2.05	4.18
16<70 years	0.42	0.97	2.26	4.39

[a] Individuals in the 0<2 years age group are not anticipated to engage in high intensity activities (OEHHA, 2012).

B.3.2.2.2. Estimation of One-Hour Breathing Rates Based on Literature Studies

Human studies on the pulmonary function of athletes suggest that trained athletes have higher breathing frequencies and larger tidal volumes while exercising than the general population. OEHHA compiled the BRs for use in estimating inhalation exposure of athletes when conducting sport activities on synthetic turf fields based on human data reported in the literature (Table B-66 to Table B-69 and studies summarized in chronological order below).

Table B-66. Literature One-Hour Breathing Rates for Sedentary and Passive Activities, in cubic meters per hour

Age Group	Sedentary and Passive Breathing Rate	Reference
2<6 years	0.26	Wallis et al, 2005; Hallett & Ashurst 2020
6<11 years	0.37	Wallis et al, 2005; Hallett & Ashurst 2020
11<16 years	0.46	Wallis et al, 2005; Hallett & Ashurst 2020
16<70 years	0.41	Wallis et al, 2005; Hallett & Ashurst 2020

Values are rounded to two decimal places.

Table B-67. Literature One-Hour Breathing Rates for Light Intensity Activities, in cubic meters per hour

Age Group	Light Intensity Activity Breathing Rate	Reference
2<6 years	0.68	Adams 1993, OEHHA, 2012
6<11 years	1.04	Swain et al. 2010
11<16 years	0.96	Spier et al. 1992
16<70 years	1.38	Adams 1993

Values are rounded to two decimal places.

Table B-68. Literature One-Hour Breathing Rates for Moderate Intensity Activities, in cubic meters per hour

Age Group	Moderate Intensity Activity Breathing Rate	Reference
6<11 years	1.49	Swain et al. 2010
11<16 years	1.26	Spier et al. 1992
16<70 years	2.35	Adams 1993

Values are rounded to two decimal places.

Table B-69. Literature One-Hour Breathing Rates for High Intensity Activities, in cubic meters per hour

Age Group	High Intensity Activity Breathing Rate	Reference
6<11 years	3.87	Cunningham et al. 1976
11<16 years	5.37	Bongers et al. 2014
16<70 years	8.43	Guenette et al. 2007

Values are rounded to two decimal places.

Cunningham et al. (1976)

Cunningham *et al.* (1976) measured the cardiopulmonary capacity of 15 competitive hockey players (an average age of 10.6 years). Subjects performed incremental cycle ergometer testing. The study reported a mean ventilation rate (V_E) of 64.5 liters per minute at maximal cycling exercise. OEHHA used this value to derive the one-hour BR (cubic meters per hour) at high intensity activities for 6<11-year-old athletes (Table B-69).

Spier et al. (1992)

Spier *et al.* (1992) examined the activity patterns of 19 high school students aged 13 to 17 years. The study monitored BRs during supervised outdoor activity at various levels: slow (slow walking), medium (fast walking), or fast (running). It recorded mean BRs of 0.96, 1.26, and 1.44 cubic meters per hour for slow, medium, and fast activities, respectively. OEHHA used the mean BR for slow and medium activities as the BR of 11 to <16 years old for light (walking) and moderate (jogging) intensity activities on field (Table B-67 and Table B-68). We did not choose the mean BR for fast activities from Spier *et al.* (1992) as the Study-specific high intensity activity BR for this age group. Instead, the Study adopted a BR for high-intensity activity derived from measurements of ventilatory response of adolescents performing maximal exercise tests (Bongers *et al.*, 2014), which provided a better estimate of BR for high-intensity activities, especially for the highly competitive athletes (see description of the Bonger *et al.,* 2014 below).

Adams (1993)

Adams (1993) investigated the range of BRs for specific activities for various ages and both genders. Twelve young children, aged 3 to 5.9 years, participated in active "*spontaneous play*" protocols. The study reported a mean V_E of 0.68 cubic meters per

hour. OEHHA (2012) employed this value as the light intensity activity BR of 2 to <6 years old (Table B-67). Additionally, 76 teenagers and adults, aged 13 to >60 years, participated in laboratory activities including light (walking at 1.5 to 3.0 miles per hour) and moderate (fast walking, 3.3 to 4.0 miles per hour) levels. The study reported mean BRs of 1.38 and 2.35 cubic meters per hour for light and moderate activities, respectively. OEHHA applied these values as the BR of 16 to <70 years old for light and moderate intensity activities (Table B-67 and Table B-68).

Wallis et al. (2005)

Wallis *et al.* (2005) examined the heart rate (beats per minute) and breathing frequency (breaths per minute) of school children in order to produce reference ranges for these vital signs. The group assessed the resting heart rate and breathing frequency of 1,109 children, aged 4 to 16, while sitting. OEHHA averaged the median breathing frequency according to the Synthetic Turf Study age groups (Table B-70). We then multiplied these resting breathing frequencies by tidal volumes reported in Hallett & Ashurst (2020) (Table B-71, see details in Hallet & Ashurt, 2020 below) to derive the resting BR for each age group (Table B-66).

Table B-70. Breathing Frequency for Sedentary and Passive Activities (Wallis et al. 2005)

Age Group	Number of Subjects	Age Range of Subjects (Years)	Average of the Median Breathing Frequency (Breaths per Minute)
2<6 years	118	4<6	21.5
6<11 years	400	6<11	19.4
11<16 years	531	11<16	15.8
16-70 years	60	16	14.0

Values are rounded to one decimal place.

Guenette et al. (2007)

Guenette *et al.* (2007) measured the respiratory mechanics of adult athletes. Eight male (average age of 25.9 ± 4.9 years) and 10 female (average age of 24.7 ± 2.8 years) endurance athletes participated in the study. The researchers collected data on the breaths per minute and volume of air per breath for athletes during incremental exercise tests on a cycle ergometer. The group reported mean V_E (breaths per minute x volume of air per breath) of 120 and 161 liters per minute (equivalent to 7.2 and 9.7 cubic meters per hour) for females and males, respectively, at maximal cycling exercise. OEHHA calculated the average value of the mean male and mean female V_E and applied the average value as the one-hour BR for high intensity activities for 16 to <70-year-old athletes (Table B-69).

Swain et al. (2010)

Swain *et al.* (2010) measured the pulmonary function of 40 healthy 7 to 11-year-old children during exercise to study expiratory flow limitation (EFL). EFL is the

phenomenon where increased respiratory requirements, as needed during physical exercise, results in an individual's maximal expiratory rate (i.e., the maximum amount of air an individual may exhale). The researchers collected V_E continuously during incremental exercise tests on a cycle ergometer. The average V_E values for boys and girls combined were 17 liters per minute (equivalent to 1.04 cubic meters per hour) at 40 percent VO_{2max} (VO_{2max} is the maximum amount of oxygen the body can absorb and use during exercise) and 25 liters per minute (equivalent to 1.49 cubic meters per hour) at 60 percent VO_{2max}, which OEHHA used as surrogate BRs for light and moderate intensity activities, respectively, for 6 to <11 years old (Table B-67 and Table B-68).

Bongers et al. (2014)

Bongers *et al.* (2014) examined the ventilatory response of 22 adolescents (average age of 14.3 ± 1.3 years) with cystic fibrosis, using a cardiopulmonary exercise test on a cycle ergometer. Twenty-two sex- and age-matched controls also participated in study and performed maximal exercise tests. The study reported a mean V_E of 89.5 liters per minute (equivalent to 5.37 cubic meters per hour) for the control group. Although the control subjects were not identified as athletes, the V_E represents a breathing rate during intense exercise that may be comparable to the intensity occurring in soccer events. As such, OEHHA used this value as the high intensity breathing rate for 11 to <16-year-old athletes (Table 0-60).

Hallett & Ashurst (2020)

Hallett *et al.* (2020) discusses the clinical importance of tidal volume, the amount of air volume inhaled in a single breath. They cite clinical studies and a reported normal tidal volume of 7 milliliters per kilogram in average adults and 10 milliliters per kilogram in pediatric patients (adopted for age groups showed in Table B-71). OEHHA multiplied the age-specific breathing frequencies (reported by Wallis et al., 2005 discussed above and showed in Table B-70) by the corresponding age-related tidal volumes to obtain one-hour BRs for resting activity shown in Table B-66. These rates are slightly higher than the OEHHA (2012) recommended mean BRs of children (6 to 11 years old) and adult (16 to 70 years old) (Table B-64).

Table B-71. Tidal Volumes for Sedentary and Passive Activities, in milliliters per Breath (Hallett & Ashurst 2020)

Age Group	Body weight (kilograms)[a,b]	Body weight Normalized Tidal Volume (milliliters per kilogram)	Tidal Volume (milliliters per breath)[b]
2<6 years	20.5	10	204.5
6<11 years	32.0	10	320.2
11<16 years	48.7	10	486.7
16-70 years	69.4	7	486.1

[a] Mean body weight calculated based on self-reported TAS Survey data (TSD Section B2.2.3).
[b] Values are rounded to one decimal place.

B.3.3. Inhalation Absorption Factor

The inhalation absorption factor, A_{chem}, represents the fraction of the exposure dose of a chemical absorbed following entrance into the lungs. In the absence of chemical-specific data, OEHHA assumed this parameter to be a value of one (100 percent absorption) according to our guidelines (OEHHA, 2015) as a conservative health-protective assumption. We applied this chemical-specific factor to calculate the inhalation exposure dose of chemicals in air, for each receptor category, on synthetic turf fields (Section B.3.5).

B.3.4. Inhalation Exposure Concentrations for Non-Cancer Hazard Assessment

For exposure to chemicals with non-cancer endpoints, an inhalation exposure concentration (C_{inh}) is used to estimate the non-cancer hazard. Based on the exposure duration (acute, one-day, or chronic) and the exposed chemical type (discussed in Section 4.3 of the Main Report), four types of C_{inh} were developed (Acute C_{inh}, $C_{inh\text{-}DART\text{-}field}$, Chronic $C_{inh\text{-}sensory}$, and Chronic C_{inh}) as described in the following sections. When necessary, OEHHA applied an adjustment factor (AF_{inh}) to derive the adjusted chronic exposure concentration of a chemical in air on the field. These receptor- and age-specific AF_{inh} address a less than 365 days per year and a less than 24 hours per day exposure at synthetic turf fields for each receptor category and the specific age group. The equations and exposure parameters used to calculate these factors are described in the following sections.

B.3.4.1. Acute Exposure Concentration

For acute exposures (exposure to a chemical for one hour on an intermittent basis), no AF_{inh} is needed. This exposure is independent of receptor category or age. The acute exposure concentration (Acute C_{inh}) is equal to the maximum one-hour concentration of a VOC in air on or off the fields, the maximum (one- to three-hour) concentration of a carbonyl in air on the fields, and the maximum three-hour concentration of a SVOC in air on or off the fields during simulated soccer activity ($C_{air\text{-}max}$, Main Report Section 5.4.1) as shown in Equation B-4.

$$\text{Acute } C_{inh} = C_{air-max} \qquad \text{Equation B-4}$$

where,

Acute C_{inh} = acute exposure concentration for exposure to a chemical via the inhalation route, nanograms per cubic meter (values in Appendix F.4.1)

$C_{air\text{-}max}$ = maximum one- to three-hour concentration of a chemical detected in air on or off fields during soccer activities among any of the 35 fields in the study, nanograms per cubic meter (values in Appendix F.4.1)

B.3.4.2. One-day Exposure Concentration for Developmental and Reproductive Toxicants (DART)

For chemicals considered to be developmental and/or reproductive toxicants (DART), OEHHA derived the adjusted one-day exposure concentration for inhalation exposure to a DART ($C_{inh\text{-}DART}$) using Equation B-5. We modified each individual field average concentration of a chemical ($C_{air\text{-}field}$) by an adjustment factor ($AF_{inh\text{-}DART}$) to adjust for less than 24 hours per day exposure (similar to AF_{inh}), but without adjusting for a less than everyday event frequency (i.e., an event frequency for assessing exposure to DART, EV_{DART} equals to 1 event per day) using Equation B-6. This value assumes that a single exposure event could be sufficient to cause adverse effects.

$$C_{inh-DART-field} = C_{air-field} \times AF_{inh-DART} \quad \text{Equation B-5}$$

$$AF_{inh-DART} = \frac{V_{event} \times EV_{DART} \times BW_{default-adult}}{BW \times V_{default-adult}} \quad \text{Equation B-6}$$

$$V_{event} = \frac{\sum_{event\ type}(BR_{TW} \times ET_{DART})}{2} \quad \text{Equation B-7}$$

where,

$C_{inh\text{-}DART\text{-}field}$ = adjusted one-day exposure concentration for exposure to a DART via the inhalation pathway, nanograms per cubic meter (values in Appendix F.4.4)

$C_{air\text{-}field}$ = mean concentration of a chemical detected in air on or off an individual field during soccer activities, nanograms per cubic meter (values in Appendix Section D.4.2.3)

$AF_{inh\text{-}DART}$ = adjustment factor of one-day inhalation exposure to a DART, for a receptor category in an age group, unitless (Table B-72)

V_{event} = average volume of air a receptor inhales during a soccer event (game and practice), cubic meters per event. For athletes, coaches, and spectators: V_{event} = average of V_{game} and $V_{practice}$; for referees: V_{event} = V_{game}.

EV_{DART} = event frequency for assessing exposure to DART, 1 event per day

$BW_{default\text{-}adult}$= default adult body weight, 70 kilograms

$V_{default\text{-}adult}$ = default adult daily inhalation volume of chronic exposure, 20 cubic meters of air per day

BW = bodyweight of an age group, kilograms (Section B.2.2, Table B-2)

BR_{TW} = mean time-weighted one-hour breathing rate of a receptor category in an age group for an event type, cubic meters per hour (Section B3.2.2, Table B-52 to Table B-59)

ET_{DART} = mean maximum exposure time, maximum time spent on field per event, of a receptor category in an age group for an event type, hours per event (Section B.2.4, Table B-18 to Table B-24)

We included an estimate of the average volume of air a receptor might inhale during a field event (V_{event}), calculated as shown in Equation B-7. This value is calculated as the average of the volume of air a receptor might breathe during practice and the volume of air a receptor might breathe during a game. This is to account for a single event exposure to a DART for the different exertion levels and hence different breathing volume during a soccer event for each receptor category and age group. Table B-72 summarizes the values of $AF_{inh\text{-}DART}$ for all the age groups and receptor categories. OEHHA calculated these values by using the mean exposure parameters listed in Table B-73 to Table B-76.

Table B-72. Values of Adjustment Factor of One-day Inhalation Exposure to DART ($AF_{inh\text{-}DART}$, unitless) for Each Receptor Category—Combined Gender

Age Group (Years)	Athletes	Coaches	Referees	Spectators
Third trimester fetus[a]	Not applicable	Not applicable	Not applicable	0.049
0<2	Not applicable	Not applicable	Not applicable	0.40
2<6	0.73	Not applicable	Not applicable	0.21
6<11	0.55	Not applicable	Not applicable	0.20
11<16	0.46	Not applicable	Not applicable	0.086
16<30	0.68	0.29	0.27	0.057
30<40	0.45	0.25	0.23	0.050
40<50	0.45	0.25	0.24	0.050
50<70	0.49	0.25	0.24	0.050

[a] Third trimester fetus age group represents unborn fetus in pregnant spectators, and the mean value of the 16 to <40 years old females.
Values are rounded to two significant figures.

Table B-73. Values of Exposure Factors and Adjustment Factor of One-day Inhalation Exposure to DART ($AF_{inh\text{-}DART}$, unitless)–Combined Gender Athletes

Age Group (Years)	Practice BR_{TW}, cubic meters per hour	Practice ET, hours per event	Game BR_{TW}, cubic meters per hour	Game ET, hours per event	V_{event}, cubic meters per event	BW, kilograms	$AF_{inh\text{-}DART}$, unitless
2<6	1.4	1.5	1.5	4.3	4.3	20.5	0.73
6<11	2.3	2.1	2.3	2.3	5.1	32.0	0.55
11<16	2.8	2.3	2.9	2.2	6.4	48.7	0.46
16<30	4.2	2.8	4.4	3.1	12.7	65.8	0.68
30<40	3.6	3.1	4.0	2.1	9.8	75.3	0.45
40<50	3.9	2.5	4.0	2.4	9.7	74.5	0.45
50<70	4.1	2.3	4.4	2.6	10.4	74.3	0.49

$AF_{inh\text{-}DART}$: adjustment factor of one-day exposure to a DART for a receptor category in an age group, values are rounded to two significant figures; BR_{TW}: time-weighted one-hour breathing rate of a receptor category in an age group for an event type, values are rounded to one decimal place; ET: mean of the maximum time spent on field per event of a receptor category in an age group for an event type, values are rounded to one decimal place; V_{event}: average volume of air a receptor inhales during a soccer event, values are rounded to one decimal place; and BW: receptor category and age-specific body weight in kilograms, values are rounded to one decimal place.

Table B-74. Values of Exposure Factors and Adjustment Factor of One-day Inhalation Exposure to DART ($AF_{inh\text{-}DART}$, unitless)—Combined Gender Coaches

Age Group (Years)	Practice BR_{TW}, cubic meters per hour	Practice ET, hours per event	Game BR_{TW}, cubic meters per hour	Game ET, hours per event	V_{event}, cubic meters per event	BW, kilograms	$AF_{inh\text{-}DART}$, unitless
16<30	1.9	3.1	1.6	3.1	5.4	65.8	0.29
30<40	1.9	3.1	1.6	3.1	5.4	75.3	0.25
40<50	1.9	3.1	1.6	3.1	5.4	74.5	0.25
50<70	1.9	3.1	1.6	3.1	5.4	74.3	0.25

$AF_{inh\text{-}DART}$: adjustment factor of one-day exposure to a DART for a receptor category in an age group, values are rounded to two significant figures; BR_{TW}: time-weighted one-hour breathing rate of a receptor category in an age group for an event type, values are rounded to one decimal place; ET: mean of the maximum time spent on field per event of a receptor category in an age group for an event type, values are rounded to one decimal place; V_{event}: average volume of air a receptor inhales during a soccer event, values are rounded to one decimal place; and BW: receptor category and age-specific body weight in kilograms, values are rounded to one decimal place.

Table B-75. Values of Exposure Factors and Adjustment Factor of One-day Inhalation Exposure to DART ($AF_{inh\text{-}DART}$, unitless)—Combined Gender Referees

Age Group (Years)	Practice BR_{TW}, cubic meters per hour	Practice ET, hours per event	Game BR_{TW}, cubic meters per hour	Game ET, hours per event	V_{event}[a], cubic meters per event	BW, kilograms	$AF_{inh\text{-}DART}$, unitless
16<30	Not applicable	Not applicable	1.6	3.1	5.0	65.8	0.27
30<40	Not applicable	Not applicable	1.6	3.1	5.0	75.3	0.23
40<50	Not applicable	Not applicable	1.6	3.1	5.0	74.5	0.24
50<70	Not applicable	Not applicable	1.6	3.1	5.0	74.3	0.24

[a] Referees are not present during practice events. Their V_{event} is calculated as the volume of air inhaled during games only instead of the average air inhaled during practice and games.
$AF_{inh\text{-}DART}$: adjustment factor of one-day exposure to a DART for a receptor category in an age group, values are rounded to two significant figures; BR_{TW}: time-weighted one-hour breathing rate of a receptor category in an age group for an event type, values are rounded to one decimal place; ET: mean of the maximum time spent on field per event of a receptor category in an age group for an event type, values are rounded to one decimal place; V_{event}: average volume of air a receptor inhales during a soccer event, values are rounded to one decimal place; and BW: receptor category and age-specific body weight in kilograms, values are rounded to one decimal place.

Table B-76. Values of Exposure Factors and Adjustment Factor of One-day Inhalation Exposure to DART ($AF_{inh\text{-}DART}$, unitless)–Combined Gender Spectators

Age Group (Years)	Practice BR_{TW}, cubic meters per hour	Practice ET, hours per event	Game BR_{TW}, cubic meters per hour	Game ET, hours per event	V_{event}, cubic meters per event	BW, kilograms	$AF_{inh\text{-}DART}$, unitless
Third trimester fetus[a]	0.4	2.1	0.4	3.1	1.1	75.6	0.049
0<2	0.4	2.1	0.4	3.1	1.1	9.4	0.40
2<6	0.5	2.1	0.5	3.1	1.2	20.5	0.21
6<11	0.7	2.1	0.7	3.1	1.8	32.0	0.20
11<16	0.5	2.1	0.5	3.1	1.2	48.7	0.086
16<30	0.4	2.1	0.4	3.1	1.1	65.8	0.057
30<40	0.4	2.1	0.4	3.1	1.1	75.3	0.050
40<50	0.4	2.1	0.4	3.1	1.1	74.5	0.050
50<70	0.4	2.1	0.4	3.1	1.1	74.3	0.050

[a] Third trimester fetus age group represents unborn fetus in pregnant spectators, and the mean value of the 16 to <40 years old females.

$AF_{inh\text{-}DART}$: adjustment factor of one-day exposure to a DART for a receptor category in an age group, values are rounded to two significant figures; BR_{TW}: time-weighted one-hour breathing rate of a receptor category in an age group for an event type, values are rounded to one decimal place; ET: mean of the maximum time spent on field per event of a receptor category in an age group for an event type, values are rounded to one decimal place; V_{event}: average volume of air a receptor inhales during a soccer event, values are rounded to one decimal place; and BW: receptor category and age-specific body weight in kilograms, values are rounded to one decimal place.

B.3.4.3. Chronic Exposure Concentration

B.3.4.3.1. Sensory Irritants

For the purposes of assessing chronic non-cancer inhalation exposure to a sensory irritant on synthetic turf fields (Chronic $HQ_{inh\text{-}sensory}$), OEHHA did not apply modification to the chemical concentration in air ($C_{air\text{-}avg}$) to adjust for a less than 365 days per year and a less than 24 hours per day exposure at synthetic turf fields, i.e., $AF_{inh\text{-}sensory}$ is equal to one (Equation B-8). We, therefore, applied the $C_{air\text{-}avg}$ of the chemicals detected in air as their exposure concentrations (Chronic $C_{inh\text{-}sensory}$) via the inhalation pathway (Equation B-9). The Chronic $C_{inh\text{-}sensory}$ is not specific to receptor category or age.

$$AF_{inh-sensory} = 1 \qquad \text{Equation B-8}$$

$$\text{Chronic } C_{inh-sensory} = C_{air-avg} \qquad \text{Equation B-9}$$

where,

$AF_{inh\text{-}sensory}$ = adjustment factor of one-day exposure to an irritant via the inhalation pathway, equal to one, unitless

Chronic $C_{inh\text{-}sensory}$ = non-cancer chronic exposure concentration for a sensory irritant via the inhalation pathway, nanograms per cubic meter (values in Appendix F.4.5)

$C_{air\text{-}avg}$ = mean of the 35 field average concentrations of a sensory irritant in air on or off the fields, nanograms per cubic meter (Main Report Section 3.4.6, Table 3-10)

B.3.4.3.2. General Chemicals

For chronic exposure to general chemicals (those with adverse non-cancer effects excluding reproductive, development and/or sensory irritation), OEHHA estimated Chronic C_{inh} using Equation B-10. We derived the values of AF_{inh} using the mean values of receptor-specific exposure parameters as shown in Equation B-11.

$$\text{Chronic } C_{inh} = C_{air-avg} \times AF_{inh} \qquad \text{Equation B-10}$$

$$AF_{inh} = \frac{\sum_{event\ type}(BR_{TW} \times AET) \times BW_{default-adult} \times CF}{BW \times V_{default-adult}}$$ Equation B-11

where,

Chronic C_{inh} = adjusted chronic exposure concentration for exposure to a general chemical via the inhalation route, nanograms per cubic meter (values in Appendix F.4.6)

$C_{air\text{-}avg}$ = mean of 35 individual field average concentrations of a general chemical in air on or off fields, nanograms per cubic meter (values in Main Report Section 3.4.6, Table 3-10)

AF_{inh} = adjustment factor of chronic exposure to a chemical for a receptor category in an age group, unitless (values in Table B-77)

BR_{TW} = mean time-weighted one-hour breathing rate of a receptor category in an age group for an event type, cubic meters per hour (see Section B.3.2, Table B-52 to Table B-59)

AET = mean annual event time spent on the field of a receptor category in an age group for an event type, hours per year (TSD Chapter 2, values in Table 2-25 to Table 2-34)

BW = bodyweight of an age group, kilograms (Section B.2.2, Table B-2)

$V_{default\text{-}adult}$ = default adult daily inhalation volume of chronic exposure, 20 cubic meters per day

$BW_{default\text{-}adult}$ = default adult body weight, 70 kilograms

CF = conversion factor, 1 year per 365 days

Table B-77 summarizes the values of AF_{inh} for all the age groups and receptor categories for general chemicals. OEHHA calculated these values by using the mean exposure parameters listed in Table B-78 to Table B-81 and Equation B-11.

Table B-77. Values of Adjustment Factor of Chronic Inhalation Exposure to General Chemicals (AF_{inh}, unitless) for Each Receptor Category—Combined Gender

Age Group (Years)	Athletes	Coaches	Referees	Spectators
Third trimester fetus[a]	Not applicable	Not applicable	Not applicable	0.021
0<2	Not applicable	Not applicable	Not applicable	0.17
2<6	0.16	Not applicable	Not applicable	0.087
6<11	0.20	Not applicable	Not applicable	0.083
11<16	0.20	Not applicable	Not applicable	0.036
16<30	0.37	0.15	0.057	0.024
30<40	0.24	0.13	0.050	0.021
40<50	0.24	0.14	0.050	0.021
50<70	0.23	0.14	0.050	0.021

[a] Third trimester fetus age group represents unborn fetus in pregnant spectators, and the mean value of the 16 to <40 years old females.
Values are rounded to two significant figures.

Table B-78. Values of Mean Exposure Parameters and Calculated Adjustment Factor of Chronic Inhalation Exposure to Chemicals (AF_{inh}, unitless)—Combined Gender Athletes

Age Group (Years)	Practice BR_{TW}, cubic meters per hour	Practice AET, hours per year	Game BR_{TW}, cubic meters per hour	Game AET, hours per year	BW, kilograms	AF_{inh}, unitless
2<6	1.4	126	1.5	104	20.5	0.16
6<11	2.3	156	2.3	137	32.0	0.20
11<16	2.8	223	2.9	129	48.7	0.20
16<30	4.2	354	4.4	241	65.8	0.37
30<40	3.6	343	4.0	167	75.3	0.24
40<50	3.9	256	4.0	214	74.5	0.24
50<70	4.1	187	4.4	239	74.3	0.23

AET: mean annual event time spent on the field of a receptor category in an age group for an event type, values are rounded to the nearest whole integers; AF_{inh}: adjustment factor of chronic exposure to a chemical for a receptor category in an age group, values are rounded to two significant figures; BR_{TW}: mean time-weighted one-hour breathing rate of a receptor category in an age group for an event type, values are rounded to one decimal place; and BW: mean study-specific body weight of an age group in kilograms, values are rounded to one decimal place.

Table B-79. Values of Mean Exposure Factors and Calculated Adjustment Factor of Chronic Inhalation Exposure to Chemicals (AF_{inh}, unitless)—Combined Gender Coaches

Age Group (Years)	Practice BR_{TW}, cubic meters per hour	Practice AET, hours per year	Game BR_{TW}, cubic meters per hour	Game AET, hours per year	BW, kilograms	AF_{inh}, unitless
16<30	1.9	354	1.6	241	65.8	0.15
30<40	1.9	354	1.6	241	75.3	0.13
40<50	1.9	354	1.6	241	74.5	0.14
50<70	1.9	354	1.6	241	74.3	0.14

AET: mean annual event time spent on the field of a receptor category in an age group for an event type, values are rounded to the nearest whole integers; AF_{inh}: adjustment factor of chronic exposure to a chemical for a receptor category in an age group, values are rounded to two significant figures; BR_{TW}: mean time-weighted one-hour breathing rate of a receptor category in an age group for an event type, values are rounded to one decimal place; and BW: mean study-specific body weight of an age group in kilograms, values are rounded to one decimal place.

Table B-80. Values of Mean Exposure Parameters and Calculated Adjustment Factor of Chronic Inhalation Exposure to Chemicals (AF_{inh}, unitless)—Combined Gender Referees

Age Group (Years)	Practice BR_{TW}, cubic meters per hour	Practice AET, hours per year	Game BR_{TW}, cubic meters per hour	Game AET, hours per year	BW, kilograms	AF_{inh}, unitless
16<30	Not applicable	Not applicable	1.6	241	65.8	0.057
30<40	Not applicable	Not applicable	1.6	241	75.3	0.050
40<50	Not applicable	Not applicable	1.6	241	74.5	0.050
50<70	Not applicable	Not applicable	1.6	241	74.3	0.050

AET: mean annual event time spent on the field of a receptor category in an age group for an event type, values are rounded to the nearest whole integers; AF_{inh}: adjustment factor of chronic exposure to a chemical for a receptor category in an age group, values are rounded to two significant figures; BR_{TW}: mean time-weighted one-hour breathing rate of a receptor category in an age group for an event type, values are rounded to one decimal place; and BW: mean study-specific body weight of an age group in kilograms, values are rounded to one decimal place.

Table B-81 Values of Mean Exposure Factors and Calculated Adjustment Factor of Chronic Inhalation Exposure to Chemicals (AF_{inh}, unitless)—Combined Gender Spectators

Age Group (Years)	Practice BR_{TW}, cubic meters per hour	Practice AET, hours per year	Game BR_{TW}, cubic meters per hour	Game AET, hours per year	BW, kilograms	AF_{inh}, unitless
Third trimester fetus[a]	0.4	156	0.4	241	75.6	0.021
0<2	0.4	156	0.4	241	9.4	0.17
2<6	0.5	156	0.5	241	20.5	0.087
6<11	0.7	156	0.7	241	32.0	0.083
11<16	0.5	156	0.5	241	48.7	0.036
16<30	0.4	156	0.4	241	65.8	0.024
30<40	0.4	156	0.4	241	75.3	0.021
40<50	0.4	156	0.4	241	74.5	0.021
50<70	0.4	156	0.4	241	74.3	0.021

[a] Third trimester fetus age group represents unborn fetus in pregnant spectators, and the mean value of the 16 to <40 years old females.
AET: mean annual event time spent on the field of a receptor category in an age group for an event type, values are rounded to the nearest whole integers; AF_{inh}: adjustment factor of chronic exposure to a chemical for a receptor category in an age group, values are rounded to two significant figures; BR_{TW}: mean time-weighted one-hour breathing rate of a receptor category in an age group for an event type, values are rounded to one decimal place; and BW: mean study-specific body weight of an age group in kilograms, values are rounded to one decimal place.

B.3.5. Inhalation Exposure Dose for Cancer Assessment

For exposure to carcinogens, OEHHA calculated an average daily inhalation exposure dose of a chemical (during games and practices) for each receptor category in an age group (ADD_{inh}). We applied the ADD_{inh} of each chemical to assess the cancer risk via the inhalation exposure. We included receptor-specific and age-specific exposure parameters to derive the ADD_{inh} of a chemical from $C_{air\text{-}avg}$ using the following equation:

$$ADD_{inh} = \frac{C_{air-avg} \times \sum_{event\ type}(BR_{TW} \times AET) \times CF1 \times CF2}{BW}$$ Equation B-12

where,

ADD_{inh} = daily dose of a chemical through inhalation exposure, averaged over a year, for a receptor category in an age group, milligrams per kilogram bodyweight per day (values in Appendix F.5.1)

$C_{air\text{-}avg}$ = mean of the 35 individual field average concentrations of a chemical in air on or off the fields, nanograms per cubic meter (values in Main Report Section 3.4.6, Table 3-10)

BR_{TW} = time-weighted one-hour breathing rate of a receptor category in an age group for a soccer event, cubic meters per hour (Table B-52 to Table B-59)

AET = annual event time, or time spent on the field by a receptor category in an age group for soccer events in a year, hours per year (Section B.2.5)

CF1 = conversion factor, equals to 1 year per 365 days

CF2 = conversion factor, equals to 1 mg per 1000000 ng

BW = bodyweight of an age group, kilograms (Section B.2.2, Table B-2)

B.3.6. References

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B.4. Dermal Exposure Dose and Route-Specific Parameters

The OEHHA Air Toxics Hot Spots Program Risk Assessment Guidelines (OEHHA, 2015) provide detailed directions to assess exposure to chemicals via the dermal pathway. As described in Main Report Section 4.5, detected dermal bioaccessible chemicals are grouped into the general or special chemical target system groups. The average daily dose, or exposure dose, of a chemical via dermal exposure (ADD_{der}) is a function of particle loading onto the skin surface, area of the exposed skin surface that comes into contact with the field surface, and bioaccessible concentration of a chemical in crumb rubber particles. Crumb rubber samples collected from synthetic turf fields contained crumb rubber, sand, dirt, and broken fibers of turf blade. For the purpose of risk assessment for the Synthetic Turf Study (the Study), OEHHA assumed the direct dermal contact with crumb rubber particles as the major source of chemical exposure for this pathway. In the estimation of ADD_{der}, we considered the direct transfer of chemical residues onto skin surfaces (independent of adhesion from crumb rubber particles) via dermal contacts with field surface negligible. Therefore, following the OEHHA guidelines, we derived the ADD_{der} for general chemicals using Equation B-13 below:

$$ADD_{der} = \frac{DL \times C_{der-crumb\ rubber} \times ABS \times EV \times CF1 \times CF2}{BW}$$ Equation B-13

where,

ADD_{der} = average daily dose of a chemical through dermal exposures for a specific age group and receptor category, milligrams per kilogram bodyweight per day

DL = mean total loading of crumb rubber particles on the skin in each event, grams crumb rubber per event (Section B.4.1, Table B-82 to Table B-85)

$C_{der\text{-}crumb\ rubber}$= mean of the 35 individual field average bioaccessible concentrations of a chemical from crumb rubber in artificial sweat, nanograms per gram crumb rubber (Section B.4.2, Main Report Table 3-3)

ABS = fraction of a chemical absorbed by the skin, unitless, default value equal to 1 (Section B.4.3)

EV = number of annual field events (practice and games) for a specific receptor and age group, events per year (Section B.2.3, Table B-8 to Table B-17)

CF1 = conversion factor 1, equals to 1 milligram per 1,000,000 nanograms

CF2 = conversion factor 2, equals to 1 year per 365 days

BW = bodyweight of an age group, kilograms (Section B.2.2, Table B-2)

B.4.1. Dermal Load

The dermal loading, DL, is the amount of crumb rubber particles adhered on the skin during an event. Values of DL provided in the OEHHA guidelines (2015) are for modeling residential exposure to soil contaminants. They represent an estimation of dermal loading of soil particles during daily activities of the general population. OEHHA considered these values not applicable to the Study. Instead, DL was derived by applying methods from the OEHHA guidelines and the USEPA Risk Assessment Guidance for Superfund (RAGS) Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) (USEPA, 2004) for skin contact with soil. To calculate DL from field surface contacts, we used Equation B-14.

$$DL = \sum P_i \times [SA_i \times AF_i] \times CF3$$ Equation B-14

where,

DL = mean total loading of crumb rubber particles on the skin in each event, grams crumb rubber per event

P_i = adjustment factor for partial exposure of a specified body part, unitless, 1 for full exposure and 0.5 for partial exposure

SA_i = mean skin surface area of a specific body part of an age group, square centimeters (Section B.4.1.2)

AF_i = adherence factor of crumb rubber to skin of a specified body part, amount of crumb rubber adhered per skin surface area in an event, milligrams crumb rubber per square centimeter per event (Section B.4.1.3)

CF3 = conversion factor 3, equals to 1 gram per 1000 milligrams

The value of DL depends on which body parts may be available for exposure during activities on or near the synthetic turf field, and the extent of the body part's exposure (P_i, Section B.4.1.1), the surface area of those body parts (SA_i, Section B.4.1.2) and the specific adherence factors for those body parts (AF_i, Section B.4.1.3).

The calculated values of DL for combined gender, females, and males are shown in Table B-82 (athletes), Table B-83 (coaches and referees), Table B-84 (child spectators), and Table B-85 (adolescent and adult spectators).

Table B-82. Synthetic Turf Study Mean Crumb Rubber Dermal Load (DL, grams crumb rubber per event)—Athletes

Age Group	Combined Gender	Female	Male
2<6 years	0.077	0.077	0.077
6<11 years	0.109	0.107	0.109
11<16 years	0.142	0.141	0.143
16<30 years	0.168	0.158	0.181
30<40 years	0.180	0.167	0.199
40<50 years	0.179	0.163	0.197
50<70 years	0.179	0.152	0.188

Values are rounded to three decimal places.

Table B-83. Synthetic Turf Study Mean Crumb Rubber Dermal Load (DL, grams crumb rubber per event)—Coaches and Referees

Age Group	Combined Gender	Female	Male
16<30 years	0.083	0.076	0.092
30<40 years	0.089	0.081	0.101
40<50 years	0.089	0.079	0.100
50<70 years	0.089	0.073	0.095

Values are rounded to three decimal places.

Table B-84. Synthetic Turf Study Mean Crumb Rubber Dermal Load (DL, grams crumb rubber per event)—Child Spectators

Age Group	Combined Gender	Female	Male
0<2 years	0.048	0.047	0.049
2<6 years	0.077	0.077	0.077
6<11 years	0.109	0.107	0.109

Values are rounded to 2 decimal places.

Table B-85. Synthetic Turf Study Mean Crumb Rubber Dermal Load (DL, grams crumb rubber per event)—Adolescent and Adult Spectators

Age Group	Combined Gender	Female	Male
Third trimester pregnant women	Not applicable	0.072	Not applicable
11<16 years	0.142	0.141	0.143
16<30 years	0.078	0.072	0.086
30<40 years	0.084	0.076	0.094
40<50 years	0.083	0.074	0.093
50<70 years	0.083	0.069	0.089

Values are rounded to three decimal places.

B.4.1.1. Body Parts Available for Dermal Exposure

Table B-86 shows the receptor-specific body parts considered for each receptor and the extent of exposure. The extent of a body part's exposure may be dependent on the type of clothing, which can vary based on seasons and geographic locations, and the types

of activity that occur on field. OEHHA assigned an adjustment factor (P_i) of 0.5 for partial exposure and 1 for full exposure.

Table B-86. Body Parts Considered for Dermal Exposure[a] on Synthetic Turf Fields

Receptor	Head	Trunk	Arms	Hands	Legs	Feet
Athlete	●	◐	●	●	●	●
Coach	○	○	◐	●	◐	●
Referee	○	○	◐	●	◐	●
Child Spectator <11 years and Adolescent Spectator 11<16 years	●	◐	●	●	●	●
Adult Spectator 16<70 years[b]	○	○	○	●	◐	●

[a] The extent of exposure is represented by filled circle (●) for the full area of the specified body part is available for dermal exposure, half circle (◐) for only a partial exposure of the specified body part, and empty circle (◯) for negligible exposure and is not included in the assessment.
[b] Includes third trimester fetus.

For athletes, data from the Time Activity Studies (TAS) Survey show that for the spring, summer, and fall seasons, they typically dress in short sleeve shirts, shorts, long socks, and shoes for soccer activities. Goalies also wear gloves and may wear long sleeve shirts and long pants. During the winter season, athletes frequently wear long sleeve shirts and long pants, and occasionally gloves (for players other than the goalie). Soccer uniforms generally cover the trunk (the central part or torso of the body which includes the neck, bosom, shoulders, abdomen, back, genitals, and buttocks; it excludes the head and limbs) and may act as barrier for dermal contacts to crumb rubber.

There are anecdotal evidence and collected data from the TAS Survey that regardless of how athletes are dressed, crumb rubber particles frequently get inside of undergarments, clothing, and shoes during soccer activities (such as sliding or diving) on synthetic turf fields. The TAS Survey data show that approximately 80 percent of participants found crumb rubber somewhere on their body after a practice or game (Table B-87). Less than 50 percent of participants reported never finding crumb rubber on their upper (Table B-88, Table B-89) and lower (Table B-90) bodies. Additionally, over 90 percent of participants spent time warming up on the field (Table B-91) for practices and games performing activities such as sit-ups and stretching, where their head, arms, and legs were in direct contact with the field surface. Approximately 25 percent of participants also reported being barefoot on the field for some time during field events (Table B-92). Nearly half of TAS Survey participants indicated that they did not find crumb rubber on their neck, while almost 60 percent reported never finding it on their back or chest (Table B-87). Thus, for the athletes, the head and the limbs are considered fully exposed, and the trunk has partial exposure with clothing offering partial protection from exposure (Table B-86).

Table B-87. Percent of TAS Survey Study Participants Reported Finding Crumb Rubber on Their Upper Body Parts After Playing on a Synthetic Turf Field

Percent of Time Finding Crumb Rubber	Body (Number of Participants = 1062)	Neck (Number of Participants = 908)	Chest (Number of Participants = 908)	Back (Number of Participants = 908)
0	15%	47%	62%	57%
>0-25%	46%	39%	25%	29%
>25-50%	14%	5%	4%	5%
>50-75%	8%	2%	2%	1%
>75%	14%	1%	1%	1%
Don't Know or Prefer Not To Answer	3%	6%	6%	7%

Values are rounded to the nearest whole integers.

Table B-88. Percent of TAS Survey Study Participants Reported Finding Crumb Rubber on Their Head after Playing on a Synthetic Turf Field

Percent of Time Finding Crumb Rubber[a]	Mouth	Hair	Face
0%	64%	28%	39%
>0-25%	27%	47%	44%
>25-50%	2%	10%	8%
>50-75%	1%	6%	2%
>75%	0%	4%	2%
Don't Know or Prefer Not To Answer	5%	6%	5%

[a] The data analysis contained 908 TAS Survey participants.
Values are rounded to the nearest whole integers.

Table B-89. Percent of TAS Survey Study Participants Reported Finding Crumb Rubber on Their Upper Appendages after Playing on a Synthetic Turf Field

Percent of Time Finding Crumb Rubber[a]	Upper arms	Lower arms	Hands
0%	49%	40%	30%
>0-25%	34%	38%	39%
>25-50%	7%	9%	11%
>50-75%	2%	4%	6%
>75%	1%	3%	8%
Don't Know or Prefer Not To Answer	6%	6%	6%

[a] The data analysis contained 908 TAS Survey participants.
Values are rounded to the nearest whole integers.

Table B-90. Percent of TAS Survey Participants Reported Finding Crumb Rubber on Their Lower Appendages after Playing on a Synthetic Turf Field

Percent of Time Finding Crumb Rubber[a]	Thighs	Lower Legs	Feet
0%	28%	9%	9%
>0-25%	41%	40%	29%
>25-50%	15%	22%	18%
>50-75%	6%	14%	16%
>75%	4%	11%	23%
Don't Know or Prefer Not To Answer	6%	4%	4%

[a] The data analysis contained 908 TAS Survey participants.
Values are rounded to the nearest whole integers.

Table B-91. Percent of TAS Survey Participants Reported Their Duration of Warm-Up in a Practice and a Game

Duration of Warm-up (minute)	Practice (Number of Participants = 930)	Game (Number of Participants = 1045)
0	3%	7%
>0-15	56%	64%
>15-30	33%	22%
>30-60	5%	5%
>60	1%	1%
Don't Know or Prefer Not To Answer	2%	1%

Values are rounded to the nearest whole integers.

Table B-92. Percent of TAS Survey Participants Reported Walking Barefoot on the Synthetic Turf Field

Duration of Walking Barefoot (minute)	Practice (Number of Participants = 930)	Game (Number of Participants = 1045)
0	74%	74%
>0-10	24%	25%
>10-30	1%	1%
> 30	0%	0%
Don't Know or Prefer Not To Answer	2%	1%

Values are rounded to the nearest whole integers.

For other receptor categories, the TAS Survey did not collect data on body parts which potentially come into contact with crumb rubber. In the absence of exposure data, OEHHA assigned full or partial exposures based on receptor activities. For coaches and referees, they are assumed to have full dermal exposure of hands and feet (Table B-86) because they have contact with objects, such as the ball or an equipment bag that sit on the field. They can kick up crumb rubber while walking or jogging on the field and have partial exposure of their arms and legs. They have minimal dermal exposure of their head and trunk because they do not conduct activities such as sliding, diving, falling that may result in these parts coming into direct dermal contact with the synthetic turf field.

For child and adolescent spectators under 16 years of age, they are assumed to have full exposure of all body parts except the trunk (Table B-86). Children and pre-teens may crawl around on and play on the field or sit and lounge on the turf along the sidelines of the fields. Similar to athletes, clothing is assumed to reduce the level of crumb rubber adhesion to the trunk that results in a partial exposure of this body part. The exposure for adult spectators (≥ 16 years old) are limited to full exposure of hand and feet, and partial exposure of legs (Table B-86). Adult spectators may sit on the field and result in direct dermal contact of these parts with the field surface. Negligible exposure of the arms, head, and trunk was assumed.

B.4.1.2. Surface Area of Body Parts

Table B-93, Table B-94, and Table B-95 show the surface area of specific body parts (SA_i) for combined gender, females, and males, respectively; these values are used in the dermal loading calculation (Equation B-14). SA_i is calculated as described in the OEHHA guidance (OEHHA, 2012), using Equation B-15 below:

$$SA_i = SA_{total} \times FTSA_i \qquad \text{Equation B-15}$$

where,

SA_i = mean skin surface area of a specified body part of an age group, square centimeters

SA_{total} = mean total body skin surface area of an age group, square centimeters (Section B.4.1.2.1)

$FTSA_i$ = mean fraction of the total body surface area for a specified body part of an age group, unitless (Section B.4.1.2.2)

OEHHA multiplied age and gender-matched mean total body surface area (SA_{total}, Section B.4.1.2.1; Table B-96) and specific body part fractions ($FTSA_i$, Section B.4.1.2.2; Table B-102 to Table B-104) to determine the surface area of a specified body part (SA_i).

Table B-93. Synthetic Turf Study Mean Body Part Surface Area (SA_i, square centimeters)—Combined Gender

Age Group	Head	Trunk	Arms	Hands	Legs	Feet
0<2 years	806	1654	620	256	1015	297
2<6 years	653	3280	1132	379	2034	505
6<11 years	681	4410	1555	525	3211	752
11<16 years	682	5843	2109	667	4475	966
16<30 years	734	7336	2598	801	5254	1090
30<40 years	786	7852	2781	857	5624	1167
40<50 years	781	7809	2766	852	5593	1160
50<70 years	783	7822	2770	854	5602	1162

Table values are rounded to the nearest whole integers; however, all decimal places for mean total body surface area (SA_{total}) and specific body part fractions ($FTSA_i$) area used the calculation of body part surface area (SA_i).

Table B-94. Synthetic Turf Study Mean Body Part Surface Area (SA_i, square centimeters)—Females

Age Group	Head	Trunk	Arms	Hands	Legs	Feet
Third trimester	733	Not available[a]	2344	733	4994	997
0<2 years	791	1623	609	251	996	292
2<6 years	647	3286	1122	387	2052	491
6<11 years	671	4348	1499	517	3234	726
11<16 years	683	5809	2086	639	4553	925
16<30 years	725	7181	2318	725	4939	986
30<40 years	767	7599	2453	767	5226	1043
40<50 years	748	7406	2390	748	5094	1017
50<70 years	697	6907	2229	697	4751	948

Table values are rounded to the nearest whole integers; however, all decimal places for mean total body surface area (SA_{total}) and specific body part fractions ($FTSA_i$) area used the calculation of body part surface area (SA_i).

[a] There is no data available to estimate the change in surface area of the trunk during pregnancy.

Table B-95. Synthetic Turf Study Mean Body Part Surface Area (SA_i, square centimeters)—Males

Age Group	Head	Trunk	Arms	Hands	Legs	Feet
0<2 years	808	1658	622	256	1018	298
2<6 years	659	3274	1142	371	2016	519
6<11 years	687	4441	1601	530	3165	773
11<16 years	681	5873	2130	695	4394	1006
16<30 years	752	7584	2940	894	5662	1218
30<40 years	825	8320	3226	981	6212	1336
40<50 years	816	8232	3192	971	6145	1322
50<70 years	780	7869	3051	928	5875	1264

Table values are rounded to the nearest whole integers; however, all decimal places for mean total body surface area (SA_{total},) and specific body part fractions ($FTSA_i$) area used the calculation of body part surface area (SA_i).

B.4.1.2.1. Total Body Surface Area

The total body skin surface area, SA_{total}, depends on the age and gender of a receptor. The SA_{total} increases during childhood and reaches a steady state in adulthood. OEHHA estimated SA_{total} (Table B-96) using a model that take into account the height and bodyweight of an individual. OEHHA (2012) and the USEPA Exposure Factors Handbook, EFH, (USEPA, 2011) adopted the equation proposed by Gehan and George (1970) [2] and data of bodyweight (BW) and height collected in National Health and Nutrition Examination Survey (NHANES) to estimate values of SA_{total} for the general population in the United States (Table B-97 to Table B-100). For this Study, OEHHA applied the self-reported height and bodyweight data from the TAS Survey to the equation from Gehan and George (1970)[2] to estimate the SA_{total} of individual participants (summarized in Table B-101). Since the TAS Survey did not have data for 0<2 years, we used the data from USEPA (2011) based on NHANES 1999-2006 (Table B-98, Table B-99, and Table B-100) to estimate the SA_{total} for this age group. For dermal exposure of the third trimester fetus, we used the mean SA_{total} for women age 16<40 years. The resulting mean values of SA_{total} provide more appropriate representation of the targeted receptor categories (Table B-96).

[2] The equation for total body surface area (SA_{total}) presented by Gehan and George is as follows: $SA_{total} = (BW^{0.51456}) \times (Ht^{0.42246}) \times 0.02350 \times 10000$ where SA_{total} is the total body skin surface area in square centimeters, BW is a participant's bodyweight in kilograms, and Ht is a participant's height in centimeters.

Table B-96. Synthetic Turf Study Specific Mean Total Body Surface Area (SA_{total}, square centimeters)

Age Group	Combined Gender	Female	Male
Third Trimester Fetus	Not applicable	17045[a]	Not applicable
0<2 years[b]	4646	4558	4658
2<6 years	7986	7986[c]	7986
6<11 years	11137	10998	11196
11<16 years	14745	14687	14794
16<30 years	17794	16858	19031
30<40 years	19047	17837	20880
40<50 years	18943	17384	20657
50<70 years	18974	16214	19747

[a] Dermal exposure to the third trimester fetus occurs through the skin of the pregnant mother. Therfore, we used the mean value of individual female athlete participant data ages 16<40 years for the SA_{total} of third trimester fetus.
[b] The TAS Survey was unable to collect data for this age group. We calculated a mean SA_{total} value from USEPA (2011) based on NHANES 1999-2006 (Table B-98, Table B-99, and Table B-100).
[c] The TAS Survey was unable to collect data for 2<6-year-old females. We assumed that the values of SA_{total} are similar for males and females in the 2<6 years age group and hence applied data from one male survey participant for the 2<6 years group as a surrogate value.
Values are rounded to the nearest whole integers

National Health and Nutrition Examination Surveys (NHANES) 1999-2004

For the purposes of exposure assessment, OEHHA guidance (OEHHA, 2012) recommends SA_{total} estimates derived using NHANES 1999-2004 height and body weight for 0<2, 2<9, 2<16, and >16 years age groups and the total body surface area formula proposed by Gehan and George (1970)[2]. Table B-97 shows the mean SA_{total} values.

Table B-97. OEHHA (2012) Recommended Mean Total Body Surface Area (SA_{total}, square centimeters)

Age Group	Mean
0<2 years	4590
2<9 years	8840
2<16 years	11770
>16 years	19420

National Health and Nutrition Examination Surveys (NHANES) 1999-2006

The EFH provided values of mean SA_{total} of females and males, derived from NHANES 1999-2006 height and bodyweight data and the equation proposed by Gehan and George (1970)[2]. The Study designated age groups differed from those in the EFH. OEHHA calculated time-weighted mean SA_{total} values, for our Study age groups, using the USEPA data and the method described previously (Section B.2.2). Table B-98,

Table B-99, and Table B-100 show the SA_{total} values calculated for combined gender, females, and males.

Table B-98. Total Body Surface Area (SA_{total}, square centimeters) Derived from NHANES 1999-2006 (USEPA, 2011)—Combined Gender

Age Group	25th Percentile	50th Percentile	Mean
0<2 years[a]	4321	4646	4646
2<6 years[a]	6525	7075	7225
6<11 years	9300	10500	10800
11<16 years	14000	15700	15900
16<30 years[a]	17033	18733	19000
30<40 years	17700	19500	19700
40<50 years	18000	19900	20100
50<70 years[a]	17900	19750	19900

[a] Time-weighted values due to the combining of different age groups.
Values are rounded to the nearest whole integers

Table B-99. Total Body Surface Area (SA_{total}, square centimeters) Derived from NHANES 1999-2006 (USEPA, 2011)—Females

Age Group	25th Percentile	50th Percentile	Mean
0<2 years[a]	4225	4550	4558
2<6 years[a]	6500	7025	7125
6<11 years	9200	10400	10800
11<16 years	14200	15500	15700
16<30 years[a]	15900	17567	17833
30<40 years	16700	18200	18500
40<50 years	17000	18300	18800
50<70 years[a]	17000	18500	18850
16<40 years[b]	16229	17817	18100

[a] Time-weighted values due to the combining of age groups.
[b] Used as surrogate for third trimester (33 weeks) female. Derived from 16<30 and 30<40 female SA_{total} values.
Values are rounded to the nearest whole integers

Table B-100. Total Body Surface Area (SA_{total}, square centimeters) Derived from NHANES 1999-2006 (USEPA, 2011)—Males

Age Group	25th Percentile	50th Percentile	Mean
0<2 years[a]	4408	4692	4658
2<6 years[a]	6625	7175	7250
6<11 years	9400	10600	10900
11<16 years	13900	16000	16100
16<30 years[a]	18333	19767	20133
30<40 years	19300	20800	21000
40<50 years	19700	21200	21500
50<70 years[a]	19400	21000	20950

[a] Time-weighted values due to the combining of age groups.
Values are rounded to the nearest whole integers

OEHHA Time-Activity Studies (TAS) Survey Data

OEHHA collected self-reported data on the BW and height of soccer players in the TAS Survey. Using the Gehan and George equation[2], we calculated the SA_{total} of individual participants and hence the mean SA_{total} for females, males, and combined gender (Table B-101). The TAS Survey was unable to collect data for the 0<2 age group, nor data for the 2<6 years age group females.

Table B-101. Mean Total Body Surface Area (SA_{total}, square centimeters) Derived from OEHHA TAS Survey Data

Age Group	No. of Combined Gender Participants	Combined Gender—Mean	No. of Female Participants	Female—Mean	No. of Male Participants	Male—Mean
2<6 years	1	7986	0	Not available	1	7986
6<11 years	112	11137	35	10998	76	11196
11<16 years	492	14745	241	14687	247	14794
16<30 years	260	17794	148	16858	112	19031
30<40 years	61	19047	35	17837	25	20880
40<50 years	84	18943	44	17384	40	20657
50<70 years	32	18974	7	16214	25	19747
16<40 years[a]	Not available	Not available	183	17045	Not available	Not available

[a] Used as surrogate for third trimester (33 weeks) female. Derived from individual bodyweight (BW) and height values from the 16<30 and 30<40 female groups.
Values are rounded to the nearest whole integers

The estimated SA_{total} of younger athletes (2<6 and 6<11 years groups) from the TAS Survey are similar to or slightly greater than the mean value derived from the NHANES 1999-2006 data set. For ages over 11 years old, the mean SA_{total} values for athletes are slightly lower than the mean values in the NHANES data, and fall between the 25th and

50th percentile values in the NHANES data (Table B-98, Table B-99, Table B-100). The TAS Survey data are specific for soccer athletes in California, while the NHANES data represent values of the general populations in the United States. OEHHA assumed coaches, referees, and spectators are current or past athletes and that the TAS Survey data probably are more appropriate for assessing exposures of all the receptor categories in this Study. For the Study, OEHHA therefore adopted the values of SA_{total} estimated from TAS Survey data and used the mean values from NHANES to fill in the SA_{total} data gap for the 0<2 years group (Table B-96).

B.4.1.2.2. Surface Area Fraction of Body Parts

The fraction of the total body surface area for each body part, $FTSA_i$, varies by body part and changes through growth, especially in childhood and young adulthood, and vary slightly between males and females. Minimal changes in the proportions of each body part are assumed once an individual reaches adulthood. For the Study, OEHHA used mean values of direct measurements of body part fractions for infants less than two years old reported in the EFH. For all other age groups, we adopted mean values of measured data from a population-based campaign of 2,050 human subjects recruited in various states (Boniol *et al.*, 2008). The mean values for 16 and 18 years old from the Boniol study are the estimate for receptors ages 16<70 years of the Study.

For the third trimester pregnant women, there are no data on how much the surface area of the trunk changes during pregnancy. OEHHA used the mean values for 16- and 18-year-old females from the Boniol et al. (2008) for this age group. We assumed that pregnancy does not significantly alter the surface areas of the head, arms, hands, legs or feet. The surface areas of these body parts (SA_i) of third trimester pregnant women, therefore, was estimated by multiplying mean SA_{total} of 16<40-year-old females with mean $FTSA_i$ (except for trunk) for the same age group. The dermal exposure of the trunk area for third trimester pregnant women was considered negligible and thus no $FTSA_{trunk}$ value for this receptor category was estimated for the Study. Table B-102, Table B-103, and Table B-104 show the Study-specific mean body part fraction values for combined gender, females, and males, respectively. These parameter values are used to estimate the dermal exposure doses in all receptor categories.

Table B-102. Synthetic Turf Study Specific Mean Body Part Fraction ($FTSA_i$, unitless)—Combined Gender

Age Group	Head	Trunk	Arms	Hands	Legs	Feet	Data Source
0<2 years	0.17	0.36	0.13	0.06	0.22	0.06	USEPA (2011)
2<6 years	0.08	0.41	0.14	0.05	0.25	0.06	Boniol et al (2008)
6<11 years	0.06	0.40	0.14	0.05	0.29	0.07	Boniol et al (2008)
11<16 years	0.05	0.40	0.14	0.05	0.30	0.07	Boniol et al (2008)
16<30 years	0.04	0.41	0.15	0.05	0.30	0.06	Boniol et al (2008)
30<40 years	0.04	0.41	0.15	0.05	0.30	0.06	Boniol et al (2008)
40<50 years	0.04	0.41	0.15	0.05	0.30	0.06	Boniol et al (2008)
50<70 years	0.04	0.41	0.15	0.05	0.30	0.06	Boniol et al (2008)

Values are rounded to two decimal places.

Table B-103. Synthetic Turf Study Specific Mean Body Part Fraction ($FTSA_i$, unitless)—Females

Age Group	Head	Trunk	Arms	Hands	Legs	Feet	Data Source
Third trimester[a]	0.04	Not available	0.14	0.04	0.29	0.06	Boniol et al (2008)
0<2 years	0.17	0.36	0.13	0.06	0.22	0.06	USEPA (2011)
2<6 years	0.08	0.41	0.14	0.05	0.26	0.06	Boniol et al (2008)
6<11 years	0.06	0.40	0.14	0.05	0.29	0.07	Boniol et al (2008)
11<16 years	0.05	0.40	0.14	0.04	0.31	0.06	Boniol et al (2008)
16<30 years	0.04	0.43	0.14	0.04	0.29	0.06	Boniol et al (2008)
30<40 years	0.04	0.43	0.14	0.04	0.29	0.06	Boniol et al (2008)
40<50 years	0.04	0.43	0.14	0.04	0.29	0.06	Boniol et al (2008)
50<70 years	0.04	0.43	0.14	0.04	0.29	0.06	Boniol et al (2008)

[a] OEHHA adopted mean body part fraction for females ages 16 to 18 years from Boniol et al. 2008 for the third trimester pregnant women. We assumed pregnancy does not significantly alter the surface areas of the head, arms, hands, legs or feet.
Values are rounded to two decimal places.

Table B-104. Synthetic Turf Study Specific Mean Body Part Fraction ($FTSA_i$, unitless)—Males

Age Group	Head	Trunk	Arms	Hands	Legs	Feet	Data Source
0<2 years	0.17	0.36	0.13	0.06	0.22	0.06	USEPA (2011)
2<6 years	0.08	0.41	0.14	0.05	0.25	0.07	Boniol et al (2008)
6<11 years	0.06	0.40	0.14	0.05	0.28	0.07	Boniol et al (2008)
11<16 years	0.05	0.40	0.14	0.05	0.30	0.07	Boniol et al (2008)
16<30 years	0.04	0.40	0.15	0.05	0.30	0.06	Boniol et al (2008)
30<40 years	0.04	0.40	0.15	0.05	0.30	0.06	Boniol et al (2008)
40<50 years	0.04	0.40	0.15	0.05	0.30	0.06	Boniol et al (2008)
50<70 years	0.04	0.40	0.15	0.05	0.30	0.06	Boniol et al (2008)

Values are rounded to two decimal places.

USEPA Exposure Factors Handbook, EFH (USEPA, 2011)

The EFH provides combined gender data for $FTSA_i$ of each body part for 0≤21 years old and gender specific data for 21+ years old. USEPA derived mean values of infants and young toddlers, less than two years old, from directly measured data of young children (Anderson *et al.*, 1985), while simulating values for children and young adults from computer modeling (Boniol *et al.*, 2008). Using mean height and weight data from NHANES 1996-2006 and regression models, USEPA estimated body part surface areas of adults.

Since the age groupings used in the EFH are different from the Study, OEHHA calculated weighted mean values of the USEPA $FTSA_i$ according to age groups defined in the Study. We averaged values across multiple age groups within the USEPA data for mean percent of total surface area of body parts (Table 7-2 of USEPA 2011) and weighted equally by each year of age (see footnote for example calculation)[3]. For the 16<30 years group, we used data from 16<21 years old and 21+ years adult males and females with male and female data for 21+ years weighted equally. Similarly, we used data for 21+ years females and males for the 30<40, 40<50, and 50<70 years groups. Lastly, all $FTSA_i$ values are normalized so that the sum of $FTSA_i$ of each age group equaled to one. Table B-105 shows the $FTSA_i$ values used for calculation of SA_i.

[3] To combine age group data from the EFH (USEPA, 2011) into a time-weighted mean value for a Synthetic Turf Study defined age group, USEPA data values are multiplied by weighted factors (a factor of 1 for each year of age over the number of years in the Synthetic Turf Study age group) and summed together.

For example, for the head body part fraction ($FTSA_{head}$) for the Synthetic Turf Study 2<6 years age group (Table B-105), data for the 2<3 years and 3<6 years age groups from Table 7-2 of the EFH are used to calculate the time-weighted mean value. For the 2<3 years and 3<6 years age groups, the USEPA values for the mean percent of total body surface area for the head are given weights of 1/4 and 3/4, respectively.

To calculate the time-weighted mean percent of total body surface area for the head for 2<6 years, the mean total percent of total body surface area for the head for 2<3 years and 3<6 years are multiplied by their respective weights and the values are summed together: (8.4 percent times 1/4) + (8 percent times 3/4) = 8.1 percent. To get the $FTSA_{head}$, the time-weighted percent is divided by 100: 8.1 ÷ 100 = 0.08.

Table B-105. Mean Fraction of Body Surface Area by Body Part ($FTSA_i$, unitless) Derived from EFH (USEPA, 2011)—Combined Gender

Age Group	Head	Trunk	Arms	Hands	Legs	Feet
0<2 years[a]	0.17	0.36	0.13	0.06	0.22	0.06
2<6 years[b]	0.08	0.41	0.14	0.05	0.26	0.06
6<11 years	0.06	0.40	0.14	0.05	0.29	0.07
11<16 years	0.05	0.40	0.14	0.05	0.30	0.07
16<30 years[c]	0.06	0.39	0.14	0.05	0.32	0.06
30<40 years[d]	0.06	0.38	0.14	0.05	0.33	0.07
40<50 years[d]	0.06	0.38	0.14	0.05	0.33	0.07
50<70 years[d]	0.06	0.38	0.14	0.05	0.33	0.07
16<40 years[e]	0.06	0.37	0.13	0.05	0.32	0.06

[a] Includes data for birth to <1 month, 1 to <3 months, 3 to <6 months, 6 to <12 months, and 1 to <2 years.
[b] Includes data for 2 to <3 years and 3 to <6 years.
[c] Includes data for 16 to <21 years and 21+ years adult males and females.
[d] Includes data for 21+ years adult males and females.
[e] Includes data for 16 to <21 years and 21+ years adult females.
Values are rounded to two decimal places.

Boniol et al. 2008

Boniol *et al.* (2008) developed a computer modeling program to estimate the skin surface area of children. The authors applied height and bodyweight data from 2,050 children (ages 2 to 18 years) to validate a computer human model, MAN3D. The model used facets (polygonal closed lines that are joined together to form anatomical body parts) to define anatomical body parts. OEHHA combined and normalized the age data into relevant Study age groups. Table B-106, Table B-107, and Table B-108 present the mean measurements by body part for combined gender, females, and males, respectively.

Table B-106. Mean Body Part Fraction ($FTSA_i$, unitless) Derived from Boniol *et al.* (2008)—Combined Gender

Age Group	Head	Trunk	Arms	Hands	Legs	Feet
2<6 years[a]	0.08	0.41	0.14	0.05	0.25	0.06
6<11 years[b]	0.06	0.40	0.14	0.05	0.29	0.07
11<16 years[c]	0.05	0.40	0.14	0.05	0.30	0.07
16<18 years[d]	0.04	0.41	0.15	0.05	0.30	0.06

[a] Female and male data from 2 and 4 years old.
[b] Female and male data from 6, 8, 10 years old.
[c] Female and male data from 12 and 14 years old.
[d] Female and male data from 16 and 18 years old.
Values are rounded to two decimal places.

Table B-107. Mean Body Part Fraction ($FTSA_i$, unitless) Derived from Boniol *et al.* (2008)—Females

Age Group	Head	Trunk	Arms	Hands	Legs	Feet
2<6 years[a]	0.08	0.41	0.14	0.05	0.26	0.06
6<11 years[b]	0.06	0.40	0.14	0.05	0.29	0.07
11<16 years[c]	0.05	0.40	0.14	0.04	0.31	0.06
16<18 years[d]	0.04	0.43	0.14	0.04	0.29	0.06

[a] Female data from 2 and 4 years old.
[b] Female data from 6, 8, 10 years old.
[c] Female data from 12 and 14 years old.
[d] Female data from 16 and 18 years old.
Values are rounded to two decimal places.

Table B-108. Mean Body Part Fraction ($FTSA_i$, unitless) Derived from Boniol *et al.* (2008)—Males

Age Group	Head	Trunk	Arms	Hands	Legs	Feet
2<6 years[a]	0.08	0.41	0.14	0.05	0.25	0.07
6<11 years[b]	0.06	0.40	0.14	0.05	0.28	0.07
11<16 years[c]	0.05	0.40	0.14	0.05	0.30	0.07
16<18 years[d]	0.04	0.40	0.15	0.05	0.30	0.06

[a] Male data from 2 and 4 years old.
[b] Male data from 6, 8, 10 years old.
[c] Male data from 12 and 14 years old.
[d] Male data from 16 and 18 years old.
Values are rounded to two decimal places.

B.4.1.3. Crumb Rubber Adherence Factor

The structure and function of the skin can vary based on location on the body resulting in differences in the adherence of crumb rubber on different body parts. For the Study, OEHHA assumed that the amount of particles adhered to the body might change during each skin contact with the field surface, but quickly reached a steady state (i.e., amount lost equals to amount adhered following each contact) and remained the same throughout a practice or game (Cohen Hubal *et al.*, 2005). Additionally, we assumed that adhered particles stayed on the skin surfaces until hand washing or bathing occurred (USEPA, 2004). This adherence characteristic is defined by the body part-specific adherence factor, AF_i, of crumb rubber expressed as the amount of crumb rubber (milligrams) that adheres onto a specific body part per unit of surface area (square centimeter) in an event.

OEHHA obtained values for this parameter from the dermal adherence study of crumb rubber by Kissel *et al.* (1996). The investigators measured skin loading of particles for soccer players after 90-minute soccer games played on crumb rubber infilled synthetic turf fields. They measured skin loading of the hands, arms, legs, and face; but not the feet or trunk. Considering similarities of skin of the hand to the feet (Bovell, 2015; Kolarsick *et al.*, 2011; Smith and Thiboutot, 2008), OEHHA adopted the value of AF_{hand}

as a surrogate for AF_{feet}. Additionally, we used the value of AF_{legs} as a surrogate for AF_{trunk}. Table B-109 summarizes these values.

Table B-109. Mean Body Part-Specific Adherence Factors (AF_i, milligrams crumb rubber per square centimeter per event) from Kissel *et al.* (1996)

Body Part	Mean AF_i[a]
Hands	0.026
Arms	0.004
Legs	0.011
Face (Head)	0.014
Feet[b]	0.026
Trunk[c]	0.011

[a] Values are the geometric mean reported in Kissel et al, 1996.
[b] Feet assumed to be the same as the hands.
[c] Trunk assumed to be the same as the legs.

B.4.2. Bioaccessbile Dermal Concentration

OEHHA collected crumb rubber samples from the selected 35 fields in our Field Characterization Study (Main Report Section 2.3.2.4). LBNL used the samples to conduct bioaccessibility measurements to identify chemicals and quantify the amount of chemicals that can be released upon extraction with artificial sweat under physiological conditions (Appendix Section D.4.1.3). The dermal bioaccessible concentrations of chemicals in crumb rubber ($C_{der\text{-}crumb\ rubber}$) represent the mean of the 35 individual field average amounts of a chemical that is available for dermal absorption through the skin.

B.4.3. Chemical Skin Absorption Fraction

In Equation B-13, the fraction of a chemical absorbed across skin, ABS, is a unitless factor that describes the fraction of a chemical that is absorbed through the skin. This value is not available for any of the chemicals detected. Thus, OEHHA used an ABS of one in the ADD_{der} calculation as a conservative health-protective value, with the assumption that the entire amount of chemical dissolved into the artificial sweat from crumb rubber, is transferred onto the skin and subsequently absorbed into the body.

B.4.4. Considerations for Chemicals with Reproductive and/or Developmental Endpoints

To assess the non-cancer dermal hazard from exposure to chemicals with developmental and/or reproductive adverse effects as the basis for the toxicity criteria (Main Report Section 4.5.1), referred to as DART, OEHHA estimated the average dermal one day dose for DART ($AD_{der\text{-}DART\text{-}field}$) using Equation B-13 with modification. To evaluate a one-day dermal exposure scenario for all receptors on the field, OEHHA applied mean bioaccessible dermal concentrations by individual field ($C_{der\text{-}crumb\ rubber\text{-}field}$).

OEHHA considered the average concentration across all 35 fields ($C_{der\text{-}crumb\ rubber}$) would not accurately represent a single day exposure as a receptor could not be present on each field in a single day. Instead, the individual field concentrations, which represent a single day sample collection, better reflect a single day exposure and are more appropriate for this evaluation. Additionally, instead of using an EV specific for a receptor and age group, we assumed an everyday exposure frequency, i.e., an event frequency (EV_{DART}) equal to 1 event per day. The link between the timing and duration of exposure to a special chemical during sensitive periods for susceptible sub-populations to the development of adverse effects is unknown. The assumption of an everyday EV_{DART} considers that a single exposure event may be sufficient to cause adverse effects.

B.4.5. References

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B.5. Ingestion Exposure Dose and Route-Specific Parameters

OEHHA derived an average daily dose, or exposure dose, of each chemical via ingestion of crumb rubber (ADD_{ing}). The ingestion exposure dose is a function of chemicals extracted from crumb rubber samples and intake expressed as ingestion rate. These samples contain crumb rubber, sand and broken fiber blades. We assumed ingestion of crumb rubber particles (the actual crumb rubber granules, not airborne crumb rubber dust) was the only source of chemicals for the oral exposure by direct and indirect ingestion routes. As described in Sections B3 through B5, detected Gastrointestinal (GI) bioaccessible chemicals are grouped into the general or special chemical target system groups.

For general chemicals, to estimate the ADD_{ing-} for each receptor category in an age group, we adopted the following equation:

$$ADD_{ing} = \frac{C_{GI-crumb\ rubber} \times GRAF \times IR_{daily}}{BW}$$ Equation B-16

where,

ADD_{ing} = average daily dose of a chemical via ingestion exposures to crumb rubber for a specific receptor category in an age group, milligrams per kilogram bodyweight per day

$C_{GI\text{-}crumb\ rubber}$= mean of the 35 individual field average gastrointestinal (GI) bioaccessible concentrations of a chemical from crumb rubber, $mg_{chemical}$ per $g_{crumb\ rubber}$ (Section B.5.1)

GRAF = GI relative absorption factor, unitless, default value equals 1 (Section B.5.2)

IR_{daily} = daily average of total amount of crumb rubber ingested over a year for a specific receptor category in an age group, $g_{crumb\ rubber}$ per day (Section B.5.3, Table B-110 to Table B-117)

BW = bodyweight of an age group, kilograms (Section B.2.2, Table B-2)**Gastrointestinal Biaccessible Concentration**

The gastrointestinal (GI) bioaccessible concentration of a chemical in crumb rubber ($C_{GI\text{-}crumb\ rubber}$) is a chemical-specific value measured from crumb rubber sampled in the Field Characterization Study. Main Report Section 3.2.3 and Appendix Sections D.4.1.1.5 and D.4.1.4 present details on the bioaccessibility measurements of chemicals from the crumb rubber using artificial GI biofluids. LBNL conducted the experiments to identify chemicals and measure levels which can be released upon extraction with artificial GI biofluids. This concentration ($C_{GI\text{-}crumb\ rubber}$) in Equation B-16 represents the mean of the 35 individual field average amounts of a chemical that is

available for absorption in the GI tract following ingestion of the crumb rubber (see Main Report Table 3-2).

B.5.2. Gastrointestinal Relative Absorption Factor

The GI relative absorption factor, GRAF, is a chemical-specific parameter, which represents the relative amount of a chemical absorbed by the GI tract, compared to the amount of a chemical available for exposure via ingestion. In the absence of chemical-specific information, we assumed the GRAF equal to a value of 1, or 100 percent, for all chemicals detected as a conservative health-protective assumption.

B.5.3. Ingestion Rate

The daily rate of crumb rubber ingestion, IR_{daily}, represents the total amount of crumb rubber that a receptor (athlete, coach, referee, or spectator) may swallow while present during games or practices on a synthetic turf field. It is the summation of ingestion intake via all the direct and indirect ingestion routes as shown in Equation B-17 and Equation B-18 below.

$$IR_{daily} = [(IR_{direct} \times EV) + (IR_{indirect} \times AET)] \times CF \quad \text{Equation B-17}$$

$$IR_{indirect} = IR_{HTM} + IR_{OTM} + IR_{HTOTM} \quad \text{Equation B-18}$$

where,

IR_{daily} = daily average of total amount of crumb rubber ingested over a year for a receptor category in an age group, grams crumb rubber per day

IR_{direct} = amount of crumb rubber ingested via the direct ingestion route, during an event on the field for a receptor category in an age group, grams crumb rubber per event (Section B.5.3.1)

EV = mean event frequency, or the average number of events participated on the field per year for a receptor category in an age group, events per year (Section B.2.3, Table B-8 to Table B-17)

$IR_{indirect}$ = amount of crumb rubber ingested per hour via all the indirect ingestion routes during an event for a receptor category in an age group, grams crumb rubber per hour (Section B.5.3.2)

AET = mean annual event time, or the average number of hours spent on the field per year for a receptor category in an age group, hours per year (Section B.2.5, Table B-25 to Table B-34)

CF = conversion factor, equals to 1 year per 365 days

IR_{HTM}= amount of crumb rubber indirectly ingested per hour via the hand-to-mouth (HTM) behaviors during an event for a receptor category in an age group, grams crumb rubber per hour (Section B.5.3.2.1)

IR_{OTM}= amount of crumb rubber indirectly ingested per hour via the object-to-mouth (OTM) behaviors during an event for a receptor category in an age group, grams crumb rubber per hour (Section B.5.3.2.2)

IR_{HTOTM} = amount of crumb rubber indirectly ingested per hour via the hand-to-object-to-mouth (HTOTM) behaviors during an event for a receptor category in an age group, grams crumb rubber per hour (Section B.5.3.2.3)

As described in Main Report Section 5.2.3.3, hand-to-mouth (HTM), object-to-mouth (OTM), and hand-to-object-to-mouth (HTOTM) behaviors cause indirect ingestion through carriers, which transfer chemical residues or crumb rubber particles from the field into the mouth. The Synthetic Turf Study (referred to as the Study) adopted the OEHHA guidelines (2008; 2011) for the transfer of lead from consumer products and the framework for human health assessment at Superfund sites as stated in the USEPA Risk Assessment Guidelines for Superfund (RAGS) Volume I, Human Health Evaluation Manual (Part A) (USEPA, 1989) to develop the equations of these indirect ingestion rates.

Section B.5.3.1 to B.5.3.2.3 below detail the derivation of IR_{daily} values for various receptor categories and age groups. Table B-110 to Table B-117 present the estimates of IR_{daily} from both direct and indirect ingestion routes for athletes (Table B-110 and Table B-111), coaches (Table B-112 and Table B-113), referees (Table B-115), and spectators (Table B-116 and Table B-117). IR_{daily} values are calculated by adding age and receptor-matched IR_{direct} and $IR_{indirect}$[4]. Mean, median, and 95th percentile values of indirect ingestion rate ($IR_{indirect}$, calculated in Equation B-18) are used to calculate mean, median, and 95th percentile IR_{daily} values, respectively (e.g., adopting the mean IR_{HTM}, mean IR_{OTM}, and mean IR_{HTOTM} to calculate the mean IR_{daily}). Similarly, the mean, median, and 95th percentile values of each of the indirect ingestion rate (IR_{HTM}, IR_{OTM}, and IR_{HTOTM}) are used to calculate the mean, median, and 95th percentile $IR_{indirect}$ values, respectively.

[4] For example, to calculate $IR_{daily\text{-}ing}$ for the combined gender athlete 2<6 years group, Equation 5-2 and Equation 5-3 are used.

In Equation 5-3, we summed an IR_{HTM} value of 0.006 g crumb rubber per hour (Table 5-13), an IR_{OTM} value of 0.013 g crumb rubber per hour (Table 5-23), and an IR_{HTOTM} value of 0.017 g crumb rubber per hour (Table 5-31) for a total indirect ingestion rate ($IR_{indirect}$) of 0.036 g crumb rubber per hour.

In Equation 5-2, we summed the direct ingestion rate (IR_{direct}) of 0.2 g crumb rubber per day multiplied by an event frequency (EV, Section B2.3, Table B-8) of 139 events per year and the $IR_{indirect}$ of 0.036 g crumb rubber per hour multiplied by the annual event time (AET, Section B2.5, Table B-25) of 195 hours per year for a total of 34.8 g per year. Multiplied by a conversion factor (CF) of 1 year per 365 days, the resulting daily ingestion rate for both direct and indirect ingestion routes over a year ($IR_{daily\text{-}ing}$) equals 0.09 g crumb rubber per day.

Table B-110. Synthetic Turf Study Daily Ingestion Rate for Direct and Indirect Routes (IR_{daily}, grams crumb rubber per day)—Combined Gender Athletes

Age Group	Mean	Median	95th Percentile
2<6 years	0.095	0.101	0.187
6<11 years	0.099	0.074	0.346
11<16 years	0.117	0.097	0.399
16<30 years	0.176	0.148	0.541
30<40 years	0.135	0.112	0.452
40<50 years	0.113	0.070	0.486
50<70 years	0.115	0.074	0.526

Values are rounded to three decimal places.

Table B-111. Synthetic Turf Study Daily Ingestion Rate for Direct and Indirect Routes (IR_{daily}, grams crumb rubber per day)—Female and Male Athletes

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
2<6 years	0.030	0.028	0.039	0.127	0.120	0.186
6<11 years	0.080	0.067	0.276	0.107	0.082	0.359
11<16 years	0.127	0.104	0.420	0.108	0.086	0.340
16<30 years	0.167	0.153	0.520	0.186	0.165	0.553
30<40 years	0.109	0.077	0.413	0.167	0.145	0.419
40<50 years	0.097	0.071	0.430	0.130	0.103	0.512
50<70 years	0.069	0.074	0.143	0.127	0.081	0.616

Values are rounded to three decimal places.

Table B-112. Synthetic Turf Study Daily Ingestion Rate for Direct and Indirect Routes (IR_{daily}, grams crumb rubber per day)—Combined Gender Coaches

Age Group	Mean	Median	95th Percentile
16<30 years	0.045	0.030	0.114
30<40 years	0.048	0.033	0.123
40<50 years	0.046	0.033	0.123
50<70 years	0.046	0.033	0.123

Values are rounded to three decimal places.

Table B-113. Synthetic Turf Study Daily Ingestion Rate for Direct and Indirect Routes (IR_{daily}, grams crumb rubber per day)—Female and Male Coaches

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
16<30 years	0.044	0.038	0.107	0.042	0.026	0.119
30<40 years	0.047	0.041	0.112	0.046	0.029	0.131
40<50 years	0.047	0.040	0.110	0.045	0.028	0.131
50<70 years	0.044	0.037	0.103	0.044	0.027	0.123

Values are rounded to three decimal places.

Table B-114. Synthetic Turf Study Daily Ingestion Rate for Direct and Indirect Routes (IR_{daily}, grams crumb rubber per day)—Combined Gender Referees

Age Group	Mean	Median	95th Percentile
16<30 years	0.020	0.013	0.050
30<40 years	0.021	0.014	0.054
40<50 years	0.020	0.014	0.054
50<70 years	0.020	0.014	0.054

Values are rounded to three decimal places.

Table B-115. Synthetic Turf Study Daily Ingestion Rate for Direct and Indirect Routes (IR_{daily}, grams crumb rubber per day)—Female and Male Referees

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
16<30 years	0.019	0.017	0.047	0.019	0.011	0.052
30<40 years	0.021	0.018	0.049	0.020	0.013	0.057
40<50 years	0.021	0.018	0.048	0.020	0.012	0.057
50<70 years	0.019	0.016	0.045	0.019	0.012	0.054

Values are rounded to three decimal places.

Table B-116. Synthetic Turf Study Daily Ingestion Rate for Direct and Indirect Routes (IR_{daily}, grams crumb rubber per day)—Combined Gender Spectators

Age Group	Mean	Median	95th Percentile
Third trimester fetus[a]	0.018	0.020	0.032
0<2 years	0.153	0.113	0.345
2<6 years	0.158	0.112	0.370
6<11 years	0.173	0.115	0.447
11<16 years	0.021	0.016	0.052
16<30 years	0.016	0.014	0.036
30<40 years	0.017	0.015	0.039
40<50 years	0.016	0.015	0.039
50<70 years	0.016	0.015	0.039

[a] Values are estimated using the ingestion rates for 16<40 year old females to evaluate exposure to third trimester fetuses.

Values are rounded to three decimal places.

Table B-117. Synthetic Turf Study Daily Ingestion Rate for Direct and Indirect Routes (IR_{daily}, grams crumb rubber per day)—Female and Male Spectators

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
Third trimester	0.018	0.020	0.032	Not applicable	Not applicable	Not applicable
0<2 years	0.152	0.113	0.333	0.154	0.113	0.346
2<6 years	0.158	0.111	0.371	0.158	0.112	0.369
6<11 years	0.171	0.115	0.446	0.173	0.115	0.447
11<16 years	0.027	0.020	0.058	0.013	0.010	0.027
16<30 years	0.017	0.020	0.030	0.014	0.011	0.038
30<40 years	0.018	0.022	0.032	0.016	0.012	0.042
40<50 years	0.018	0.022	0.032	0.015	0.012	0.042
50<70 years	0.016	0.019	0.030	0.015	0.012	0.039

Values are rounded to three decimal places.

B.5.3.1. Direct Ingestion Rate

For the direct ingestion route, the parameters to estimate the contribution to the daily ingestion rate (IR_{daily}) are the ingestion rate (IR_{direct}, grams crumb rubber per event) and number of events per year (EV). The data supporting the mean values for EV are already discussed in Section B.2.3.

The direct rate of ingestion (IR_{direct}, $g_{crumb\ rubber}$ per event) represents the amount of crumb rubber granules that receptors accidently or incidentally swallow while on a synthetic turf field. OEHHA assumed athletes and child spectators to have exposure through this route. This assumption is based on the Time Activity Studies (TAS) Survey data, in which the athletes reported direct ingestion is possible, but infrequent. Over 90 percent survey participants in the TAS Survey reported that less than or equal to half of the times they got crumb rubber in their mouth during games or practices (Table B-118). However, data for amount of crumb rubber ingested were not collected in the TAS Survey or measured in any published studies. OEHHA, therefore, estimated the values of IR_{direct} based on assumptions in published risk assessment reports from Europe from the (European Chemical Agency, 2017; National Institute for Public Health and the Environment, 2017).[5]

[5] The National Institute for Public Health and the Environment is commonly referred to as the “RIVM”, since in Dutch it translates to Rijksinstituut voor Volksgezondheid en Milieu.

Table B-118. Percent of Time Activity Studies Survey Participants Reporting Getting Crumb Rubber in Their Mouth during Practices or Games on a Synthetic Turf Field

Percent of Times Got Crumb Rubber in the Mouth	Practice (Total Number of Participants = 930)	Game (Total Number of Participants = 1045)
0	27	33
>0-25	49	46
>25-50	16	14
>50-75	3	2
>75	1	1
Don't Know or Prefer Not To Answer	4	3

European Studies: Estimated Direct Ingestion Values

The European studies (European Chemical Agency, 2017; National Institute for Public Health and the Environment, 2017) assessed the health risks associated with exposures to crumb rubber on synthetic turf fields and provided values on the estimated amounts of incidental ingestion of crumb rubber while on the field for athletes and child spectators. Table B-119 shows the scenarios and the estimated direct crumb rubber ingestion amount. OEHHA considered scenarios for children and adults and for competitive and recreational play relevant to our Study. From these studies, we selected the highest value of 0.2 $g_{crumb\ rubber}$ per event for the parameter IR_{direct} for athletes and child spectators, to simulate the exposure of field receptors for the Study.

Table B-119. Estimated Direct Crumb Rubber Ingestion Amount (grams crumb rubber per event)

Exposure Scenario	Direct Crumb Rubber Ingestion Amount	Reference
Adults, Worst-case, Competitive soccer play	0.01	European Chemical Agency, 2017
Children, Worst-case, Competitive soccer play	0.05	
Children ages 4-11 years, Worst-case, Recreational soccer play	0.2[a]	National Institute for Public Health and the Environment (RIVM), 2017
Goalkeepers ages >7 years, Competitive soccer play	0.2[a]	
Children 11-18 years, Worst-case, Competitive soccer play	0.05	
Adults 18-35 years, Competitive play	0.05	

[a] Selected value for the OEHHA Study.

B.5.3.2. Indirect Ingestion Rate

The indirect rate of ingestion ($IR_{indirect}$, grams crumb rubber per hour) represents the amount of crumb rubber granules that receptors might ingest from contact of a carrier (such as hands or objects) with the mouth. As seen in Equation B-18, this rate is a sum

of the ingestion rates from the HTM, OTM, and HTOTM routes. The sections below discuss how the ingestion rate for each of the three indirect ingestion routes (IR_{HTM}, IR_{HTM}, IR_{HTM}) are derived. The total $IR_{indirect}$ for athletes are presented in Table B-120 and Table B-121, for coaches in Table B-122 and Table B-123, for referees in Table B-124 and Table B-125, and for spectators in Table B-126 and Table B-127.

Table B-120. Synthetic Turf Study Indirect Ingestion Rate ($IR_{indirect}$, grams crumb rubber per hour)—Combined Gender Athletes

Age Group	Mean	Median	95th Percentile
2<6 years	0.036	0.028	0.087
6<11 years	0.047	0.036	0.105
11<16 years	0.041	0.028	0.111
16<30 years	0.039	0.028	0.104
30<40 years	0.042	0.031	0.112
40<50 years	0.041	0.031	0.111
50<70 years	0.041	0.031	0.111

Values are rounded to three decimal places.

Table B-121. Synthetic Turf Study Indirect Ingestion Rate ($IR_{indirect}$, grams crumb rubber per hour)—Female and Male Athletes

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
2<6 years	0.040	0.030	0.083	0.034	0.024	0.083
6<11 years	0.050	0.038	0.099	0.044	0.031	0.104
11<16 years	0.047	0.032	0.116	0.034	0.023	0.089
16<30 years	0.038	0.033	0.097	0.039	0.027	0.110
30<40 years	0.041	0.035	0.101	0.042	0.030	0.121
40<50 years	0.040	0.035	0.100	0.042	0.029	0.121
50<70 years	0.037	0.032	0.093	0.040	0.028	0.115

Values are rounded to three decimal places.

Table B-122. Synthetic Turf Study Indirect Ingestion Rate ($IR_{indirect}$, grams crumb rubber per hour)—Combined Gender Coaches

Age Group	Mean	Median	95th Percentile
16<30 years	0.030	0.020	0.030
30<40 years	0.032	0.022	0.032
40<50 years	0.031	0.022	0.031
50<70 years	0.031	0.022	0.031

Values are rounded to three decimal places.

Table B-123. Synthetic Turf Study Indirect Ingestion Rate ($IR_{indirect}$, grams crumb rubber per hour)—Female and Male Coaches

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
16<30 years	0.029	0.026	0.029	0.028	0.017	0.028
30<40 years	0.031	0.027	0.031	0.030	0.019	0.030
40<50 years	0.031	0.027	0.031	0.030	0.019	0.030
50<70 years	0.029	0.024	0.029	0.030	0.018	0.030

Values are rounded to three decimal places.

Table B-124. Synthetic Turf Study Indirect Ingestion Rate ($IR_{indirect}$, grams crumb rubber per hour)—Combined Gender Referees

Age Group	Mean	Median	95th Percentile
16<30 years	0.030	0.020	0.076
30<40 years	0.032	0.022	0.082
40<50 years	0.031	0.022	0.082
50<70 years	0.031	0.022	0.082

Values are rounded to three decimal places.

Table B-125. Synthetic Turf Study Indirect Ingestion Rate ($IR_{indirect}$, grams crumb rubber per hour)—Female and Male Referees

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
16<30 years	0.029	0.026	0.071	0.028	0.017	0.079
30<40 years	0.031	0.027	0.075	0.030	0.019	0.087
40<50 years	0.031	0.027	0.073	0.030	0.019	0.087
50<70 years	0.029	0.024	0.069	0.030	0.018	0.082

Values are rounded to three decimal places.

Table B-126. Synthetic Turf Study Indirect Ingestion Rate ($IR_{indirect}$, grams crumb rubber per hour)—Combined Gender Spectators

Age Group	Mean	Median	95th Percentile
Third trimester	0.016	0.019	0.029
0<2 years	0.060	0.023	0.236
2<6 years	0.064	0.022	0.259
6<11 years	0.078	0.024	0.330
11<16 years	0.019	0.015	0.047
16<30 years	0.015	0.013	0.033
30<40 years	0.016	0.014	0.036
40<50 years	0.015	0.014	0.036
50<70 years	0.015	0.014	0.036

Values are rounded to three decimal places.

Table B-127. Synthetic Turf Study Indirect Ingestion Rate ($IR_{indirect}$, grams crumb rubber per hour)—Female and Male Spectators

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
Third trimester	0.016	0.019	0.029	Not applicable	Not applicable	Not applicable
0<2 years	0.058	0.022	0.225	0.061	0.023	0.237
2<6 years	0.064	0.021	0.260	0.064	0.022	0.258
6<11 years	0.076	0.024	0.329	0.078	0.025	0.330
11<16 years	0.025	0.018	0.053	0.012	0.010	0.025
16<30 years	0.015	0.019	0.028	0.013	0.010	0.035
30<40 years	0.016	0.020	0.030	0.014	0.011	0.039
40<50 years	0.016	0.020	0.029	0.014	0.011	0.039
50<70 years	0.015	0.018	0.028	0.014	0.011	0.036

Values are rounded to three decimal places.

B.5.3.2.1. Indirect Ingestion: Hand-to-Mouth Ingestion Rate

Contributing to one of the three routes for indirect ingestion, the rate of ingestion through hand-to-mouth (HTM) behaviors, IR_{HTM}, represents the amount of crumb rubber ingested after the hand or fingers have direct contacts with crumb rubber from the field and then touch the mouth area, during an event on the field. The parameters for the calculation are shown in Equation 5-4. The mean, median, and 95th percentile values of HTM contact frequency (f_{HTM}) are used to calculate the mean, median, and 95th percentile IR_{HTM} values, respectively. The IR_{HTM} values are calculated for athletes (Table B-128 and Table B-129), coaches and referees (Table B-130 and Table B-131), spectators (Table B-132 and Table B-133).

$$IR_{HTM} = AF_{hand} \times SA_{HTM} \times TF_{HTM} \times f_{HTM} \times CF \qquad \text{Equation B-19}$$

where,

IR_{HTM} = amount of crumb rubber indirectly ingested per hour via the HTM behaviors during a field event, for a specific receptor category in an age group , grams crumb rubber per hour

AF_{hand} = crumb rubber adherence factor of the hands, the amount of crumb rubber that adheres to the skin per unit of surface area of the hands, milligrams crumb rubber per square centimeter (Section B.5.3.2.1.1)

SA_{HTM} = mean surface area of the part of the hands in direct contact with the mouth, square centimeters (Section B.5.3.2.1.2)

TF_{HTM} = fraction of the crumb rubber transferred from the part of the hands in contact with the mouth, unitless, default value equal to 0.5 (Section B.5.3.2.1.3)

f_{HTM}= frequency of HTM contacts, i.e., the number of hand touches to the mouth or peri-bucal area per hour during a field event, per hour (Section B.5.3.2.1.4)

CF = conversion factor, 0.001 grams per milligram

Table B-128. Synthetic Turf Study Hand-To-Mouth Ingestion Rate (IR_{HTM}, grams crumb rubber per hour)—Combined Gender Athletes

Age Group	Mean	Median	95th Percentile
2<6 years	0.006	0.005	0.018
6<11 years	0.009	0.007	0.024
11<16 years	0.011	0.009	0.031
16<30 years	0.013	0.011	0.037
30<40 years	0.014	0.012	0.040
40<50 years	0.014	0.012	0.039
50<70 years	0.014	0.012	0.039

Values are rounded to three decimal places.

Table B-129. Synthetic Turf Study Hand-To-Mouth Ingestion Rate (IR_{HTM}, grams crumb rubber per hour)—Female and Male Athletes

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
2<6 years	0.006	0.006	0.018	0.006	0.005	0.017
6<11 years	0.009	0.007	0.024	0.009	0.008	0.025
11<16 years	0.011	0.009	0.030	0.011	0.010	0.032
16<30 years	0.012	0.010	0.034	0.015	0.013	0.041
30<40 years	0.013	0.011	0.035	0.016	0.014	0.045
40<50 years	0.012	0.011	0.035	0.016	0.014	0.045
50<70 years	0.011	0.010	0.032	0.015	0.013	0.043

Values are rounded to three decimal places.

Table B-130. Synthetic Turf Study Hand-To-Mouth Ingestion Rate (IR_{HTM}, grams crumb rubber per hour)—Combined Gender Coaches and Referees

Age Group	Mean	Median	95th Percentile
16<30 years	0.004	0.003	0.009
30<40 years	0.004	0.003	0.010
40<50 years	0.004	0.003	0.010
50<70 years	0.004	0.003	0.010

Values are rounded to three decimal places.

Table B-131. Synthetic Turf Study Hand-To-Mouth Ingestion Rate (IR_{HTM}, grams crumb rubber per hour)—Female and Male Coaches and Referees

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
16<30 years	0.003	0.003	0.008	0.004	0.003	0.010
30<40 years	0.003	0.003	0.009	0.004	0.004	0.011
40<50 years	0.003	0.003	0.008	0.004	0.004	0.011
50<70 years	0.003	0.003	0.008	0.004	0.003	0.010

Values are rounded to three decimal places.

Table B-132. Synthetic Turf Study Hand-To-Mouth Ingestion Rate (IR_{HTM}, grams crumb rubber per hour)—Combined Gender Spectators

Age Group	Mean	Median	95th Percentile
0<2 years	0.006	0.004	0.019
2<6 years	0.008	0.005	0.029
6<11 years	0.011	0.007	0.040
11<16 years	0.003	0.003	0.007
16<30 years	0.004	0.003	0.009
30<40 years	0.004	0.003	0.010
40<50 years	0.004	0.003	0.010
50<70 years	0.004	0.003	0.010

Values are rounded to three decimal places.

Table B-133. Synthetic Turf Study Hand-To-Mouth Ingestion Rate (IR_{HTM}, grams crumb rubber per hour)—Female and Male Adult Spectators

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
Third trimester	0.003	0.003	0.008	Not applicable	Not applicable	Not applicable
0<2 years	0.005	0.004	0.019	0.006	0.004	0.019
2<6 years	0.008	0.006	0.030	0.008	0.005	0.028
6<11 years	0.011	0.007	0.039	0.011	0.008	0.040
11<16 years	0.003	0.002	0.007	0.003	0.003	0.008
16<30 years	0.003	0.003	0.008	0.004	0.003	0.010
30<40 years	0.003	0.003	0.009	0.004	0.004	0.011
40<50 years	0.003	0.003	0.008	0.004	0.004	0.011
50<70 years	0.003	0.003	0.008	0.004	0.003	0.010

Values are rounded to three decimal places.

B.5.3.2.1.1. Crumb Rubber Hand Adherence Factor

Section B.4.1.3 describes the crumb rubber adherence factors of several body parts ($AF_{body\ parts}$). Table B-109 shows the value for the crumb rubber adherence factor for the hand, AF_{hand}. In our Study, OEHHA assumed the following (Cohen Hubal *et al.*, 2005):

- uniform crumb rubber adherence across the surface of the hand

- crumb rubber loading on the hand reaching a steady level after several contacts
- the rate of transfer from subsequent hand-to-mouth contacts is less than or equal to the field-to-hand loading rate.

B.5.3.2.1.2. Hand Surface Area in Contact with Mouth

The skin surface area, SA_{HTM}, represents the surface area of the part of a hand in direct contact with the mouth. OEHHA assumed each hand contact with the mouth as four fingers of the grasping side (the palm side) of a hand. Following OEHHA guidelines (OEHHA, 2008), we estimated the grasping side of one hand to be 25 percent of the total surface area of both hands. Each finger represents 10 percent of the grasping side surface of one hand, so four fingers approximately equal to 10 percent of total surface area of both hands. To obtain SA_{HTM}, we multiplied the values of SA_{hands} for each age group and gender (described and calculated in Section B.4.1.2) by 10 percent or a value of 0.1. Table B-134 provides the values of SA_{HTM}.

Table B-134. Hand Surface Area in Contact with Mouth[a] (SA_{HTM}, square centimeters)

Age Group	Combined Gender Mean	Female Mean	Male Mean
Third trimester	Not applicable	73	Not applicable
0<2 years	26	25	26
2<6 years	38	39	37
6<11 years	53	52	53
11<16 years	67	64	70
16<30 years	80	72	89
30<40 years	86	77	98
40<50 years	85	75	97
50<70 years	85	70	93

[a] Values for hands surface area (Table B-93 to Table B-95) were multiplied by 10 percent, or a value of 0.1. Values are rounded to the nearest whole integer.

B.5.3.2.1.3. Hand-to-Mouth Transfer Factor

The HTM transfer factor, TF_{HTM}, is a unitless factor describing the fraction of the amount of crumb rubber that is transferred from the portion of the skin of the hand in contact with the mouth. Without any specific information of HTM transfer of crumb rubber from the literature, OEHHA assumed the factor to be independent of age and receptor category. We adopted a value of 0.5 for TF_{HTM} according to the OEHHA guidelines for the transfer of lead from consumer products (OEHHA, 2008; OEHHA, 2011). This value was derived from a human study (Camann *et al.*, 2000) that measured the removal of pesticides from hands.

B.5.3.2.1.4. Hand-to-Mouth Contact Frequency

The HTM contact frequency, f_{HTM}, is the number of hand touches to the mouth or peri-bucal area in an hour during a field event. The TAS Observation Study (Appendix Section F.3) collected data on f_{HTM} for athletes and young child spectators. For athletes,

our study found no differences in the values of f_{HTM} due to participant age, gender, position, or event type (i.e., practice versus game). The TAS also processed archived video footage of one- to twelve-year-old children playing outdoors on natural turf to obtain the values of f_{HTM} for child spectators (TAS Archive Study, Lopez-Galvez *et al.* (2022)). The archived data were collected in the Outdoor Residential Exposure Task Force (ORETF) and USEPA Project from 1998 to 2000 in the California Bay Area (AuYeung *et al.*, 2004; Xue *et al.*, 2007). OEHHA considered that playful behaviors on natural turf were similar to those on synthetic turf and thus, the archived video data were appropriate for estimating exposures of child spectators on synthetic turf in California. Analysis of the video footage showed no differences in f_{HTM} due to age or gender of the children. Table B-135 summarizes the values of f_{HTM} for athletes and child spectators.

OEHHA did not collect HTM contact data for adults in our TAS Observation Study. We identified two publications measuring f_{HTM} in the literature, Gorman Ng *et al.* (2016) and Wilson *et al.* (2021), and chose the values of f_{HTM} reported by Wilson *et al.* because they are more relevant and recently collected.

Gorman Ng *et al.*, 2016—Occupational Study

An observational study (Gorman Ng *et al.*, 2016) examined 48 adults during a one-hour period at eight different workplaces. The researchers recorded the values of f_{HTM} for the workers while the workers performed various tasks (such as deskwork or operating machinery) and between work tasks. The study found differences in contacts during work tasks and between work tasks. While engaged in deskwork, the assumption was that one's hands were actively engaged and not available for frequent HTM contact. Conversely, while in between tasks, one's hands were anticipated to be free and available for HTM contact, a similar situation to what one might anticipate for adult spectators in a field setting. During the between task periods, Gorman Ng et al. (2016) noted the occurrence of smoking in some workers. This type of behavior often resulted in frequent HTM contacts. Since owners of synthetic turf field prohibit smoking at the fields, OEHHA considered these f_{HTM} values not appropriate for our Study.

Wilson et al., 2021—Children and Adults Study

A more recent study (Wilson *et al.*, 2021) characterized HTM contacts of adults in various locations including sporting events. The researchers observed the eating and non-eating behaviors of 199 adult subjects for 30 minutes and noted the number of HTM contacts. There were no differences in the values of f_{HTM} between females and males, or among the various locations. While engaging in eating behaviors, however, the f_{HTM} was higher than when engaged in non-eating behaviors. During the 30-minute observation, adult subjects engaged in various eating (snacking and drinking) and non-eating (e.g., providing instruction or arbitration, or clapping and cheering) behaviors. Additionally, all of them had periods of time when the hands were idle. OEHHA chose the values of f_{HTM} observed for non-eating behaviors at sporting events (eating is

typically prohibited on synthetic turf fields) from the Wilson study as the best estimate of f_{HTM} for coaches, referees, and adult spectators (Table B-135).

Table B-135. Hand-to-Mouth Contact Frequency (f_{HTM}, per hour)

Receptor	Mean	Median	95th Percentile	Data Source
Athlete (2<70 years)	8.9	7.6	25	TAS Observation Study
Coach (16<70 years)	2.4	2.0	6	Wilson et al., 2021, non-eating behaviors at sports event
Referee (16<70 years)	2.4	2.0	6	Wilson et al., 2021, non-eating behaviors at sports event
Child Spectator (0<11 years)	11.7	7.6	41	TAS Archived Study, Lopez-Galvez et al., 2022
Adult Spectator (Third trimester, 11<70 years)	2.4	2.0	6	Wilson et al. 2021, non-eating behaviors at sports event

B.5.3.2.2. Indirect Ingestion: Object-to-Mouth Ingestion Rate

The second part of the indirect ingestion route involves object-to-mouth (OTM) ingestion. The rate of ingestion through OTM behaviors, IR_{OTM}, represents the amount of crumb rubber ingested per hour after objects come into contact with crumb rubber on the field and are then put into the mouth or touch the peri-bucal area, during an event on the field.

OEHHA calculated values of IR_{OTM} of athletes (Table B-136 and Table B-137), coaches and referees (Table B-138 and Table B-139), and child spectators (Table B-140 and Table B-141), by adopting the following equation. We anticipated negligible IR_{OTM} for adult spectators. Mean, median, and 95th percentile of frequency of OTM contacts (f_{OTM}) were used in Equation B-20 to calculate mean, median, and 95th percentile IR_{OTM} values, respectively.

$$IR_{OTM} = AF_{obj} \times SA_{obj} \times TF_{obj} \times f_{OTM} \times CF \qquad \text{Equation B-20}$$

where,

IR_{OTM} = amount of crumb rubber indirectly ingested per hour via OTM behaviors during a field event, for a specific receptor category in an age group, grams crumb rubber per hour

AF_{obj} = adherence factor of crumb rubber for an object, $mg_{crumb\ rubber}$ per cm^2 (Section B.5.3.2.2.1)

SA_{obj} = mean surface area of the part of the object in contact with the mouth, square centimeters (Section B.5.3.2.2.2)

TF_{obj} = fraction of the amount of crumb rubber transferred from the object into the mouth, unitless (Section B.5.3.2.2.3)

f_{OTM}= frequency of OTM contacts, i.e., the number of touches for an object to the mouth or peri-bucal area per hour during a field event, per hour (Section B.5.3.2.2.4)

CF = conversion factor, 0.001 grams per milligram

Table B-136. Synthetic Turf Study Object-To-Mouth Ingestion Rate (IR_{OTM}, grams crumb rubber per hour)—Combined Gender Athletes

Age Group	Mean	Median	95th Percentile
2<6 years	0.013	0.006	0.039
6<11 years	0.014	0.007	0.040
11<16 years	0.014	0.007	0.040
16<30 years	0.015	0.007	0.043
30<40 years	0.016	0.008	0.046
40<50 years	0.016	0.008	0.046
50<70 years	0.016	0.008	0.046

Values are rounded to three decimal places.

Table B-137. Synthetic Turf Study Object-To-Mouth Ingestion Rate (IR_{OTM}, grams crumb rubber per hour)—Female and Male Athletes

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
2<6 years	0.013	0.006	0.038	0.013	0.006	0.039
6<11 years	0.013	0.006	0.039	0.014	0.007	0.040
11<16 years	0.014	0.007	0.040	0.014	0.007	0.040
16<30 years	0.014	0.007	0.043	0.015	0.007	0.044
30<40 years	0.015	0.007	0.045	0.016	0.008	0.048
40<50 years	0.015	0.007	0.044	0.016	0.008	0.048
50<70 years	0.014	0.007	0.041	0.016	0.008	0.046

Values are rounded to three decimal places.

Table B-138. Synthetic Turf Study Object-To-Mouth Ingestion Rate (IR_{OTM}, grams crumb rubber per hour)—Combined Gender Coaches and Referees

Age Group	Mean	Median	95th Percentile
16<30 years	0.015	0.007	0.043
30<40 years	0.016	0.008	0.046
40<50 years	0.016	0.008	0.046
50<70 years	0.016	0.008	0.046

Values are rounded to three decimal places.

Table B-139. Synthetic Turf Study Object-To-Mouth Ingestion Rate (IR_{OTM}, grams crumb rubber per hour)—Female and Male Coaches and Referees

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
16<30 years	0.014	0.007	0.043	0.015	0.007	0.044
30<40 years	0.015	0.007	0.045	0.016	0.008	0.048
40<50 years	0.015	0.007	0.044	0.016	0.008	0.048
50<70 years	0.014	0.007	0.041	0.016	0.008	0.046

Values are rounded to three decimal places.

Table B-140. Synthetic Turf Study Object-To-Mouth Ingestion Rate (IR_{OTM}, grams crumb rubber per hour)—Combined Gender Spectators

Age Group	Mean IR_{OTM}	Median IR_{OTM}	95th Percentile IR_{OTM}
0<2 years	0.036	0.018	0.130
2<6 years	0.030	0.015	0.100
6<11 years	0.031	0.015	0.110
16<30 years	Not assessed	Not assessed	Not assessed
30<40 years	Not assessed	Not assessed	Not assessed
40<50 years	Not assessed	Not assessed	Not assessed
50<70 years	Not assessed	Not assessed	Not assessed

Values are rounded to three decimal places.

Table B-141. Synthetic Turf Study Object-To-Mouth Ingestion Rate (IR_{OTM}, grams crumb rubber per hour)—Female and Male Spectators

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
0<2 years	0.036	0.018	0.120	0.037	0.018	0.130
2<6 years	0.029	0.014	0.100	0.030	0.015	0.100
6<11 years	0.030	0.015	0.110	0.031	0.015	0.110
16<30 years	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
30<40 years	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
40<50 years	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
50<70 years	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed

Values are rounded to three decimal places.

B.5.3.2.2.1. Object Adherence Factor

The adherence factor of crumb rubber for an object, AF_{obj}, describes the amount of crumb rubber that adheres to an object after contact with the field. Many factors such as the particle size of crumb rubber, surface nature of the object (e.g., a hard surface versus a fabric surface), contact pressure (e.g., a child bouncing a ball versus an adult bouncing a ball), and the moisture content of the object and the crumb rubber (e.g., wet

versus dry surface) affect the value of AF_{obj}. OEHHA did not measure adherence factors of crumb rubber to objects in the Field Characterization Study. We anticipated toys and pacifiers to be the most common objects involved in OTM behaviors of children. These objects are often made of materials such as plastics or silicone, which have adherence properties similar to human skin surfaces (Kile *et al.*, 2016; Nicole, 2018; O'Connell *et al.*, 2014). It is for this reason that some exposure studies used silicone wristbands to simulate personal dermal exposures to environmental chemicals (Hamzai *et al.*, 2021). OEHHA assumed that:

- the material of objects on the field has similar surface properties as the skin
- crumb rubber is loaded onto the surface of objects and reaches a steady level quickly in a field event
- crumb rubber is reloaded onto the object to the steady level quickly after each OTM contact throughout the field event.

In the absence of specific data on AF_{obj}, OEHHA adopted the literature value of 0.026 milligrams crumb rubber per square centimeter per event for the adherence factor of crumb rubber for hands (AF_{hand}, Table B-109) measured by Kissel and coworkers (1996) as the value of AF_{obj}. The Kissel study is described in Section B.4.1.3.

B.5.3.2.2.2. Object Surface Area

OEHHA assumed that the surface area of the part of the object reaching the mouth, SA_{obj}, was limited by the surface area of the mouth area. These values for this parameter are age and gender specific. USEPA Exposure Factors Handbook (EFH) (2011) assumed the face to be one-third of the surface area of the head and OEHHA assumed the area around the mouth to be one-third of the face. Together, the mouth area is one-nineth of the head surface area. Thus, to estimate SA_{obj}, we divided SA_{head} (described and calculated in Section B.4.1.2, Table B-93 to Table B-95) by a factor of nine. Table B-142 provides the values of SA_{obj}.

Table B-142. Surface Area for Object-To-Mouth Behaviors[a] (SA_{obj}, square centimeters)

Age Group	Combined Gender—Mean	Female—Mean	Male—Mean
Third trimester	Not applicable	81	Not applicable
0<2 years	90	88	90
2<6 years	73	72	73
6<11 years	76	75	76
11<16 years	76	76	76
16<30 years	82	81	84
30<40 years	87	85	92
40<50 years	87	83	91
50<70 years	87	77	87

[a] Values for head surface area (Section B.4.1.2, Table B-93 to Table B-95) were divided by a factor of nine.
Table values are round to the nearest whole integers.

B.5.3.2.2.3. Object-to-Mouth Transfer Factor

The OTM transfer factor, TF_{obj}, is the fraction of the amount of crumb rubber transferred from the surface of an object into the mouth in an OTM incident. Without specific data on the correlations between the value of TF_{obj} and age or activity pattern, OEHHA assumed this factor to be the same regardless of age and receptor category. For this Study, we assumed that the surface property of the objects (e.g., silicone) involved in OTM activities was similar to the skin. Therefore, we assumed that each OTM contact transferred 50 percent of the crumb rubber adhered to the surface of the objects into the mouth, the same value as TF_{HTM} (Section B.5.3.2.1.3).

B.5.3.2.2.4. Object-to-Mouth Contact Frequency

The frequency of OTM contacts, f_{OTM}, describes the number of OTM contacts per hour during a field event. The value of f_{OTM} is specific to the age and receptor category. In the videos recorded in the TAS Observation Study (Appendix Section F.3), we collected frequency data on objects including clothes, field structures, and the soccer ball in contact with athletes' mouth and considered those activities a part of the OTM route. These objects all had the potential to interact with the field surface. We found no differences in the values of f_{OTM} for athletes based on age, gender, or event type. Neither our TAS Observation Study nor other studies in the literature collected data for the f_{OTM} of coaches, referees, or adult spectators. Since we anticipated coaches and referees to have similar contact as athletes with the soccer ball and other equipment, we considered their f_{OTM} the same as those for athletes.

Nevertheless, OEHHA assumed ingestion via OTM behavior negligible for the adult spectators. For child spectators, OEHHA obtained OTM behavior data from archived video footage of 1- to 12-years old children playing outdoors in the California Bay Area (TAS Archive Study, Lopez-Galvez *et al.* (2022), AuYeung *et al.* (2004)) and used the data to estimate the value of f_{OTM} for this group. We noted no significant differences in

the values of f_{OTM} due to age or gender of the children (Lopez-Galvez *et al.* (2022), Appendix Section F.2). We anticipated that behaviors with object-to-mouth contact on natural turf would be similar to those on synthetic turf and, therefore, we applied the archived video data to simulate exposures of children on synthetic turf. Table B-143 shows the values of f_{OTM} for child spectators.

Table B-143. Object-to-Mouth Contact Frequency (f_{OTM}, per hour)

Receptor	Mean	Median	95th Percentile	Data Source
Athletes (2<70 years)	9.7	4.7	28.6	TAS Observational Study
Coaches (16<70 years)	9.7	4.7	28.6	TAS Observational Study
Referees (16<70 years)	9.7	4.7	28.6	TAS Observational Study
Child Spectators (0<11 years)	22	11	76	TAS Archived Study, Lopez-Galvez, et al, 2022
Adult Spectators (Third trimester and 11<70 years)	Not assessed	Not assessed	Not assessed	Not assessed

B.5.3.2.3. Indirect Ingestion: Hand-to-Object-to-Mouth Ingestion Rate

The rate of ingestion through hand-to-object-to-mouth (HTOTM) behaviors, IR_{HTOTM}, represents the amount of crumb rubber ingested per hour due to the indirect transfer of particles from the field via the hand, to a carrier object, and then into the mouth when the carrier touches to or near the mouth (such as athletes touch the field surface and then handle food with their unwashed hands). To derive the mean, median, and 95th percentile values of IR_{HTOTM}, OEHHA applied Equation B-21, along with the mean, median, and 95th percentile f_{HTOTM}, respectively. We calculated the values of IR_{HTOTM} for each receptor category: athletes (Table B-144 and Table B-145), coaches and referees (Table B-146 and Table B-147), spectators (Table B-148 and Table B-149).

$$IR_{HTOTM} = AF_{hand} \times SA_{HTOTM} \times TF_{HTOTM} \times f_{HTOTM} \times CF \qquad \text{Equation B-21}$$

where,

IR_{HTOTM} = the amount of crumb rubber indirectly ingested per hour via HTOTM behaviors during a field event, for a specific receptor category in an age group, grams crumb rubber per hour

AF_{hand} = adherence factor of crumb rubber for the hand, milligrams crumb rubber per square centimeter (Section B.4.1.3)

SA_{HTOTM} = mean surface area of the part of the hand in contact with object reaching the mouth, square centimeters (Section B.5.3.2.3.2)

TF_{HTOTM} = fraction of the amount of crumb rubber transferred from the hand to an object then into the mouth, unitless (Section B.5.3.2.3.3)

f_{HTOTM}= frequency of HTOTM contacts, i.e., the number of touches for a hand to touch an object and then the object to touch the mouth or peri-bucal area per hour during a field event, per hour (Section B.5.3.2.3.4)

CF = conversion factor, 0.001 grams per milligrams

Table B-144. Synthetic Turf Study Hand-To-Object-To-Mouth Ingestion Rate (IR_{HTOTM}, grams crumb rubber per hour)—Combined Gender Athletes

Age Group	Mean	Median	95th Percentile
2<6 years	0.017	0.016	0.030
6<11 years	0.024	0.022	0.041
11<16 years	0.016	0.012	0.040
16<30 years	0.011	0.010	0.024
30<40 years	0.012	0.011	0.026
40<50 years	0.011	0.011	0.026
50<70 years	0.011	0.011	0.026

Values are rounded to three decimal places.

Table B-145. Synthetic Turf Study Hand-To-Object-To-Mouth Ingestion Rate (IR_{HTOTM}, grams crumb rubber per hour)—Female and Male Athletes

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
2<6 years	0.021	0.018	0.027	0.015	0.012	0.027
6<11 years	0.028	0.024	0.036	0.021	0.017	0.039
11<16 years	0.022	0.016	0.046	0.009	0.007	0.017
16<30 years	0.012	0.016	0.020	0.009	0.007	0.025
30<40 years	0.013	0.017	0.021	0.010	0.008	0.028
40<50 years	0.013	0.017	0.021	0.010	0.008	0.028
50<70 years	0.012	0.015	0.020	0.009	0.007	0.026

Values are rounded to three decimal places.

Table B-146. Synthetic Turf Study Hand-To-Object-To-Mouth Ingestion Rate (IR_{HTOTM}, grams crumb rubber per hour)—Combined Gender Coaches and Referees

Age Group	Mean	Median	95th Percentile
16<30 years	0.011	0.010	0.024
30<40 years	0.012	0.011	0.026
40<50 years	0.011	0.011	0.026
50<70 years	0.011	0.011	0.026

Values are rounded to three decimal places.

Table B-147. Synthetic Turf Study Hand-To-Object-To-Mouth Ingestion Rate (IR_{HTOTM}, grams crumb rubber per hour)—Female and Male Coaches and Referees

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
16<30 years	0.012	0.016	0.020	0.009	0.007	0.025
30<40 years	0.013	0.017	0.021	0.010	0.008	0.028
40<50 years	0.013	0.017	0.021	0.010	0.008	0.028
50<70 years	0.012	0.015	0.020	0.009	0.007	0.026

Values are rounded to three decimal places.

Table B-148. Synthetic Turf Study Hand-To-Object-To-Mouth Ingestion Rate (IR_{HTOTM}, grams crumb rubber per hour)—Combined Gender Spectators

Age Group	Mean	Median	95th Percentile
0<2 years	0.018	0.001	0.087
2<6 years	0.026	0.002	0.130
6<11 years	0.036	0.002	0.180
11<16 years	0.016	0.012	0.040
16<30 years	0.011	0.010	0.024
30<40 years	0.012	0.011	0.026
40<50 years	0.011	0.011	0.026
50<70 years	0.011	0.011	0.026

Values are rounded to three decimal places.

Table B-149. Synthetic Turf Study Hand-To-Object-To-Mouth Ingestion Rate (IR_{HTOTM}, grams crumb rubber per hour)—Female and Male Spectators

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
Third Trimester	0.013	0.016	0.021	Not applicable	Not applicable	Not applicable
0<2 years	0.017	0.001	0.086	0.018	0.001	0.088
2<6 years	0.027	0.002	0.130	0.026	0.001	0.130
6<11 years	0.035	0.002	0.180	0.036	0.002	0.180
11<16 years	0.022	0.016	0.046	0.009	0.007	0.017
16<30 years	0.012	0.016	0.020	0.009	0.007	0.025
30<40 years	0.013	0.017	0.021	0.010	0.008	0.028
40<50 years	0.013	0.017	0.021	0.010	0.008	0.028
50<70 years	0.012	0.015	0.020	0.009	0.007	0.026

Values are rounded to three decimal places.

B.5.3.2.3.1. Crumb Rubber Adherence Factor

For estimating the IR_{HTOTM}, the adherence factor of crumb rubber on the hands (AF_{hand}) is the same parameter used in the calculation of IR_{HTM} shown in Equation B-19. The field measured value of AF_{hand} is available from the literature (Kissel et al. 1996) and summarized in Table B-109.

B.5.3.2.3.2. Indirect Surface Area Contact

The surface area of the part of a hand in contact an object, SA_{HTOTM}, varies based on the type of HTOTM contact behavior and the receptor category. In the TAS Observation Study, OEHHA observed and quantified HTOTM behaviors of athletes on fields. We used micro-level activity time series (MLATS) data to identify the type of objects considered for this pathway of exposure and the part of the hand involved in the HTOTM contacts. OEHHA used the surface area of the hand (Table B-93 to Table B-95) to estimate the skin surface area in contact with an object.

Video data show that the objects involved in HTOTM activities for athletes were dietary objects such as water bottles and food. OEHHA assumed that contacts involved are:

- the whole hand (palm side) if eating one-handed,
- all the fingers (palm side) if eating with two hands, and
- a few fingers (palm side) if drinking from a water bottle.

These types of contact represent 25, 25, and less than or equal to 12.5 percent, respectively, of the surface area of the hands. As a conservative estimate, we assumed that all receptors used one hand (only the palm side) when eating food or drinking on the field, i.e., 25 percent of the surface area of both hands. For child spectator contacts with non-dietary objects such as toys and pacifiers, we also assumed one-hand contacts with the objects (i.e., 25 percent of the surface area of both hands). Table B-150 presents the values for SA_{HTOTM}.

Table B-150. Hand Surface Area in Contact with Dietary and Non-Dietary Objects[a] (SA_{HTOTM}, square centimeters)

Age Group	Combined Gender Mean	Female Mean	Male Mean
Third trimester	Not applicable	183	Not applicable
0<2 years	64	63	64
2<6 years	95	97	93
6<11 years	131	129	132
11<16 years	167	160	174
16<30 years	200	181	224
30<40 years	214	192	245
40<50 years	213	187	243
50<70 years	213	174	232

[a] OEHHA assumed that HTOTM with dietary and non-dietary objects involved 25 percent of the total surface area of the hands (the palm side).
Values are rounded to the nearest whole integers.

B.5.3.2.3.3. Hand-to-Object-to-Mouth Transfer Factor

The HTOTM transfer factor, TF_{HTOTM}, is a unitless factor describing the fraction of the amount of crumb rubber that is transferred from the part of the hand(s) in contact with an object, to the object, and then into the mouth. This factor is independent of age or

receptor category. Following the OEHHA guidelines (2008; 2011), we calculated the transfer factor as follows:

$$TF_{HTOTM} = TF_{HTM} \times (1 - TF_{loss})$$ Equation B-22

where,

TF_{HTOTM}= fraction of the amount of crumb rubber transferred from the portion of a hand in contact with an object and then to the mouth (i.e., HTOTM behavior), unitless

TF_{HTM}= fraction of the amount of crumb rubber transferred from the hand to the mouth via hand-to-mouth behaviors, default equals to 0.5, unitless

TF_{loss}= the fraction of crumb rubber lost from the hand prior to transfer into the mouth, unitless

The fraction of the amount of crumb rubber loading lost from the hand prior to transfer onto an object, TF_{loss}, describes the amount of crumb rubber that is lost from the hand after certain activities. The loss of crumb rubber occurs after activities such as hand washing, prior to touching the object, which eventually comes in contact with the mouth.

OEHHA guidelines (2008; 2011) recommend a value of 50 percent (factor of 0.5) for both TF_{HTM} and TF_{loss}, accounting for reduction of residues by hand washing. However under the synthetic turf scenarios, hand washing is not readily or conveniently available at a field, so we applied a TF_{loss} value of zero percent (no loss of residues) for the Study. When these values are entered into Equation B-22, the resulting value for TF_{HTOTM} is 0.5.

B.5.3.2.3.4. Hand-to-Object-to-Mouth Contact Frequency

The frequency of HTOTM contacts, f_{HTOTM}, describes the number of HTOTM contacts per an hour. Values of this parameter varies among different age group and different between genders. OEHHA applied the MLATS data of the Time-Activity Studies to estimate the value of this parameter for each age groups and receptor categories.

Analyses of the video data of 40 athletes (TAS Observation Study data for f_{HTOTM} of athletes) and archived footage of children playing on natural turf (TAS Archived Study data for f_{HTOTM} of child spectators 0<11 years) show dietary objects such as food and water bottles to be the items most commonly involved in these types of exposure. OEHHA found differences in the values of f_{HTOTM} due to the gender and age of athletes (in TAS Observation Study), but no differences by age or gender for the values of f_{HTOTM} for child spectators (in TAS Archived Study). We obtained values of f_{HTOTM} for athletes (Table B-151 and Table B-152) and child spectators aged 0<11 years (Table B-155 and Table B-156) from TAS data analyses. We, then, applied the age-specific values of f_{HTOTM} of dietary object for athletes for coaches (Table B-153 and Table B-154), referees (Table B-153 and Table B-154), and adolescent and adult spectators (Table B-155 and

Table B-156). Our studies did not collect data for coaches or referees (e.g., whistle blowing and contacts with other objects on the field) and OEHHA did not find relevant studies in the literature. We anticipated that coaches and referees held the whistles by the sides and would have very limited, if any, hand contact on the portion that goes into the mouth. Thus, coaches and referees have negligible exposures from this particular HTOTM behavior.

Table B-151. Hand-to-Object-to-Mouth Contact Frequency (f_{HTOTM}, per hour) from TAS Observation Study—Combined Gender Athletes

Age Group	Mean	Median	95th Percentile
2<6 years	9.9	9.2	16.9
6<11 years	9.9	9.2	16.9
11<16 years	5.2	3.9	13.0
16<30 years	2.9	2.8	6.6
30<40 years	2.9	2.8	6.6
40<50 years	2.9	2.8	6.6
50<70 years	2.9	2.8	6.6

Table B-152. Hand-to-Object-to-Mouth Contact Frequency (f_{HTOTM}, per hour) from TAS Observation Study —Female and Male Athletes

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
2<6 years	11.6	10.0	14.9	8.7	6.9	16.0
6<11 years	11.6	10.0	14.9	8.7	6.9	16.0
11<16 years	7.6	5.3	15.5	2.8	2.1	5.3
16<30 years	3.7	4.8	6.1	2.2	1.7	6.1
30<40 years	3.7	4.8	6.1	2.2	1.7	6.1
40<50 years	3.7	4.8	6.1	2.2	1.7	6.1
50<70 years	3.7	4.8	6.1	2.2	1.7	6.1

Table B-153. Hand-to-Object-to-Mouth Contact Frequency (f_{HTOTM}, per hour) from TAS Observation Study —Combined Gender Coaches and Referees

Age Group	Mean	Median	95th Percentile
16<30 years	2.9	2.8	6.6
30<40 years	2.9	2.8	6.6
40<50 years	2.9	2.8	6.6
50<70 years	2.9	2.8	6.6

Table B-154. Hand-to-Object-to-Mouth Contact Frequency (f_{HTOTM}, per hour) from TAS Observation Study —Female and Male Coaches and Referees

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
16<30 years	3.7	4.8	6.1	2.2	1.7	6.1
30<40 years	3.7	4.8	6.1	2.2	1.7	6.1
40<50 years	3.7	4.8	6.1	2.2	1.7	6.1
50<70 years	3.7	4.8	6.1	2.2	1.7	6.1

Table B-155. Hand-to-Object-to-Mouth Contact Frequency (f_{HTOTM}, per hour)— Combined Gender Spectators

Age Group	Mean	Median	95th Percentile	Data Source
0<11 years	14.8	0.8	74.0	TAS Archived Study
11<16 years	5.2	3.9	13.0	TAS Observation Study
16<70 years	2.9	2.8	6.6	TAS Observation Study

Table B-156. Hand-to-Object-to-Mouth Contact Frequency (f_{HTOTM}, contacts per hour) from TAS Observation Study —Female and Male Spectators

Age Group	Female Mean	Female Median	Female 95th Percentile	Male Mean	Male Median	Male 95th Percentile
Third trimester	3.7	4.8	6.1	Not applicable	Not applicable	Not applicable
0<11 years[a]	14.8	0.8	74.0	14.8	0.8	74.0
11<16 years	7.6	5.3	15.5	2.8	2.1	5.3
16<70 years	3.7	4.8	6.1	2.2	1.7	6.1

[a] No differences by age or gender for 0<11 years child spectators.

B.5.4. Considerations for Chemicals with Reproductive and/or Developmental Endpoints

To assess the non-cancer hazard from exposure to DART chemicals for ingestion exposure, OEHHA made special considerations for the GI bioaccessible chemical concentration, and duration and frequency of exposure in the estimation of the $AD_{ing\text{-}DART\text{-}field}$. Similar to the dermal pathway (described in Section B.4.4), for a one-day ingestion exposure scenario on the field, OEHHA applied average chemical concentrations by individual field ($C_{GI\text{-}crumb\ rubber\text{-}field}$). This assumption considers that an individual will be present at only one field on any day, thus an average chemical concentration value across all of the fields would not be appropriate to assess a single day exposure. As described in Sections B.3 and B.4, the susceptible period for adverse reproductive and/or developmental effects from the exposure to DART chemicals is unclear. As such OEHHA, made assumptions regarding the EV and AET used to estimate the ingestion rate for each receptor and age group in Equation B-17. First, we assumed an event frequency for assessing exposure to DART chemicals (EV_{DART}) equal to 1 event per day. Second, for the annual event time for assessing exposure to

DART chemicals (AET_{DART}), we assumed that a receptor would have either a practice or game event on every day of the week (i.e., event frequency, EV_{DART}, equal to one event per day) for all seasons. Accordingly, Equation B-2 in Section B.2.5 was modified as shown in Equation B-23. In order to estimate the total number of event hours per year (AET_{DART}) for assessing exposure to special chemicals, we multiplied the EV_{DART} by the average of the mean practice and game ET (ET_{DART}, Equation B-24).

$$AET_{DART} = EV_{DART} \times ET_{DART}$$ Equation B-23

$$ET_{DART} = \left(\frac{ET_{practice,j} + ET_{game,j}}{2}\right)$$ Equation B-24

Where,

AET_{DART} = annual event time for assessing exposure to DART on synthetic turf fields, total practice and game time, hours per day

EV_{DART} = event frequency for assessing exposure to DART, 1 event per day

ET_{DART} = event time for assessing exposure to DART, hours per event, calculated using Equation B-24

$ET_{practice,j}$ = mean event time of practices for an age group, hours per event (Section B.2.4)

$ET_{game,j}$ = mean event time of games for an age group, hours per event (Section B.2.4)

Table B-157 to Table B-159 shows the ET_{DART} calculated from the mean $ET_{practice}$ and ET_{game} for combined gender, female, and male receptors, respectively. Table B-160 to Table B-162 shows the AET_{DART} that is used in the calculation of the daily ingestion rate (IR_{DART}) for DART chemicals for combined gender, female, and male receptors, respectively.

Table B-157. Event Time (ET_{DART}, hours per event) – Combined Gender

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	2.6
0<2 years	Not applicable	Not applicable	Not applicable	2.6
2<6 years	2.9	Not applicable	Not applicable	2.6
6<11 years	2.2	Not applicable	Not applicable	2.6
11<16 years	2.3	Not applicable	Not applicable	2.6
16<30 years	3.0	3.1	3.1	2.6
30<40 years	2.6	3.1	3.1	2.6
40<50 years	2.5	3.1	3.1	2.6
50<70 years	2.5	3.1	3.1	2.6

Values are rounded to one decimal place.

Table B-158. Event Time (ET_{DART}, hours per event) – Female

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	2.6
0<2 years	Not applicable	Not applicable	Not applicable	2.6
2<6 years	6.0	Not applicable	Not applicable	2.6
6<11 years	2.2	Not applicable	Not applicable	2.6
11<16 years	2.2	Not applicable	Not applicable	2.6
16<30 years	3.0	3.1	3.1	2.6
30<40 years	2.7	3.1	3.1	2.6
40<50 years	2.5	3.1	3.1	2.6
50<70 years	2.1	3.1	3.1	2.6

Values are rounded to one decimal place.

Table B-159. Event Time (ET_{DART}, hours per event) – Male

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	Not applicable
0<2 years	Not applicable	Not applicable	Not applicable	2.6
2<6 years	1.4	Not applicable	Not applicable	2.6
6<11 years	2.3	Not applicable	Not applicable	2.6
11<16 years	2.4	Not applicable	Not applicable	2.6
16<30 years	3.0	3.1	3.1	2.6
30<40 years	2.5	3.1	3.1	2.6
40<50 years	2.5	3.1	3.1	2.6
50<70 years	2.6	3.1	3.1	2.6

Values are rounded to one decimal place.

Table B-160. Annual Event Time (AET, hours per year) for Assessing Exposure to DART – Combined Gender

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	949
0<2 years	Not applicable	Not applicable	Not applicable	949
2<6 years	1059	Not applicable	Not applicable	949
6<11 years	803	Not applicable	Not applicable	949
11<16 years	821	Not applicable	Not applicable	949
16<30 years	1077	1132	1132	949
30<40 years	949	1132	1132	949
40<50 years	894	1132	1132	949
50<70 years	894	1132	1132	949

Table values are rounded to the nearest whole integer.

Table B-161. Annual Event Time (AET_{DART}, hours per day) for Assessing Exposure to DART – Female

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	949
0<2 years	Not applicable	Not applicable	Not applicable	949
2<6 years	2190	Not applicable	Not applicable	949
6<11 years	803	Not applicable	Not applicable	949
11<16 years	803	Not applicable	Not applicable	949
16<30 years	1077	1132	1132	949
30<40 years	967	1132	1132	949
40<50 years	894	1132	1132	949
50<70 years	748	1132	1132	949

Table values are rounded to the nearest whole integer.

Table B-162. Annual Event Time (AET_{DART}, hours per day) for Assessing Exposure to DART – Male

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	Not applicable
0<2 years	Not applicable	Not applicable	Not applicable	949
2<6 years	511	Not applicable	Not applicable	949
6<11 years	840	Not applicable	Not applicable	949
11<16 years	858	Not applicable	Not applicable	949
16<30 years	1095	1132	1132	949
30<40 years	894	1132	1132	949
40<50 years	894	1132	1132	949
50<70 years	949	1132	1132	949

Table values are rounded to the nearest whole integer.

These parameters are used in a modified version of Equation 5-2 as shown below in Equation B-25. The estimated daily ingestion rates for assessing exposure to DART chemicals (IR_{DART}) are shown in Table B-163 (combined gender receptors), Table B-164 (female receptors), and Table B-165 (male receptors) and are applied to Equation B-16 to estimate the $AD_{ing\text{-}DART\text{-}field}$.

$$IR_{DART} = [(IR_{direct} \times EV_{DART}) + (IR_{indirect} \times AET_{DART})] \qquad \text{Equation B-25}$$

where,

IR_{DART} = one-day average of total amount of crumb rubber ingested over an event for a receptor category in an age group for assessing exposure to DART, grams crumb rubber per day

IR_{direct} = amount of crumb rubber ingested via the direct ingestion pathway, during an event on the field for a receptor category in an age group, grams crumb rubber per event (Section B.5.3.1)

EV_{DART} = event frequency for assessing exposure to DART, 1 event per day

$IR_{indirect}$ = amount of crumb rubber ingested per hour via all the indirect ingestion routes during an event for a receptor category in an age group, grams crumb rubber per hour

AET_{DART} = annual event time for exposure to DART on synthetic turf fields, total practice and game time, hours per day

Table B-163. Synthetic Turf Study Daily Ingestion Rate ($IR_{daily\text{-}DART}$, grams crumb rubber per day) for Assessing Exposure to DART—Combined Gender

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	0.042
0<2 years	Not applicable	Not applicable	Not applicable	0.355
2<6 years	0.305	Not applicable	Not applicable	0.367
6<11 years	0.303	Not applicable	Not applicable	0.403
11<16 years	0.292	Not applicable	Not applicable	0.049
16<30 years	0.315	0.092	0.092	0.038
30<40 years	0.309	0.099	0.099	0.041
40<50 years	0.300	0.095	0.095	0.038
50<70 years	0.300	0.095	0.095	0.038

Values are rounded to three decimal places.

Table B-164. Synthetic Turf Study Daily Ingestion Rate ($IR_{daily\text{-}DART}$, grams crumb rubber per day) for Assessing Exposure to DART—Female

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	0.042
0<2 years	Not applicable	Not applicable	Not applicable	0.352
2<6 years	0.442	Not applicable	Not applicable	0.367
6<11 years	0.309	Not applicable	Not applicable	0.398
11<16 years	0.303	Not applicable	Not applicable	0.064
16<30 years	0.312	0.091	0.091	0.040
30<40 years	0.309	0.097	0.097	0.043
40<50 years	0.298	0.097	0.097	0.042
50<70 years	0.276	0.090	0.090	0.039

Values are rounded to three decimal places.

Table B-165. Synthetic Turf Study Daily Ingestion Rate ($IR_{daily\text{-}DART}$, grams crumb rubber per day) for Assessing Exposure to DART—Male

Age Group	Athletes	Coaches	Referees	Spectators
Third trimester	Not applicable	Not applicable	Not applicable	Not applicable
0<2 years	Not applicable	Not applicable	Not applicable	0.357
2<6 years	0.248	Not applicable	Not applicable	0.366
6<11 years	0.301	Not applicable	Not applicable	0.403
11<16 years	0.280	Not applicable	Not applicable	0.031
16<30 years	0.317	0.087	0.087	0.034
30<40 years	0.303	0.094	0.094	0.037
40<50 years	0.303	0.094	0.094	0.037
50<70 years	0.305	0.091	0.091	0.035

Values are rounded to three decimal places.

B.5.5. References

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B.6. Risk Assessment Methods

For the Synthetic Turf Study (the Study), the Office of Environmental Health Hazard Assessment (OEHHA) integrated the exposure levels for soccer-related activities on synthetic turf fields (Main Report Chapter 5) with the toxicity of detected chemicals (Main Report Chapter 4) to assess the human health hazard or risk from exposures during uses of these fields. We focused on a soccer player exposure scenario. This TSD Chapter outlines methodologies applied to estimate the non-cancer hazard and cancer risk of human exposures via the single and multiple routes of exposure, i.e., inhalation, ingestion, and dermal contacts.

B.6.1. Methodology for Assessing Non-Cancer Hazard

Following the OEHHA (2012; 2015) and United States Environmental Protection Agency (USEPA)(1989; 2019) risk assessment guidelines, OEHHA assessed the non-cancer hazard of human exposure to chemicals released from synthetic turf fields using the hazard index (HI) approach. On an individual chemical basis, the hazard is defined as the hazard quotient (HQ), which is the ratio of an exposure level over the chemical specific toxicity criterion (TC) under each specific exposure scenario. While a HQ value of less than 1 suggests that adverse health effects are not expected at the specified exposure level, a HQ value of 1 or greater suggests an increased possibility of adverse health effects at the specified exposure level. The HI is the summation of the HQs of multiple chemicals (that may exhibit additive effects in a similar target organ system), exposed under multiple routes on the field, for each receptor category in a specific age group (USEPA, 1989). A HI value greater than 1 suggests that there is an increased probability for adverse effects for the specific target organ.

For this Study, we calculated the HI for three effect categories: (1) developmental or reproductive effects for one-day exposure, (2) irritation for chronic exposure, and (3) all other effects for chronic exposure. We incorporated the receptor-category specific exposure parameters (Section B.2 to B.5) to estimate exposure concentrations and exposure doses for multiple exposure routes (inhalation, dermal, and ingestion). Together with chemical TCs, the exposure concentrations and exposure dose are used to derive the values of HQ and HI. Finally, we employed the results of HI to assess and compare the non-cancer hazard for each receptor category and age group examined in the Study. The sections below describe the methodology adopted to calculate the HQ of an individual chemical exposed through each of the three exposure routes assessed in this Study and the One-day and Chronic HI exposure via multiple routes to a group of chemicals that may exhibit additive adverse health effects.

B.6.1.1. Acute Exposures

There are no established TC to support the risk assessment of acute exposures to chemicals via ingestion or dermal pathway. This section describes the assessment of non-cancer hazard for acute exposure only via inhalation pathway.

OEHHA (1999) considered acute inhalation exposure as exposure to a chemical for one hour on an intermittent basis. The toxicity criterion for acute inhalation exposure (Acute TC_{inh}) are air concentrations or exposure doses intended for assessing acute health impacts for infrequent one-hour peak exposure to chemicals in the air (maximum one-hour concentration in the air) that occurs no more than once every two weeks each year. Derivation of this category of TCs includes an assumption that the effects of each peak exposure are independent of previous exposures.

For this Study, OEHHA assessed acute non-cancer hazards of inhalation exposure to airborne chemicals on synthetic turf field by calculating an acute HQ of each chemical (Acute HQ_{inh}). We used the maximum one-hour concentration of a VOC detected in air samples collected on or off the fields, the maximum concentration of a carbonyl in air on the fields, or the maximum concentration of a SVOC in air (combined extracts of the SVOC sample train) on or off the fields during soccer drills conducted by volunteers on the fields ($C_{air\text{-}max}$, Main Report Section 5.4.1) as the acute inhalation exposure concentration, Acute C_{inh} (Equation B-4). As shown in Equation B-4, Acute C_{inh} is independent of receptor category or age. We calculated Acute HQ_{inh} according to Equation B-26 (OEHHA, 2015) below:

$$\text{Acute } HQ_{inh} = \frac{\text{Acute } C_{inh}}{\text{Acute } TC_{inh}} \qquad \text{Equation B-26}$$

where,

Acute HQ_{inh} = non-cancer hazard quotient of acute inhalation exposure to a chemical, unitless (values in Appendix Section G.2.1)

Acute C_{inh} = acute exposure concentration for inhalation exposure to a chemical in air, equal to the maximum one-hour concentration of a chemical detected in air on or off fields, during soccer activities occurring on the fields, among any of the 35 fields in the study, nanograms per cubic meter (values in Appendix Section F.4.1)

Acute TC_{inh} = acute toxicity criterion for inhalation exposure to a chemical, nanograms per cubic meter (values in Main Report Section 4.4.1, Table 4-3)

Following the calculation of Acute HQ_{inh} for each chemical in air, OEHHA derived a pathway total hazard quotient of acute inhalation exposure (Acute $HQ_{inh\text{-}sum}$) to the chemicals by summing the Acute HQ_{inh} among the individual chemicals. Same as the

Acute HQ_{inh}, the Acute $HQ_{inh\text{-}sum}$ is independent of the receptor category or age. We calculated Acute $HQ_{inh\text{-}sum}$ using Equation B-27 for acute inhalation exposure to chemicals assuming additive effects:

$$\text{Acute HQ}_{\text{inh-sum}} = \sum_{\text{chem}} \text{Acute HQ}_{\text{inh}} \qquad \text{Equation B-27}$$

where,

Acute $HQ_{inh\text{-}sum}$ = total non-cancer hazard quotient of acute inhalation exposure to chemicals in air, unitless (values in Appendix Section G.2.1)

Acute HQ_{inh} = non-cancer hazard quotient of acute inhalation exposure to a chemical, unitless (values in Section Appendix G.2.1)

B.6.1.2. One-Day and Chronic Exposures

For the purposes of assessing the non-cancer hazards from exposure to chemicals on synthetic turf fields, OEHHA divided chemicals detected in field samples into three target system groups based on the pathway-specific toxicity target systems provided in Main Report Section 4.3. One-day exposure to DART (development and/or reproductive toxicants) was assessed. For sensory irritants and general chemicals (all other effects), non-cancer hazard was assessed for chronic exposure. The following sections describe the methodology used to assess the one-day and chronic non-cancer hazards for exposure to these chemical groups via the multiple routes.

B.6.1.3. Inhalation Hazard Quotient

The DART, Sensory, and Chronic TCs are air concentrations or exposure doses developed for assessing non-cancer health impacts from short- and long-term inhalation exposure to chemicals. OEHHA assumed that an adverse health response depends on an average daily inhalation exposure dose (averaged over a year for chronic exposure) of a chemical. OEHHA assessed the hazard quotient of inhalation exposure to a chemical (One-day $HQ_{inh\text{-}DART}$ for a DART, Chronic $HQ_{inh\text{-}sensory}$ for a sensory irritant, and Chronic HQ_{inh} for a general chemical) for a receptor category in an age group using the TCs.

For one-day exposures, HQ values were calculated using individual field average concentrations detected for a VOC, a carbonyl, or a SVOC. For chronic exposures, we applied the mean of the 35 individual field average concentrations of a VOC, a carbonyl, or a SVOC in air ($C_{air\text{-}avg}$, Main Report Table 3-10) to calculate HQ values. Adjustment factors ($AF_{inh\text{-}DART}$ for DART, AF_{inh} for general chemicals, and no adjustment for sensory irritants) are used where appropriate, to calculate an adjusted one-day or chronic exposure concentration via inhalation (One-day $C_{inh\text{-}DART}$ for DART and Chronic C_{inh} for general chemicals, respectively) and the chronic exposure concentration via inhalation of a sensory irritant (Chronic $C_{inh\text{-}sensory}$). Section B.3.4 describes the calculation and the

values of the adjustment factor for each chemical group and Appendix F.4 summarizes the value of the adjusted or non-adjusted exposure concentration of each chemical.

B.6.1.3.1. One-Day Exposure to DART

For the purposes of assessing the non-cancer hazards from exposure to the class of DART (One-day $HQ_{inh\text{-}DART\text{-}field}$) in the Study, OEHHA derived the DART TC_{inh} only for the chemicals where that endpoint was the most sensitive known. We calculated One-day $HQ_{inh\text{-}DART}$ using Equation B-29 below, which contains an adjusted one-day inhalation exposure concentration of a DART ($C_{inh\text{-}DART\text{-}field}$) and the DART TC_{inh}. We modified the one-day exposure concentration of DART by adjusting for less than 24 hours per day exposure, but without adjusting for a less than everyday event frequency (Section B.3.4.2.2) using Equation B-29.

$$\text{One} - \text{Day } HQ_{inh-DART-field} = \frac{C_{air-field}}{\text{DART } TC_{inh}} \qquad \text{Equation B-28}$$

where,

One-day $HQ_{inh\text{-}DART\text{-}field}$ = non-cancer hazard quotient of one-day inhalation exposure to a DART, for a receptor category in an age group, unitless (values in Appendix Section G.2.2)

$C_{air\text{-}field}$ = adjusted one-day exposure concentration of a DART in air, nanograms per cubic meter (values in Appendix Section F.4.4)

DART TC_{inh} = one-day toxicity criterion for inhalation exposure to a DART, nanograms per cubic meter (values in Main Report Tables 4-4 and 4-5)

B.6.1.3.2. Chronic Exposure to Sensory Irritants

OEHHA developed the Sensory TCs of irritants (chemicals with sensory irritation as a critical endpoint, e.g., styrene) without time-adjusted exposure to the irritant. For the purposes of assessing non-cancer hazard quotient of inhalation exposure to the sensory irritant on synthetic turf fields (Chronic $HQ_{inh\text{-}sensory}$), OEHHA applied the non-adjusted chronic exposure concentration in air (Chronic $C_{inh\text{-}sensory}$) and the Sensory TC_{inh}. We derived the Chronic $HQ_{inh\text{-}sensory}$ of a sensory irritant for all receptor categories and age groups as follows:

$$\text{Chronic } HQ_{inh-sensory} = \frac{\text{Chronic } C_{inh-sensory}}{\text{Sensory } TC_{inh}} \qquad \text{Equation B-29}$$

where,

Chronic $HQ_{inh\text{-}sensory}$ = non-cancer hazard quotient of a sensory irritant via chronic inhalation exposure of a receptor category in an age group, unitless (values in Appendix Section G.2.3)

Chronic $C_{inh\text{-}sensory}$ = non-cancer chronic exposure concentration for a sensory irritant via inhalation pathway, nanograms per cubic meter air (values in Appendix Section F.4.5)

Sensory TC_{inh} = chronic toxicity criterion for inhalation exposure to a sensory irritant, nanograms per cubic meter (values in Main Report Table 4-6)

B.6.1.3.3. Chronic Exposure to General Chemicals

For assessing the chronic non-cancer hazard of a general chemical, OEHHA derived the Chronic $HQ_{inh\text{-}}$ using Equation B-30 below.

$$\text{Chronic HQ}_{\text{inh}} = \frac{\text{Chronic C}_{\text{inh}}}{\text{Chronic TC}_{\text{inh}}} \qquad \text{Equation B-30}$$

where,

Chronic HQ_{inh} = non-cancer hazard quotient of chronic inhalation exposure to a general chemical for a receptor category in an age group, unitless (values in Appendix Section G.2.4)

Chronic C_{inh} = adjusted chronic exposure concentration for inhalation exposure to a general chemical, nanograms per cubic meter (values in Appendix Section F.4.6)

Chronic TC_{inh} = chronic toxicity criterion for inhalation exposure to a chemical, nanograms per cubic meter (values in Main Report Tables 4-7 and 4-8)

As described above for DART, a toxicity criterion for oral exposure (Chronic TC_{oral}) may be appropriate to extrapolate for use as a Chronic TC_{inh}.

B.6.1.3.4. Inhalation Pathway Hazard Quotient

OEHHA derived a pathway total hazard quotient of inhalation exposure to each chemical group (One-day $HQ_{inh\text{-}DART\text{-}field\text{-}sum}$ for DART, Chronic $HQ_{inh\text{-}sensory\text{-}sum}$ for sensory irritants, and Chronic $HQ_{inh\text{-}sum}$ for general chemicals) for each receptor category and age group. One-day $HQ_{inh\text{-}DART\text{-}sum}$ (Chronic $HQ_{inh\text{-}sensory\text{-}sum}$ or Chronic $HQ_{inh\text{-}sum}$) is the summation of the One-day $HQ_{inh\text{-}DART}$ (Chronic $HQ_{inh\text{-}sensory}$ or Chronic HQ_{inh} respectively) for a receptor category (i.e., athletes, coaches, referees, or spectators) in an age group, through inhalation exposure of a group of chemicals that may exhibit additive effects.

For DART:

$$\text{One} - \text{day HQ}_{\text{inh}-\text{DART}-\text{sum}} = \sum_{\text{chem}} \text{One} - \text{day HQ}_{\text{inh}-\text{DART}} \qquad \text{Equation B-31}$$

For Sensory Irritants:

$$\text{Chronic HQ}_{\text{inh-sensory-sum}} = \sum_{\text{chem}} \text{Chronic HQ}_{\text{inh-sensory}} \qquad \text{Equation B-32}$$

and,

For General Chemicals:

$$\text{Chronic HQ}_{\text{inh-sum}} = \sum_{\text{chem}} \text{Chronic HQ}_{\text{inh}} \qquad \text{Equation B-33}$$

where,

One-day $HQ_{inh\text{-}DART\text{-}sum}$ = total non-cancer hazard quotient of one-day inhalation exposure to DART in air for a receptor category in an age group, unitless (values in Appendix Section G.2.2)

One-day $HQ_{inh\text{-}DART}$ = non-cancer hazard quotient of one-day inhalation exposure to a DART for a receptor category in an age group, derived from Equation B-29, unitless (values in Appendix Section G.2.2)

Chronic $HQ_{inh\text{-}sensory\text{-}sum}$ = total non-cancer hazard quotient of chronic inhalation exposure to sensory irritants in air, unitless (values in Appendix Section G.2.3)

Chronic $HQ_{inh\text{-}sensory}$ = non-cancer hazard quotient of a sensory irritant via chronic inhalation exposure , derived from Equation B-28, unitless (values in Appendix Section G.2.3)

Chronic $HQ_{inh\text{-}sum}$ = total non-cancer hazard quotient of chronic inhalation exposure to general chemicals in air for a receptor category in an age group, unitless (values in Appendix Section G.2.4)

Chronic HQ_{inh} = non-cancer hazard quotient of chronic inhalation exposure to a general chemical for a receptor category in an age group, derived from Equation B-30, unitless (values in Appendix Section G.2.4)

Subsequently, we used these pathway total hazard quotients to develop the non-cancer hazard indices of the multiroute exposure to each chemical group (One-day HI_{DART} for DART, Chronic $HI_{sensory}$ for sensory irritants, and Chronic HI for general chemicals) on synthetic turf fields for each receptor category and age group (Section B.6.1.6).

B.6.1.4. Dermal Hazard Quotient

Main Report Section 5.2.3.2 describes the dermal exposure routes. Section B4 describes quantification of the one-day and chronic dermal exposure dose on synthetic turf fields (average one day or daily dose of a chemical exposed via the dermal routes, $AD_{der\text{-}DART}$ or ADD_{der}, respectively). This section outlines the application of TCs to

evaluate the non-cancer hazard associated with dermal exposure to DART and general chemicals for the Study.

For all the chemicals detected in the dermal bioaccessibility measurements of crumb rubber collected on the fields, there are no established TCs specific for the dermal exposures. For the purposes of assessing the non-cancer hazard for dermal exposures in this Study, and according to the OEHHA Risk Assessment Guidelines (2012; 2015), OEHHA applied the one-day or chronic non-cancer TCs for ingestion exposures (DART TC_{oral} or Chronic TC_{oral}) in the non-cancer hazard assessment (Main Report Sections 4.5 and 4.6).

B.6.1.4.1. One-Day Exposure to DART

OEHHA derived TCs for the dermal exposure of DART (DART TC_{oral}) where that endpoint was the most sensitive known. We calculated One-day $HQ_{der\text{-}DART}$ using the equation below, which includes the $AD_{der\text{-}DART}$ (estimated in TSD Chapter 4, values in Appendix F.5.2) and the DART TC_{oral}.

$$\text{One} - \text{day HQ}_{\text{der}-\text{DART}} = \frac{\text{AD}_{\text{der}-\text{DART}-\text{field}}}{\text{DART TC}_{\text{oral}}} \qquad \text{Equation B-34}$$

where,

One-day $HQ_{der\text{-}DART}$ = non-cancer hazard quotient for one-day dermal exposure to a DART for a receptor category in an age group, unitless (values in Appendix Section G.5.2)

$AD_{der\text{-}DART}$ = average one day dose for dermal exposure to a DART for a receptor category in an age group, milligrams per kilogram bodyweight per day (values in Appendix Section F.5.2)

DART $TC_{oral\text{-}DART}$ = toxicity criterion for one-day oral exposure to a DART used to evaluate exposure through dermal routes, milligrams per kilogram bodyweight per day (values in Main Report Tables 4-10 and 4-11)

B.6.1.4.2. Chronic Exposure to General Chemicals

OEHHA derived hazard quotients for chronic exposure to a general chemical via the dermal routes (Chronic HQ_{der}) using the average daily dermal exposure dose of the chemical (ADD_{der}) and the Chronic TC_{oral} of the chemical. We adopted the following equation to derive Chronic HQ_{der} for a general chemical exposed via the dermal routes, for a receptor category in an age group:

$$\text{Chronic HQ}_{\text{der}} = \frac{\text{ADD}_{\text{der}}}{\text{Chronic TC}_{\text{oral}}} \qquad \text{Equation B-35}$$

where,

Chronic HQ_{der} = non-cancer hazard quotient of chronic dermal exposure to a general chemical for a receptor category in an age group, unitless (values in Appendix Section G.2.6)

ADD_{der} = average daily dose of chronic dermal exposure to a general chemical for a receptor category in an age group, milligrams per kilogram bodyweight per day (values in Appendix Section F.5.3)

Chronic TC_{oral} = toxicity criterion of a chemical exposed through the ingestion routes, milligrams per kilogram bodyweight per day (values in Main Report Tables 4-12 and 4-13)

B.6.1.4.3. Dermal Pathway Hazard Quotient

OEHHA also calculated a pathway total hazard quotient for dermal exposures (One Day $HQ_{der\text{-}DART\text{-}field\text{-}sum}$ for DART and Chronic $HQ_{der\text{-}sum}$ for general chemicals) for each receptor category in an age group. One Day $HQ_{der\text{-}DART\text{-}field\text{-}sum}$ (or Chronic $HQ_{der\text{-}sum}$) is the summation of the One Day $HQ_{der\text{-}DART}$ (or Chronic HQ_{der}) of the group of chemicals that may exhibit additive effects for each receptor category in an age group:

For DART:

$$\text{One} - \text{day HQ}_{\text{der}-\text{DART}-\text{field}-\text{sum}} = \sum_{\text{chem}} \text{One} - \text{day HQ}_{\text{der}-\text{DART}-\text{field}} \qquad \text{Equation B-36}$$

For General Chemicals:

$$\text{Chronic HQ}_{\text{der}-\text{sum}} = \sum_{\text{chem}} \text{Chronic HQ}_{\text{der}} \qquad \text{Equation B-37}$$

where,

One-day $HQ_{der\text{-}DART\text{-}field\text{-}sum}$ = total non-cancer hazard quotient for one-day dermal exposure to DART for a receptor category in an age group, unitless (values in Appendix Section G.2.5)

One-day $HQ_{der\text{-}DART\text{-}field}$ = non-cancer hazard quotient for one-day dermal exposure to a DART for a receptor category in an age group, unitless (values in Appendix Section G.2.5)

Chronic $HQ_{der\text{-}sum}$ = total non-cancer hazard quotient for chronic dermal exposure to general chemicals for a receptor category in an age group, unitless (values in Appendix Section G.2.6)

Chronic HQ_{der} = non-cancer hazard quotient for chronic dermal exposure to a general chemical for a receptor category in an age group, unitless (values in Appendix Section G.2.6)

We used these pathway total chronic hazard quotients to derive the non-cancer hazard indices of the multiroute exposure to each chemical group (One-day HI_{DART} for DART and Chronic HI for general chemicals) on synthetic turf fields for each receptor category and age group (Section B.6.1.6).

B.6.1.5. Ingestion Hazard Quotient

Main Report Section 5.2.3.3 and Section B5 describe the ingestion exposure routes and quantification of the ingestion (direct and indirect) exposure doses on synthetic turf fields (average daily dose of a chemical exposed via the ingestion routes, ADD_{ing}). This section outlines the application of one-day and chronic TCs for oral exposures (DART TC_{oral} and Chronic TC_{oral}, Main Report Sections 4.4, 4.5 and 4.6) to evaluate the one-day and chronic non-cancer hazard associated with ingestion exposures (One-day $HQ_{ing\text{-}DART\text{-}field}$ and Chronic HQ_{ing}) to bioaccessible chemicals (organic chemicals, metals and metalloids) from crumb rubber on synthetic turf fields.

B.6.1.5.1. One-Day Exposure to DART

Similar to the one-day inhalation and dermal hazard assessment for DART, OEHHA derived DART TCs (DART TC_{oral}) for the one-day oral exposure of DART where that endpoint was the most sensitive known. Since the timing and duration of the sensitive period to the adverse outcomes from exposure to reproductive or developmental toxicants is unclear, OEHHA made special assumptions for exposure frequency and duration in the estimation of the average ingestion daily exposure dose ($AD_{ing\text{-}DART}$) as described in TSD Chapter 5. We calculated One-day $HQ_{ing\text{-}DART\text{-}field}$ using Equation B-38 below.

$$\text{One} - \text{day HQ}_{\text{ing}-\text{DART}-\text{field}} = \frac{\text{AD}_{\text{ing}-\text{DART}-\text{field}}}{\text{DART TC}_{\text{oral}}} \qquad \text{Equation B-38}$$

where,

One-day $HQ_{ing\text{-}DART\text{-}field}$ = non-cancer hazard quotient for one-day ingestion exposure to a DART for a receptor category in an age group, unitless (values in Appendix Section G.2.7)

$AD_{ing\text{-}DART}$ = average one day dose for exposure of a DART through the ingestion route, for a receptor in an age group, milligrams per kilogram bodyweight per day (values in Appendix Section F.5.5)

DART TC_{oral} = oral toxicity criterion for one-day ingestion exposure to a DART, milligrams per kilogram bodyweight per day (values in Main Report Tables, 4-10, 4-11, and 4-15)

B.6.1.5.2. Chronic Exposure to General Chemicals

According to the OEHHA Risk Assessment Guidelines (2012 and 2015), OEHHA adopted the following equation to derive Chronic HQ_{ing} of a general chemical exposed via the ingestion exposure routes on synthetic turf fields for a receptor category in an age group:

$$\text{Chronic HQ}_{\text{ing}} = \frac{\text{ADD}_{\text{ing}}}{\text{Chronic TC}_{\text{oral}}} \qquad \text{Equation B-39}$$

where,

Chronic HQ_{ing} = non-cancer hazard quotient for chronic ingestion exposures to a general chemical exposed for a receptor category in an age group, unitless (values in Appendix Section G.2.8)

ADD_{ing} = average daily dose of a general chemical exposed through the ingestion routes, for a receptor in an age group, milligrams per kilogram bodyweight per day (values in Appendix Section F.5.6)

Chronic TC_{oral} = toxicity criterion for chronic ingestion exposure to a chemical, milligrams per kilogram bodyweight per day (values in Main Report Tables 4-12, 4-13, and 4-16)

B.6.1.5.3. Ingestion Pathway Hazard Quotient

OEHHA also calculated a total hazard quotient for the ingestion exposure routes (One-day $HQ_{ing\text{-}DART\text{-}field\ sum}$ for DART and Chronic $HQ_{ing\text{-}sum}$ for general chemicals) for each receptor category in an age group. One-day $HQ_{ing\text{-}DART\text{-}field\text{-}sum}$ (or Chronic $HQ_{ing\text{-}sum}$) is the summation of the One-day $HQ_{ing\text{-}DART\text{-}field}$ (or Chronic HQ_{ing}) of the group of chemicals exposed via ingestion that may exhibit additive effects:

For DART:

$$\text{One} - \text{day HQ}_{\text{ing}-\text{DART}-\text{field}-\text{sum}} = \sum_{\text{chem}} \text{One} - \text{day HQ}_{\text{ing}-\text{DART}-\text{field}} \qquad \text{Equation B-40}$$

For General Chemicals:

$$\text{Chronic HQ}_{\text{ing}-\text{sum}} = \sum_{\text{chem}} \text{Chronic HQ}_{\text{ing}} \qquad \text{Equation B-41}$$

where,

One-day $HQ_{ing\text{-}DART\text{-}field\text{-}sum}$ = total non-cancer hazard quotient for one-day ingestion exposure to DART, for a receptor category in an age group, unitless (values in Appendix Section G.2.7)

One-day $HQ_{ing\text{-}DART\text{-}field}$ = non-cancer hazard quotient for one-day ingestion exposure to a DART for a receptor category in an age group, unitless (values in Appendix Section G.2.7)

Chronic $HQ_{ing\text{-}sum}$ = total non-cancer hazard quotient for chronic ingestion exposure to general chemicals, for a receptor category in an age group, unitless (values in Appendix Section G.2.8)

Chronic HQ_{ing} = non-cancer hazard quotient for chronic ingestion exposure to a general chemical for a receptor category in an age group, unitless (values in Appendix G.2.8)

We used the pathway total One-day $HQ_{ing\text{-}DART\text{-}field\text{-}sum}$ or Chronic $HQ_{ing\text{-}sum}$, respectively, to estimate the non-cancer hazard index of the multiroute exposures to DART (One-day HI_{DART}) or general chemicals (Chronic HI) on synthetic turf fields (Section B.6.1.6).

B.6.1.6. Hazard Index for Multiroute Exposure

OEHHA assessed the non-cancer hazard of synthetic turf field users according to the OEHHA (2012; 2015) and USEPA (1986; 1989) guidelines for health risk assessment. For each receptor category in an age group, we derived a one-day HI for DART (One-day HI_{DART}), and a chronic HI for sensory irritants (Chronic $HI_{sensory}$) and general chemicals (Chronic HI) for multiroute exposures to a group of chemicals on field that may exhibit additive adverse health effects, using the equation below:

For DART:

$$\begin{aligned}\text{One} - \text{day HI}_{\text{DART}} &= \text{One} - \text{day HQ}_{\text{inh-DART-field-sum}} \\ &+ \text{One} - \text{day HQ}_{\text{der-DART-field-sum}} \\ &+ \text{One} - \text{day HQ}_{\text{ing-DART-field-sum}}\end{aligned}$$

Equation B-42

For Sensory Irritants:

$$\text{Chronic HI}_{\text{sensory}} = \text{Chronic HQ}_{\text{inh-sensory-sum}}$$

Equation B-43

For General Chemicals:

$$\begin{aligned}\text{Chronic HI} &= \text{Chronic HQ}_{\text{inh-sum}} + \text{Chronic HQ}_{\text{der-sum}} \\ &+ \text{Chronic HQ}_{\text{ing-sum}}\end{aligned}$$

Equation B-44

where,

One-day HI_{DART} = non-cancer hazard index of one-day exposure to DART through multiple routes for a receptor category in an age group, unitless (values in Appendix Section G.2.9)

One-day $HQ_{inh\text{-}DART\text{-}field\text{-}sum}$ = total non-cancer hazard quotient of one-day inhalation exposure to DART in air for a receptor category in an age group, unitless, calculated from Equation B-31 (values in Appendix Section G.2.2)

One-day $HQ_{der\text{-}DART\text{-}field\text{-}sum}$ = total non-cancer hazard quotient for one-day dermal exposures to DART for a receptor category in an age group, unitless, calculated from Equation B-36 (values in Appendix Section G.2.5)

One-day $HQ_{ing\text{-}DART\text{-}field\text{-}sum}$ = total non-cancer hazard quotient for one-day ingestion exposures to DART for a receptor category in an age group, unitless, calculated from Equation B-40 (values in Appendix Section G.2.7)

Chronic $HI_{sensory}$ = non-cancer hazard index of chronic exposure to sensory irritants exposed through inhalation for a receptor category in an age group, unitless (values in Appendix Section G.2.3)

Chronic $HQ_{inh\text{-}sensory\text{-}sum}$ = total non-cancer hazard quotient of chronic inhalation exposure to sensory irritants in air for a receptor category in an age group, unitless, calculated from Equation B-32 (values in Appendix Section G.2.3)

Chronic HI = non-cancer hazard index of general chemicals chronically exposed through multiple routes for a receptor category in an age group, unitless (values in Appendix Section G.2.10)

Chronic $HQ_{inh\text{-}sum}$ = total non-cancer hazard quotient of chronic inhalation exposure to general chemicals in air for a receptor category in an age group, unitless, calculated from Equation B-33 (values in Appendix Section G.2.4)

Chronic $HQ_{der\text{-}sum}$ = total non-cancer hazard quotient for chronic dermal exposures to general chemicals for a receptor category in an age group, unitless, calculated from Equation B-37 (values in Appendix Section G.2.6)

Chronic $HQ_{ing\text{-}sum}$ = total non-cancer hazard quotient for chronic ingestion exposures to general chemicals, for a receptor category in an age group, unitless, calculated from Equation B-41 (values in Appendix Section G.2.8)

OEHHA estimated the one-day multiroute HI of DART and chronic multiroute HI of exposures to sensory irritants and general chemicals on synthetic turf field for each

receptor category in an age group and presented further discussions of the non-cancer hazard results in Main Report Chapter 6.

B.6.2. Methodology for Assessing Cancer Risk

The USEPA Human Health Evaluation Manual (USEPA, 1989) defines cancer risk as '*the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen."* The USEPA Guideline for Carcinogen Risk Assessment (USEPA, 2005) further indicates that it is appropriate to assume a cumulative lifetime dose, or a lifetime average daily dose (LADD), as measure of dose or exposure. OEHHA risk assessment guidelines (2009; 2015) applied the same assumption on dose-response relationship between the incremental cancer risk and LADD in assessing cancer risk of exposure to chemicals. In this Study, we consider one excess cancer in a million people (10^{-6}) as an acceptable exposure level to a carcinogen.

Furthermore, OEHHA (2009) determined that the cancer potency of chemicals and thus cancer risk, varied based on lifestage at exposure. In estimating the incremental lifetime cancer risk, the OEHHA Risk Assessment Guidelines (2012) recommend applying age sensitivity factors (ASFs) to weight lifetime cancer risk (Risk) or dose (LADD) from exposures occurring early in life. In addition, to address the greater exposure on a per kilogram bodyweight that occurs early in life, the Guidelines recommend using bodyweight normalized intake rates (e.g., ingestion rate normalized to bodyweight) to calculate the ADDs, which are used to calculate the LADDs. However, these default parameter values are best suited in assessing residential exposures of environmental chemicals in traditional risk assessment studies.

In assessing the cancer risk of exposure to chemical on synthetic turf fields, OEHHA used the cancer slope factors described in the Main Report Sections 4.4.5, 4.5.3, and 4.6.3 and the LADD calculated in the Main Report Section 5.4.5. We followed our risk assessment guidelines (OEHHA, 2012; OEHHA, 2015) with modifications for the cancer risk assessment in the Synthetic Turf Study. We applied the guideline recommended age-specific ASFs (Table B-166) in the cancer risk calculations to modify the cancer potency. Considering that this Study focuses on assessing exposures of synthetic turf field users (particularly athletes), who, compared to the general population, have different intake rates (e.g., augmented breathing rate during physical exercises) and bodyweight (athletes maintain an active lifestyle and hence are less likely to be overweight compared to the general population), OEHHA applied the study-specific bodyweights, as well as age- and activity-dependent intake rates derived from the Time-Activity Studies (TAS) Survey (Section B.2.2).

Table B-166. OEHHA Recommended Age Sensitivity Factors (ASF, unitless) for Cancer Risk Assessment (OEHHA, 2009)

Age Group	Age Sensitivity Factor
Third trimester<2 years	10
2<16 years	3
16<70 years	1

This section outlines the methodology we developed to estimate the incremental lifetime cancer risk from exposures of carcinogens through the multiple routes on the synthetic turf fields.

B.6.2.1. Cancer Risk via Inhalation Exposure

OEHHA assumed that the incremental lifetime inhalation cancer risks contributed by individual chemicals in the air (and other routes) are additive, in the absence of chemical-specific information. Therefore, for each receptor category, we an incremental lifetime cancer risk from inhalation exposure to chemicals in air on the field, $Risk_{inh\text{-}sum}$, as the sum of incremental lifetime cancer risk of individual chemicals exposed through the inhalation pathway for each receptor category.

Based on the assumption that an incremental lifetime cancer risk from exposure to a chemical via inhalation is proportional to the lifetime average daily inhalation dose of the chemical ($LADD_{inh}$), OEHHA calculated the $Risk_{inh\text{-}sum}$ using the equations below:

$$Risk_{inh-sum} = \sum_{chem} [LADD_{inh} \times CSF_{inh}] \qquad \text{Equation B-45}$$

where,

$Risk_{inh\text{-}sum}$ = total lifetime incremental cancer risk from inhalation exposure to chemicals in air on the field for a receptor category, unitless (values in Appendix Section G.3.1

$LADD_{inh}$ = age-sensitivity weighted lifetime average daily dose of a chemical exposed through the inhalation pathway for a receptor category, milligrams per kilogram bodyweight per day (values in Appendix Section F.6.1)

CSF_{inh} = cancer slope factor of a chemical exposed through the inhalation pathway, (milligrams per kilogram bodyweight per day)$^{-1}$ (values in Main Report Table 4-9)

and,

$$LADD_{inh} = \sum_{age} \frac{ADD_{inh} \times ASF \times ED}{AT} \qquad \text{Equation B-46}$$

where,

ADD_{inh} = average daily dose of a chemical through inhalation exposure averaging over a year, for a receptor category in an age group, milligrams per kilogram bodyweight per day (Section B.3, values in Appendix F.5.1)

ASF = age sensitivity factor for an age group, unitless, Table B-166

ED = exposure duration of an age group, years (Section B.2.6, Table B-35)

AT = average time of a lifetime, equals for 70 years for cancer risk assessment

A lifetime average daily dose of a chemical exposure through inhalation for a receptor category, $LADD_{inh}$, is an age-sensitivity-adjusted average daily exposure dose of a chemical over a lifetime. As discussed earlier in this section, the ASF accounts for increased sensitivity to exposures occurring during early life by modifying the cancer potency (CSF) of a chemical. By including the ASF, an age group-dependent factor, in the $LADD_{inh}$ calculation, the calculation of total lifetime risk (Equation B-45) is simplified as OEHHA calculated the $LADD_{inh}$ of a chemical by adding the lifestage average daily doses across the age groups for each receptor category.

An inhalation cancer slope factor of a chemical, CSF_{inh} describes the dose-response relationship of carcinogenic effects or cancer potency of the chemical when exposed through the inhalation pathway.

B.4 and Equation B-12 describe the derivation of an average daily dose of a chemical through inhalation exposure for a receptor category in an age group, ADD_{inh}, for the estimation of inhalation exposure to carcinogens in air on the field.

Exposure duration of an age group, ED, designates the number of years an age group participated in activities on the synthetic turf fields (Section B.2.6, Table B-35). It is a non-chemical-specific or receptor-category-specific, but an age-group-specific exposure parameter.

For the purposes of assessing cancer risk from exposures to chemicals on the synthetic turf fields for each receptor category, OEHHA assumed 70 years per a lifetime for cumulative exposures to carcinogens. We averaged the $LADD_{inh}$ of a chemical over a lifetime exposure, AT, of 70 years.

B.6.2.2. Cancer Risk via Dermal Exposure

Similar to the calculation of $Risk_{inh\text{-}sum}$, OEHHA applied the same assumptions of the additivity of cancer risk from individual chemicals and the dose response relationship between incremental lifetime cancer and lifetime average daily dose for exposure through the dermal routes. We derived the cancer risks of exposure to chemicals through dermal routes, $Risk_{der\text{-}sum}$, as the summation of individual chemical cancer risk for each receptor category using the equations below:

$$\text{Risk}_{\text{der-sum}} = \sum_{\text{chem}} [\text{LADD}_{\text{der}} \times \text{CSF}_{\text{oral}}]$$ Equation B-47

where,

$\text{Risk}_{\text{der-sum}}$ = lifetime incremental cancer risk from dermal exposures to bioaccessible chemicals from the field for a receptor category, unitless (values in Appendix G.3.2)

LADD_{der} = age-sensitivity-weighted lifetime average daily dose of a chemical exposed through dermal routes for a receptor category, milligrams per kilogram bodyweight per day (values in Appendix F.6.2)

CSF_{oral} = cancer slope factor of a chemical exposure through the ingestion route and used for dermal exposure risk assessment, (milligrams per kilogram bodyweight per day)$^{-1}$ (values in Main Report Table 4-14)

and,

$$\text{LADD}_{\text{der}} = \sum_{\text{age}} \frac{\text{ADD}_{\text{der}} \times \text{ASF} \times \text{ED}}{\text{AT}}$$ Equation B-48

where,

ADD_{der} = average daily dose of a chemical through dermal exposure for a receptor category in an age group, milligrams per kilogram bodyweight per day, (described in Section B.4, values in Appendix F.5.1)

ASF = age sensitivity factor for an age group, unitless, Table B-166

ED = exposure duration of an age group, years (Section B.2.6, Table B-35)

AT = average time of a lifetime, 70 years for cancer risk assessment

A lifetime average daily dose of a chemical exposure through dermal routes for a receptor category, LADD_{der}, is an age-sensitivity-weighted lifetime daily chemical dose (accounted for increase susceptibility from exposures occurring during early in life, OEHHA (2009)) over a lifetime. OEHHA calculated a LADD_{der} of a chemical by adding the lifestage-weighted average daily doses across the age groups for each receptor category.

A cancer slope factor for oral exposure to a chemical (CSF_{oral}) describes the dose-response relationship of carcinogenic effects or cancer potency of exposures to the chemical. No dermal-specific CSFs for the bioaccessible chemicals detected in the Synthetic Turf Study are available so the ones for oral exposure were used. Main Report Section 4.2.2.3 elaborates the derivation, cancer endpoints, and adopted values of this factor.

Similar to the inhalation cancer risk, we applied age sensitivity factors to calculate a lifestage-weighted the $LADD_{der}$ for each receptor category. Table B-166 lists the values of ASF for each age group.

Secction B.4 and Equation B-13 describe the derivation of an average daily dose of a chemical through dermal exposures for a receptor category in an age group, ADD_{der}, for use in evaluating dermal exposures of bioaccessible chemicals on the field.

Both ED and AT are neither chemical nor pathway specific. However, ED is an age-group-specific exposure parameter. Section B.2 presents detailed discussion and values of these parameters.

B.6.2.3. Cancer Risk via Ingestion Exposure

Similar to the calculations of $Risk_{inh\text{-}sum}$ and $Risk_{der\text{-}sum}$, OEHHA applied the same assumptions of the additivity of cancer risk from individual chemicals and the dose response relationship between incremental lifetime cancer and lifetime average daily dose for exposure through the ingestion routes. We derived the cancer risks of exposure to chemicals through ingestion routes, $Risk_{ing\text{-}sum}$, as the summation of individual chemical cancer risk for a receptor category using the equations below:

$$Risk_{ing-sum} = \sum_{chem} [LADD_{ing} \times CSF_{oral}] \qquad \text{Equation B-49}$$

where,

$Risk_{ing\text{-}sum}$ = lifetime incremental cancer risk from ingestion exposures to bioaccessible chemicals from the field for a receptor category, unitless (values in Appendix Section G.3.3)

$LADD_{ing}$ = age-sensitivity-weighted lifetime average daily dose of a chemical exposed through ingestion routes for a receptor category, milligrams per kilogram bodyweight per day (values in Appendix Section F.6.3)

CSF_{oral} = cancer slope factor of a chemical exposed through oral ingestion and used for dermal risk assessment, (milligrams per kilogram bodyweight per day)$^{-1}$, values in Main Report Tables 4-14 and 4-17

and,

$$LADD_{ing} = \sum_{age} \frac{ADD_{ing} \times ASF \times ED}{AT} \qquad \text{Equation B-50}$$

where,

ADD_{ing} = average daily dose of a chemical through ingestion exposures for a receptor category in an age group, milligrams per kilogram bodyweight per day (Section B5, values in Appendix Section F.5.7)

ASF = age sensitivity factor for an age group, unitless, Table B-166

ED = exposure duration of an age group, years (Section B.2.6, Table B-35)

AT = average time of a lifetime, 70 years for cancer risk assessment

A lifetime average daily dose of a chemical exposure through ingestion routes for a receptor category, $LADD_{ing}$, is an age-sensitivity-weighted lifetime daily chemical dose (accounted for increase susceptibility from exposures occurring during early in life) over a lifetime. OEHHA calculated a $LADD_{ing}$ of a chemical by adding the lifestage-weighted average daily doses across the age groups for each receptor category.

An oral cancer potency factor of a chemical, CSF_{oral}, describes the dose-response relationship of carcinogenic effects or cancer potency of oral exposures to the chemical. Main Report Section 4.2.2.3 elaborates the derivation, cancer endpoints, and adopted values of this chemical-specific factor.

Similar to the inhalation and dermal cancer risks, we applied age sensitivity factors to calculate a lifestage-weighted the $LADD_{ing}$. Table B-166 lists the values of ASF for each age group.

Section B.5 and Equation B-16 describe the derivation of an average daily dose of a chemical through ingestion exposures for a receptor category in an age group, ADD_{ing}, for use in evaluating oral ingestion exposures of bioaccessible carcinogens on the field.

Both ED and AT are neither chemical nor pathway specific (Section B.2). However, ED is an age-group-specific exposure parameter. Exposure of chemicals through the three routes considered in this report share the same values of ED and AT in the respective dose and risk calculations.

B.6.2.4. Cumulative Lifetime Excess Cancer Risk for Multiroute Exposure

In considering the cumulative lifetime excess cancer risk or incremental lifetime cancer risk ($Risk_{field}$), OEHHA assumed risks from exposures to each individual pathway are additive in the absence of chemical- or pathway-specific knowledge of carcinogenic effects (USEPA, 1989; USEPA, 2005). We calculated the cumulative lifetime excess cancer risk for each receptor category using the equation below:

$$Risk_{field} = Risk_{inh-sum} + Risk_{der-sum} + Risk_{ing-sum}$$ Equation B-51

where,

$Risk_{field}$ = lifetime incremental cancer risk of chemicals through multiroute exposures for a receptor category (unitless) (values in Appendix Section G.3.4)

$Risk_{inh-sum}$ = lifetime incremental cancer risk from inhalation exposure to chemicals in the air on the field for a receptor category, unitless, calculated from Equation B-45 (values in Appendix Section G.3.1)

$Risk_{der\text{-}sum}$ = lifetime incremental cancer risk from dermal exposures to bioaccessible chemicals from the field for a receptor category, unitless, calculated from Equation B-47 (values in Appendix Section G.3.2)

$Risk_{ing\text{-}sum}$ = lifetime incremental cancer risk from ingestion exposures to bioaccessible chemicals from the field for a receptor category, unitless, calculated from Equation B-49 (values in Appendix Section G.3.3)

OEHHA estimated the lifetime excess cancer for chronic exposures to chemicals on synthetic turf field for each receptor category and presented further discussions of the cancer risk results in Main Report Chapter 7.

B.6.3. References

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