

Section 4

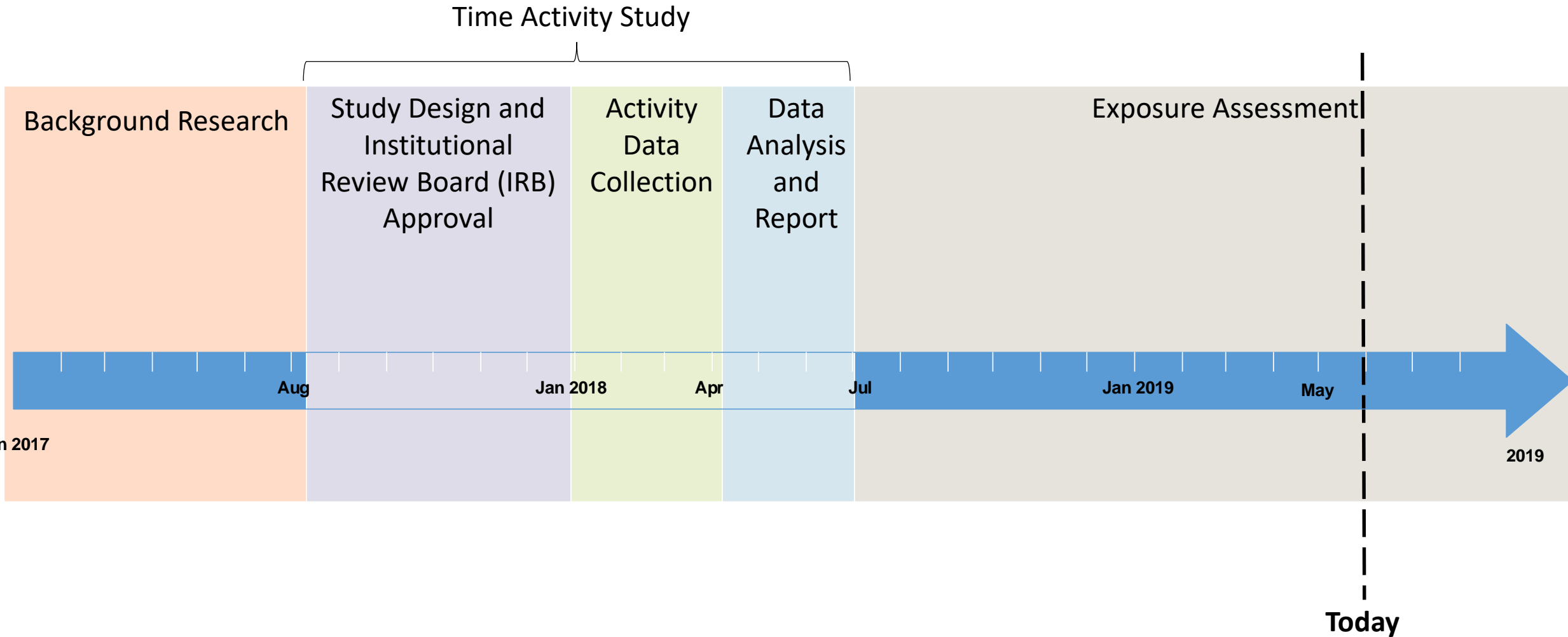
Synthetic Turf Field Exposure

Model

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Timeline of Exposure Scenario Development



Exposure Study on Soccer Players—Background

Survey

- N=1,069 participants
 - 4-71 years old
 - M/F
 - All soccer positions

Information on:

- Demographics
- Practice vs. Game
- On-field activities
- Exertion levels
- Player history
- Hygiene practices

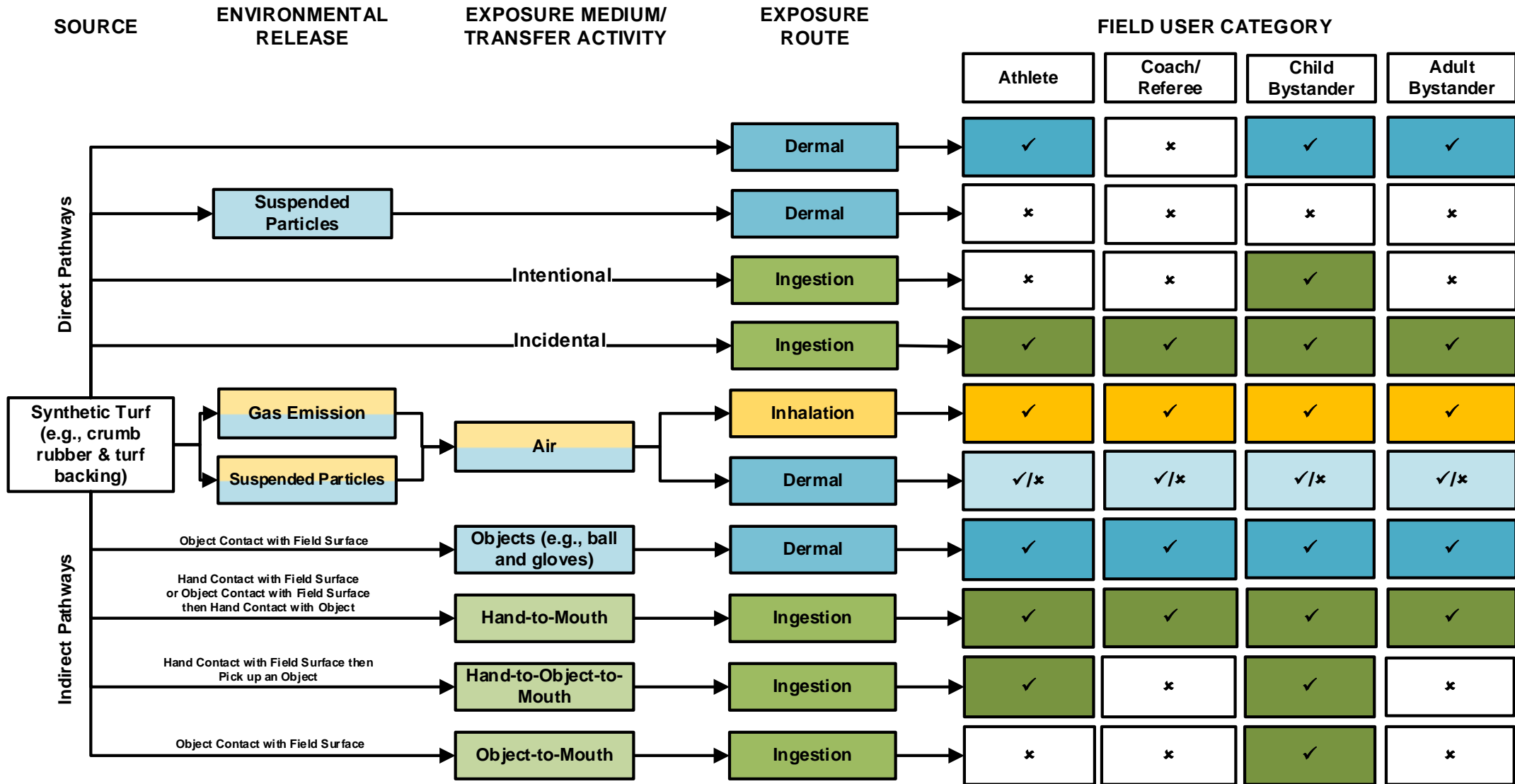
Videotaping

- N=40
 - 7-22 years old
 - M/F
 - All soccer positions
 - Practice/Game

Information on:

- Contact frequency and duration
- Exertion levels

Synthetic Turf Exposure Model



YELLOW—Inhalation Pathway
 GREEN—Ingestion Pathway
 BLUE—Dermal Pathway

✓ Complete Pathway
 x Incomplete or Negligible Pathway
 ✓/x Probably Not a Predominant Pathway



Exposure Dose: General Equation

$$\text{Dose} = \text{Concentration} \times \text{Intake Rate} \times \text{Exposure Time}$$

Parameter	Definition
Dose	Exposure dose of a chemical in a media
Concentration	Concentration of a chemical in media
Intake Rate	Intake rate of a media through an exposure pathway
Exposure Time	Duration of time for an exposure

→ **Measured in field study**

→ **Derived from literature and time activity study**

→ **Derived from time activity study**



Non-Cancer Hazard: General Equation

$$\text{HQ} = \frac{\text{Dose}_{\text{NC}}}{\text{Chronic REL}}$$

Parameter	Definition
HQ	Chronic hazard quotient of a chemical
Dose_{NC}	Non-cancer exposure dose of a chemical
Chronic REL	Chronic reference exposure level of a chemical

Cancer Risk: General Equation

$$\text{Risk} = \frac{\text{Dose}_c \times \text{CPF} \times \text{ASF} \times \text{ED}}{\text{AT}}$$

Parameter	Definition
Risk	Cancer risk of a chemical
Dose _c	Cancer exposure dose of a chemical
CPF	Cancer potency factor of a chemical
ASF	Age sensitivity factor
ED	Exposure duration
AT	Averaging time

Inhalation: Exposure Dose

Non-Cancer Exposure Concentration

$$C_{\text{air-adj}} = C_{\text{air}} \times ET \times \frac{1 \text{ day}}{24 \text{ hours}}$$

Parameter	Definition
$C_{\text{air-adj}}$	Adjusted concentration of a chemical in air for a partial day exposure, $\mu\text{g}_{\text{chemical}}/\text{m}^3$
C_{air}	Total concentration of a chemical in air, $\mu\text{g}_{\text{chemical}}/\text{m}^3$
ET	Exposure time, hours/day

→ Measured in field study

→ Derived from time activity study survey data

Inhalation: Exposure Time (Athlete)

Age Group	Season	Females					Males				
		N	Practice (Hours/day)		Game (Hours/day)		N	Practice (Hours/day)		Game (Hours/day)	
			Median	95%	Median	95%		Median	95%	Median	95%
2<6 years	Spring	0	-	-	-	-	1	0.0	-	0.0	-
	Summer		-	-	-	-		0.0	-	0.0	-
	Fall		-	-	-	-		0.0	-	0.0	-
	Winter		-	-	-	-		0.0	-	0.0	-
6<11 years	Spring	40	1.0	3.0	1.0	5.2	84	1.5	3.0	1.0	3.8
	Summer		0.1	2.0	0.0	5.3		1.0	2.8	0.4	3.8
	Fall		1.0	3.0	1.0	10.1		1.5	3.8	1.0	4.0
	Winter		1.0	2.1	0.0	2.2		1.0	4.0	0.1	3.8
11<16 years	Spring	246	1.5	3.0	1.0	4.0	250	1.5	4.0	1.0	3.0
	Summer		1.5	3.0	1.0	4.0		1.5	4.0	0.4	3.0
	Fall		1.5	3.0	1.5	4.0		1.5	4.0	1.0	4.0
	Winter		1.5	3.0	1.0	4.0		1.5	4.8	1.0	4.0
16-70 years	Spring	236	1.5	4.0	2.0	4.0	204	2.0	4.0	2.0	5.8
	Summer		1.0	4.0	1.5	5.0		2.0	4.0	1.5	4.0
	Fall		1.5	4.3	2.0	6.0		2.0	4.9	2.0	4.8
	Winter		1.0	6.0	1.5	5.0		2.0	5.0	2.0	6.0

SOURCE: Time Activity Study—Survey Data

May 31, 2019



OEHA Synthetic Turf Scientific Advisory Panel Meeting

Inhalation: Exposure Time (Coach, Referee, Bystander)

Receptor	N	Season	Practice (Hours/day)		Game (Hours/day)	
			Median	95%	Median	95%
Coach	1069	Spring	1.5	4.0	1.5	4.0
		Summer	1.5	4.0	1.0	4.0
		Fall	1.5	4.0	1.5	4.0
		Winter	1.5	4.0	1.0	4.0
Referee	1069	Spring	-	-	1.5	4.0
		Summer	-	-	1.0	4.0
		Fall	-	-	1.5	4.0
		Winter	-	-	1.0	4.0
Child Bystander	628	Spring	1.5	3.0	1.0	4.0
		Summer	1.5	3.0	1.0	3.0
		Fall	1.5	4.0	1.0	4.0
		Winter	1.5	4.0	1.0	4.0
Adult Bystander	628 (Practice)	Spring	1.5	3.0	1.5	4.0
		Summer	1.5	3.0	1.0	4.0
	1069 (Game)	Fall	1.5	4.0	1.5	4.0
		Winter	1.5	4.0	1.0	4.0

Values are based on assumptions using time activity study—survey data

SOURCE: Time Activity Study—Survey Data



Inhalation: Exposure Dose

$$\text{Dose}_{\text{inh}} = C_{\text{air}} \times A \times \sum_{\text{activity level}} \left(\frac{\text{IR}}{\text{BW}} \times \text{EL} \right) \times \text{ET} \times \text{EF} \times \text{CF}$$

Concentration
Intake Rate
Exp Time

Parameter	Definition
Dose_{inh}	Exposure dose of a chemical through inhalation, $\mu\text{g}_{\text{chemical}}/\text{kg bw-day}$
C_{air}	Total concentration of a chemical in air, $\mu\text{g}_{\text{chemical}}/\text{m}^3$
A	Inhalation absorption factor, unitless
$\frac{\text{IR}}{\text{BW}}$	Inhalation rate normalized to bodyweight for a specific activity level, L/kg bw-hour
EL	Exertion level, %
ET	Exposure time, hours/day
EF	Exposure frequency, days/365 days
CF	Conversion factor

→ Assume = 1

→ Adopted from OEHHA (2012) guidelines

Inhalation: Inhalation Rate Normalized to Bodyweight

Age group	IR/BW (L/kg BW-hr)					
	3 rd trimester	0<2 years	2<6 years	6<11 years	11<16 years	16-70 years
Sedentary & Passive Activities (Resting)						
Average	-	25	17	10	6	4
95th Percentile	-	31	23	14	8	5
Light Intensity Activities (Walking)						
Average	-	61	41	23	14	10
95th Percentile	-	75	54	32	19	13
Moderate Intensity Activities (Jogging)						
Average	21	-	76	44	28	21
95th Percentile	29	-	100	62	39	29
High Intensity Activities (Running)						
Average	-	-	140	82	55	38
95th Percentile	-	-	190	110	80	56

SOURCE: 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.



Inhalation: Exposure Dose

Cancer Exposure Dose	
$\text{Dose}_{\text{inh}} = C_{\text{air}} \times A \times \sum_{\text{activity level}} \left(\frac{\text{IR}}{\text{BW}} \times \text{EL} \right) \times \text{ET} \times \text{EF} \times \text{CF}$	

Parameter	Definition
Dose_{inh}	Exposure dose of a chemical through inhalation, $\mu\text{g}_{\text{chemical}}/\text{kg bw-day}$
C_{air}	Total concentration of a chemical in air, $\mu\text{g}_{\text{chemical}}/\text{m}^3$
A	Inhalation absorption factor, unitless
$\frac{\text{IR}}{\text{BW}}$	Inhalation rate normalized to bodyweight for a specific activity level, L/kg bw-hour
EL	Exertion level, %
ET	Exposure time, hours/day
EF	Exposure frequency, days/365 days
CF	Conversion factor

→ Derived from time activity study survey data



Inhalation: Exertion Level (Athlete)

Age Group	Activity Intensity	Females				Males					
		N	Practice (%)		Game (%)		N	Practice (%)		Game (%)	
			Median	95%	Median	95%		Median	95%	Median	95%
2<6 years	Rest	0	-	-	-	-	1	0.0	-	0.0	-
	Light		-	-	-	-		0.0	-	0.0	-
	Moderate		-	-	-	-		0.0	-	0.0	-
	High		-	-	-	-		0.0	-	0.0	-
6<11 years	Rest	40	10.0	25.3	10.0	30.0	84	6.5	20.0	10.0	29.3
	Light		15.0	31.0	10.0	45.3		10.0	30.0	10.0	34.3
	Moderate		30.0	50.0	25.0	50.0		25.0	50.0	30.0	50.0
	High		32.5	60.5	32.5	70.3		30.0	80.0	30.0	79.3
11<16 years	Rest	246	10.0	25.0	10.0	30.0	250	10.0	25.0	10.0	40.0
	Light		10.0	30.0	10.0	30.0		10.0	30.0	10.0	30.0
	Moderate		27.5	60.0	25.0	50.0		30.0	60.0	30.0	50.0
	High		30.0	75.0	40.0	80.0		30.0	70.0	40.0	77.7
16-70 years	Rest	236	10.0	20.0	10.0	30.0	204	10.0	25.0	10.0	30.0
	Light		10.0	30.0	10.0	30.0		15.0	39.3	15.0	40.0
	Moderate		30.0	60.0	30.0	60.0		30.0	55.0	30.0	55.0
	High		25.0	60.0	30.0	75.0		25.0	70.0	30.0	80.0

Rest: Sitting or standing
 Light: Walking
 Moderate: Jogging
 High: Running

SOURCE: Time Activity Study—Survey Data



Inhalation: Exertion Level (Coach, Referee, Bystander)

Receptor	Activity Intensity	Practice (%)	Game (%)
Coach	Rest	-	25
	Light	50	25
	Moderate	50	50
	High	-	-
Referee	Rest	-	25
	Light	-	25
	Moderate	-	50
	High	-	-
Child Bystander	Rest	50	50
	Light	50	50
	Moderate	-	-
	High	-	-
Adult Bystander	Rest	100	100
	Light	-	-
	Moderate	-	-
	High	-	-

Values are based on assumptions about the activity of coaches, referees, and bystanders

Rest: Sitting or standing
 Light: Walking
 Moderate: Jogging
 High: Running



Inhalation: Exposure Frequency (Athlete)

Age Group	Season	Females				Males					
		N	Practice (Days/week)		Game (Days/week)		N	Practice (Days/week)		Game (Days/week)	
			Median	95%	Median	95%		Median	95%	Median	95%
2<6 years	Spring	0	-	-	-	-	1	0.0	-	0.0	-
	Summer		-	-	-	-		0.0	-	0.0	-
	Fall		-	-	-	-		0.0	-	0.0	-
	Winter		-	-	-	-		0.0	-	0.0	-
6<11 years	Spring	40	1.0	3.0	1.0	4.0	84	1.0	3.0	1.0	3.0
	Summer		0.3	2.1	0.0	2.0		1.0	3.0	1.0	4.8
	Fall		1.0	3.0	1.0	2.1		1.0	3.0	1.0	3.0
	Winter		1.0	2.1	0.0	2.0		1.0	3.0	0.8	2.0
11<16 years	Spring	246	2.0	4.0	1.0	3.0	250	2.0	4.0	1.0	3.0
	Summer		1.0	4.0	1.0	3.0		1.0	4.0	0.8	2.0
	Fall		2.0	4.0	1.0	3.0		2.0	4.0	1.0	3.0
	Winter		2.0	5.0	1.0	3.0		2.0	5.0	1.0	2.5
16-70 years	Spring	236	2.0	4.3	1.0	4.0	204	2.0	5.0	1.0	4.0
	Summer		1.0	4.0	1.0	3.0		2.0	5.0	1.0	3.0
	Fall		2.0	5.0	2.0	4.3		2.0	6.0	1.3	3.8
	Winter		2.0	5.0	2.0	4.0		2.0	6.0	2.0	4.0

SOURCE: Time Activity Study—Survey Data



Inhalation: Exposure Frequency (Coach, Referee, Bystander)

Receptor	N	Season	Practice (Days/week)		Game (Days/week)	
			Median	95%	Median	95%
Coach	1069	Spring	2.0	4.0	1.0	3.0
		Summer	1.0	4.0	1.0	3.0
		Fall	2.0	5.0	1.0	3.0
		Winter	2.0	5.0	1.0	3.0
Referee	1069	Spring	-	-	1.0	3.0
		Summer	-	-	1.0	3.0
		Fall	-	-	1.0	3.0
		Winter	-	-	1.0	3.0
Child Bystander	628	Spring	2.0	4.0	1.0	3.0
		Summer	1.0	3.6	1.0	3.0
		Fall	2.0	4.0	1.0	3.0
		Winter	2.0	5.0	1.0	3.0
Adult Bystander	628 (practice) 1069 (Game)	Spring	2.0	4.0	1.0	3.0
		Summer	1.0	3.6	1.0	3.0
		Fall	2.0	4.0	1.0	3.0
		Winter	2.0	5.0	1.0	3.0

Values are based on assumptions using time activity study—survey data

SOURCE: Time Activity Study—Survey Data



Discussion



Ingestion: Exposure Dose

Non-Cancer Exposure Dose	Cancer Exposure Dose
$\text{Dose}_{\text{NC-ing}} = \frac{C_{\text{crumb rubber}} \times \text{GRAF} \times \frac{\text{Ing}}{\text{BW}} \times \text{ED}}{\text{AT}}$	$\text{Dose}_{\text{C-ing}} = C_{\text{Crumb rubber}} \times \text{GRAF} \times \frac{\text{Ing}}{\text{BW}} \times \text{ET} \times \text{EF} \times \text{CF}$
<p style="text-align: center;"> Concentration Intake Rate Exp Time </p>	<p style="text-align: center;"> Concentration Intake Rate Exp Time </p>

Parameter	Definition
Dose NC-ing/ Dose C-ing	Exposure dose of a chemical from ingestion of crumb rubber, $\text{mg}_{\text{chemical}}/\text{kg BW-day}$
$C_{\text{crumb rubber}}$	Oral bioaccessible concentration of a chemical from crumb rubber, $\text{mg}_{\text{chemical}}/\text{g}_{\text{crumb rubber}}$
GRAF	Gastrointestinal relative absorption factor, unitless
$\frac{\text{Ing}}{\text{BW}}$	Ingestion rate normalized to bodyweight, $\text{g}_{\text{crumb rubber}}/\text{kg BW-day}$
ED	Exposure duration, years
AT	Averaging time, years
ET	Exposure time, hours/day
EF	Exposure frequency, days/week
CF	Conversion factor

- Measured in field study
- Assume = 1
- Sum of ingestion rates for all direct and indirect ingestion pathways



Ingestion: Ingestion Rate

$$\frac{\text{Ing}}{\text{BW}} = \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$$

← Sum of ingestion rates for all direct and indirect ingestion pathways

Parameter	Definition
$\frac{\text{Ing}}{\text{BW}}$	Ingestion rate normalized to bodyweight for direct and indirect ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}}$	Ingestion rate normalized to bodyweight for direct ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}}$	Ingestion rate normalized to bodyweight for HTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}}$	Ingestion rate normalized to bodyweight for OTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$	Ingestion rate normalized to bodyweight for HTOTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$

→ Derived from literature values and anecdotal evidence

Ingestion: Direct Ingestion Rate

$$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}} = \frac{\text{Ingestion Amount}}{\text{Bodyweight}}$$

Ingestion Amount

Receptor	0.01 g/day	0.05 g/day	0.2 g/day	3.55 g/day	10.40 g/day
Athlete	✓	✓	✓	✓	✓
Coach	✓	✓			
Referee	✓	✓			
Child Bystander	✓	✓	✓	✓	
Adult Bystander					

SOURCE: (1) RIVM (2017). Evaluation of health risks of playing sports on synthetic turf pitches with rubber granulate - scientific background document. (2) ECHA (2017). Annex xv report: An evaluation of the possible health risks of recycled rubber granules used as infill in synthetic turf sports fields. (3) Anecdotal evidence

Bodyweight

Age Group	Mean BW (kg)
0 to <2 years	9.7
2 to <9 years	21.9
9 to <16 years	37
16 to 70 years	80

SOURCE: OEHHA (2012)

Ingestion: Ingestion Rate

$$\frac{\text{Ing}}{\text{BW}} = \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$$

← Sum of ingestion rates for all direct and indirect ingestion pathways

Parameter	Definition
$\frac{\text{Ing}}{\text{BW}}$	Ingestion rate normalized to bodyweight for direct and indirect ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}}$	ingestion rate normalized to bodyweight for direct ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}}$	ingestion rate normalized to bodyweight for HTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}}$	ingestion rate normalized to bodyweight for OTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$	ingestion rate normalized to bodyweight for HTOTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$

→ Derived from time activity study video data and the literature



Ingestion: Hand-to-Mouth Ingestion Rate

$$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}} = \frac{\text{AF}_{\text{hand}} \times \text{SA}_{\text{D}} \times \text{TF}_{\text{direct}} \times \lambda_{\text{HTM}} \times \text{CF1} \times \text{CF2}}{\text{BW}}$$

Parameter	Definition
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}}$	Ingestion rate normalized to body via HTM ingestion pathway, $\text{g}_{\text{crumb rubber}}/\text{kg BW-day}$
AF_{hand}	Adherence factor of crumb rubber for the hand, $\text{mg}_{\text{crumb rubber}}/\text{cm}^2$
SA_{D}	Surface area of the part of the hand in direct contact with the mouth, cm^2
$\text{TF}_{\text{direct}}$	Fraction of the crumb rubber transferred from a specific part hand in contact with the mouth, unitless
λ_{HTM}	Number of HTM contacts per hour
CF1, CF2	Conversion factor
BW	Body Weight, kg

→ Adopted from literature data

→ Derived from US EPA (2011) data for the surface area of both hands

Assume 4 fingers (10% of surface area of both hands) to contact mouth

Ingestion: Hand-to-Mouth Ingestion Rate

$$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}} = \frac{\text{AF}_{\text{hand}} \times \text{SA}_{\text{D}} \times \text{TF}_{\text{direct}} \times \lambda_{\text{HTM}} \times \text{CF1} \times \text{CF2}}{\text{BW}}$$

Parameter	Definition
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}}$	Ingestion rate normalized to body via HTM ingestion pathway, $\text{g}_{\text{crumb rubber}}/\text{kg BW-day}$
AF_{hand}	Adherence factor of crumb rubber for the hand, $\text{mg}_{\text{crumb rubber}}/\text{cm}^2$
SA_{D}	Surface area of the part of the hand in direct contact with the mouth, cm^2
$\text{TF}_{\text{direct}}$	Fraction of the crumb rubber transferred from a specific part hand in contact with the mouth, unitless
λ_{HTM}	Number of HTM contacts per hour
CF1, CF2	Conversion factor
BW	Body Weight, kg

OEHHA (2008). Proposition 65 interpretive guideline no. 2008-001. Guideline for hand-to-mouth transfer of lead through exposure to fishing tackle products. Sacramento, CA, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

OEHHA (2011). Proposition 65 interpretive guideline no. 2011-001. Guideline for hand-to-mouth transfer through lead exposure to consumer products. Sacramento, CA, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

→ Adopted from OEHHA (2008, 2011) guidelines
Assume $\text{TF}_{\text{direct}} = 0.50$

→ Derived from time activity study video data and literature values

Ingestion: AF_{hand} , SA_D , λ_{HTM}

Surface Area Of The Part Of The Hand In Direct Contact With The Mouth

Gender	Age Group	SA_D (cm ²)	
		Median	95%
Females	0<2 years	25	29
	2<9 years	42	59
	9<16 years	60	81
	16-70 years	90	114
Males	0<2 years	26	30
	2<9 years	43	58
	9<16 years	61	82
	16-70 years	103	124
Combined	0<2 years	26	29
	2<9 years	43	58
	9<16 years	60	81
	16-70 years	96	120

SOURCE: USEPA (2011). Exposure factors handbook: 2011 edition. Washington, D.C., Office of Research and Development, U.S. Environmental Protection Agency.

Adherence Factor Of Crumb Rubber For The Hand

Body Part	AF_{hand} (mg/cm ²)
Hands	0.037

SOURCE: Kissel JC, Richter KY and Fenske RA (1996). Field measurement of dermal soil loading attributable to various activities: Implications for exposure assessment. Risk Anal 16(1): 115-125.

Hand-To-Mouth Contacts Per Hour

Receptor	λ_{HTM} (Contacts/Hour)		
	N	Median	95%
Athlete	40	7.6	18.4
Coach	55	18.0	-
Referee	55	18.0	-
Child Bystander	56	7.6	41.0
Adult Bystander	55	18.0	-

Time Activity Study—Video Data



Ingestion: Ingestion Rate

$$\frac{\text{Ing}}{\text{BW}} = \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$$

← Sum of ingestion rates for all direct and indirect ingestion pathways

Parameter	Definition
$\frac{\text{Ing}}{\text{BW}}$	Ingestion rate normalized to bodyweight for direct and indirect ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}}$	Ingestion rate normalized to bodyweight for direct ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}}$	Ingestion rate normalized to bodyweight for HTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}}$	Ingestion rate normalized to bodyweight for OTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$	Ingestion rate normalized to bodyweight for HTOTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$

→ Derived from time activity study video data and the literature

Ingestion: Object-to-Mouth Ingestion Rate

$$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}} = \frac{\text{AF}_{\text{obj}} \times \text{SA}_{\text{D obj}} \times \text{TF}_{\text{obj}} \times \lambda_{\text{OTM}} \times \text{CF1} \times \text{CF2}}{\text{BW}}$$

Parameter	Definition
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}}$	Ingestion rate normalized to bodyweight for OTM activity, $\text{g}_{\text{crumb rubber}}/\text{kg BW-day}$
AF_{obj}	Adherence factor of crumb rubber for an object, $\text{mg}_{\text{crumb rubber}}/\text{cm}^2$
SA_{obj}	Surface area of the part of the object reaching the mouth, cm^2
TF_{obj}	Fraction of the amount of crumb rubber transferred from the object into the mouth, unitless
λ_{OTM}	Number of OTM contacts per hour
CF1, CF2	Conversion factor
BW	Body Weight, kg

→ Assume = to AF_{hand}

→ Derived from US EPA (2011) data for the surface area of the head

Assume the mouth area is 1/9 of the surface area of the head

Ingestion: Object-to-Mouth Ingestion Rate

$$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}} = \frac{\text{AF}_{\text{obj}} \times \text{SA}_{\text{D}} \times \text{TF}_{\text{obj}} \times \lambda_{\text{OTM}} \times \text{CF1} \times \text{CF2}}{\text{BW}}$$

Parameter	Definition
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}}$	Ingestion rate normalized to bodyweight for OTM activity, $\text{g}_{\text{crumb rubber}}/\text{kg BW-day}$
AF_{obj}	Adherence factor of crumb rubber for an object, $\text{mg}_{\text{crumb rubber}}/\text{cm}^2$
SA_{obj}	Surface area of the part of the object reaching the mouth, cm^2
TF_{obj}	Fraction of the amount of crumb rubber transferred from the object into the mouth, unitless
λ_{OTM}	Number of OTM contacts per hour
CF1, CF2	Conversion factor
BW	Body Weight, kg

→ Adopted from OEHHA (2008, 2011) guidelines

Assume $\text{TF}_{\text{obj}} = 1$

→ Derived from time activity study video data

Ingestion: λ_{OTM} , SA_{obj}

Surface Area Of The Part Of The Object Reaching The Mouth

Gender	Age Group	SA_{obj} (cm ²)	
		Median	95%
Females	0<2 years	88	100
	2<9 years	69	96
	9<16 years	77	104
Males	0<2 years	90	104
	2<9 years	70	94
	9<16 years	79	106

SOURCE: Calculated using data on the surface of the head from USEPA (2011)

Object-To-Mouth Contacts Per Hour

Receptor	N	λ_{OTM} (contacts/hour)	
		Median	95%
Child Bystander	56	10.87	76.19

SOURCE: Time Activity Study—Video Data

Ingestion: Ingestion Rate

$$\frac{\text{Ing}}{\text{BW}} = \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$$

← Sum of ingestion rates for all direct and indirect ingestion pathways

Parameter	Definition
$\frac{\text{Ing}}{\text{BW}}$	Ingestion rate normalized to bodyweight for direct and indirect ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}}$	Ingestion rate normalized to bodyweight for direct ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}}$	Ingestion rate normalized to bodyweight for HTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}}$	Ingestion rate normalized to bodyweight for OTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$	Ingestion rate normalized to bodyweight for HTOTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$

→ Derived from time activity study video data and the literature



Ingestion: Hand-to-Object-to-Mouth Ingestion Rate

$$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}} = \frac{\text{AF}_{\text{hand}} \times \text{SA}_I \times \text{TF}_{\text{indirect}} \times \lambda_{\text{HTOTM}} \times \text{CF1} \times \text{CF2}}{\text{BW}}$$

Parameter	Definition
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$	Ingestion rate normalized to bodyweight for HTOTM activity, $\text{g}_{\text{crumb rubber}}/\text{kg BW-day}$
AF_{hand}	Adherence factor of crumb rubber for the hand, $\text{mg}_{\text{crumb rubber}}/\text{cm}^2$
SA_I	Surface area of the part of the hand in contact with object reaching the mouth, cm^2
$\text{TF}_{\text{indirect}}$	Fraction of the amount of crumb rubber transferred from the hand to an object then into the mouth, unitless
λ_{HTOTM}	Number of HTOTM contacts per hour
CF1, CF2	Conversion factor
BW	Body Weight, kg

→ Derived from US EPA (2011) data for the surface area of both hands

Assume one hand (25% of the surface area of both hands) is used



Ingestion: Hand-to-Object-to-Mouth Ingestion Rate

$$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}} = \frac{\text{AF}_{\text{hand}} \times \text{SA}_I \times \text{TF}_{\text{indirect}} \times \lambda_{\text{HTOTM}} \times \text{CF1} \times \text{CF2}}{\text{BW}}$$

Parameter	Definition
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$	Ingestion rate normalized to bodyweight for HTOTM activity, $\text{g}_{\text{crumb rubber}}/\text{kg BW-day}$
AF_{hand}	Adherence factor of crumb rubber for the hand, $\text{mg}_{\text{crumb rubber}}/\text{cm}^2$
SA_I	Surface area of the part of the hand in contact with object reaching the mouth, cm^2
$\text{TF}_{\text{indirect}}$	Fraction of the amount of crumb rubber transferred from the hand to an object then into the mouth, unitless
λ_{HTOTM}	Number of HTOTM contacts per hour
CF1, CF2	Conversion factor
BW	Body Weight, kg

→ Adopted from OEHHA (2008, 2011) guidelines
Assume $\text{TF}_{\text{indirect}} = 0.25$ & 0.50

→ Estimated from time activity study video data

Ingestion: SA_I, λ_{HTOTM}

Surface Area Of The Part Of The Hand In Contact With Object Reaching The Mouth

Gender	Age Group	SA_I (cm ²)	
		Median	95%
Females	0<2 years	63	72
	2<9 years	106	147
	9<16 years	149	202
	16-70 years	225	284
Males	0<2 years	65	74
	2<9 years	108	144
	9<16 years	153	206
	16-70 years	257	311
Combined	0<2 years	64	73
	2<9 years	107	145
	9<16 years	151	204
	16-70 years	241	301

SOURCE: Calculated using data on the surface of both hands from USEPA (2011)

Hand-To-Object-To-Mouth Contacts Per Hour

Receptor	Gender	N	λ_{HTOTM} (contacts/hour)	
			Median	95%
Athlete	Female	19	5.3	15.7
	Male	21	2.8	7.2
Child Bystander		56	20.4	160.8

SOURCE: Time Activity Study—Video Data

Ingestion: Ingestion Rate

$$\frac{\text{Ing}}{\text{BW}} = \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}} + \left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$$

← Sum of ingestion rates for all direct and indirect ingestion pathways

Parameter	Definition
$\frac{\text{Ing}}{\text{BW}}$	Ingestion rate normalized to bodyweight for direct and indirect ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{direct}}$	Ingestion rate normalized to bodyweight for direct ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTM}}$	Ingestion rate normalized to bodyweight for HTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{OTM}}$	Ingestion rate normalized to bodyweight for OTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$
$\left(\frac{\text{Ing}}{\text{BW}}\right)_{\text{HTOTM}}$	Ingestion rate normalized to bodyweight for HTOTM ingestion, $g_{\text{crumb rubber}}/\text{kg BW-day}$



Ingestion: Ingestion Dose

Non-Cancer Exposure Dose	Cancer Exposure Dose
$\text{Dose}_{\text{NC-ing}} = \frac{C_{\text{crumb rubber}} \times \text{GRAF} \times \frac{\text{Ing}}{\text{BW}} \times \text{ED}}{\text{AT}}$	$\text{Dose}_{\text{C-ing}} = C_{\text{Crumb rubber}} \times \text{GRAF} \times \frac{\text{Ing}}{\text{BW}} \times \text{ET} \times \text{EF} \times \text{CF}$

Parameter	Definition
$\text{Dose}_{\text{NC-ing}} / \text{Dose}_{\text{C-ing}}$	Exposure dose of a chemical from ingestion of crumb rubber, $\text{mg}_{\text{chemical}} / \text{kg BW-day}$
$C_{\text{crumb rubber}}$	Oral bioaccessible concentration of a chemical from crumb rubber, $\text{mg}_{\text{chemical}} / \text{g}_{\text{crumb rubber}}$
GRAF	Gastrointestinal relative absorption factor, unitless
$\frac{\text{Ing}}{\text{BW}}$	Ingestion rate normalized to bodyweight, $\text{g}_{\text{crumb rubber}} / \text{kg BW-day}$
ED	Exposure duration, years
AT	Averaging time, years
ET	Exposure time, hours/day
EF	Exposure frequency, days/week
CF	Conversion factor

Age Group	ED (Years)
3 rd trimester	0.25
0 to <2 years	2
2 to <16 years	14
16 to 70 years	54



Ingestion: Exposure Dose

Non-Cancer Exposure Dose	Cancer Exposure Dose
$\text{Dose}_{\text{NC-ing}} = \frac{C_{\text{crumb rubber}} \times \text{GRAF} \times \frac{\text{Ing}}{\text{BW}} \times \text{ED}}{\text{AT}}$	$\text{Dose}_{\text{C-ing}} = C_{\text{Crumb rubber}} \times \text{GRAF} \times \frac{\text{Ing}}{\text{BW}} \times \text{ET} \times \text{EF} \times \text{CF}$

Parameter	Definition
$\text{Dose}_{\text{NC-ing}} / \text{Dose}_{\text{C-ing}}$	Exposure dose of a chemical from ingestion of crumb rubber, $\text{mg}_{\text{chemical}} / \text{kg BW-day}$
$C_{\text{crumb rubber}}$	Oral bioaccessible concentration of a chemical from crumb rubber, $\text{mg}_{\text{chemical}} / \text{g}_{\text{crumb rubber}}$
GRAF	Gastrointestinal relative absorption factor, unitless
$\frac{\text{Ing}}{\text{BW}}$	Ingestion rate normalized to bodyweight, $\text{g}_{\text{crumb rubber}} / \text{kg BW-day}$
ED	Exposure duration, years
AT	Averaging time, years
ET	Exposure time, hours/day
EF	Exposure frequency, days/week
CF	Conversion factor

→ Default value = 70 years

→ Derived from time activity study survey data



Ingestion: Exposure Time (Athlete)

Age Group	Season	Females					Males				
		N	Practice (Hours/day)		Game (Hours/day)		N	Practice (Hours/day)		Game (Hours/day)	
			Median	95%	Median	95%		Median	95%	Median	95%
2<9 years	Spring	7	0.0	1.7	1.0	7.6	26	1.5	2.8	1.0	3.8
	Summer		0.0	0.7	0.0	1.4		0.0	2.0	0.0	2.8
	Fall		0.0	2.0	1.0	7.6		1.3	3.0	1.0	3.6
	Winter		0.0	1.9	1.0	8.8		1.0	2.9	0.0	3.5
9<16 years	Spring	279	1.5	3.0	1.0	4.0	309	1.5	4.0	1.0	3.0
	Summer		1.5	3.0	1.0	4.0		1.5	4.0	0.5	3.0
	Fall		1.5	3.0	1.5	4.0		1.5	4.0	1.0	4.0
	Winter		1.5	3.0	1.0	4.0		1.5	4.0	1.0	4.0
16-70 years	Spring	236	1.5	4.0	2.0	4.0	204	2.0	4.0	2.0	5.8
	Summer		1.0	4.0	1.5	5.0		2.0	4.0	1.5	4.0
	Fall		1.5	4.3	2.0	6.0		2.0	4.9	2.0	4.8
	Winter		1.0	6.0	1.5	5.0		2.0	5.0	2.0	6.0

SOURCE: Time Activity Study—Survey Data



Ingestion: Exposure Frequency (Athlete)

Age Group	Season	Females				Males					
		N	Practice (Days/week)		Game (Days/week)		N	Practice (Days/week)		Game (Days/week)	
			Median	95%	Median	95%		Median	95%	Median	95%
2<9 years	Spring	7	0.3	1.0	1.0	3.4	26	1.0	3.0	1.0	3.0
	Summer		0.0	1.0	0.0	1.7		0.0	3.0	0.3	4.3
	Fall		0.3	1.7	1.0	2.0		1.0	3.8	1.0	3.0
	Winter		1.0	2.4	1.0	4.5		1.0	3.0	0.5	2.0
9<16 years	Spring	279	2.0	4.0	1.0	3.1	309	2.0	4.0	1.0	3.0
	Summer		1.0	4.0	1.0	3.0		1.0	4.0	1.0	3.0
	Fall		2.0	4.0	1.0	3.0		2.0	4.0	1.0	4.0
	Winter		2.0	5.0	1.0	3.0		2.0	4.0	1.0	4.0
16-70 years	Spring	236	2.0	4.3	1.0	4.0	204	2.0	5.0	1.0	4.0
	Summer		1.0	4.0	1.0	3.0		2.0	5.0	1.0	3.0
	Fall		2.0	5.0	2.0	4.3		2.0	6.0	1.3	3.8
	Winter		2.0	5.0	2.0	4.0		2.0	6.0	2.0	4.0

SOURCE: Time Activity Study—Survey Data



Discussion



Dermal: Exposure Dose

Non-Cancer Exposure Dose	Cancer Exposure Dose
$\text{Dose}_{\text{NC-der}} = \frac{C_{\text{crumb rubber}} \times \text{DL} \times \text{ABS} \times \text{ED} \times \text{CF}}{\text{AT}}$	$\text{Dose}_{\text{C-der}} = C_{\text{crumb rubber}} \times \text{DL} \times \text{ABS} \times \text{ET} \times \text{EF} \times \text{CF1} \times \text{CF2}$
<p>Concentration (C_{crumb rubber})</p> <p>Intake Rate (DL × ABS)</p> <p>Exp Time (ED)</p>	<p>Concentration (C_{crumb rubber})</p> <p>Intake Rate (DL × ABS)</p> <p>Exp Time (ET × EF)</p>

Parameter	Definition
Dose NC-der /Dose C-ing	Exposure dose of a chemical through dermal absorption mg _{chemical} /kg BW-day
C _{crumb rubber}	Dermal bioaccessible concentration of a chemical in particles, mg _{chemical} /g _{crumb rubber}
DL	Daily dermal skin load of particles, mg _{crumb rubber} /kg BW-day
ABS	Fraction of a chemical absorbed across skin, unitless
ED	Exposure duration, years
AT	Averaging time, years
ET	Exposure time, hours/day
EF	Exposure frequency, days/week
CF	Conversion factor

- Measured in field study
- Derived from literature data
- Assume = 1



Dermal: Dermal Load

$$DL = AF_{\text{weighted}} \times SA_{\text{BW}} \times EV$$

Parameter	Definition
DL	Daily dermal skin load of particles, $\text{mg}_{\text{crumb rubber}}/\text{kg BW-day}$
AF_{weighted}	Weighted adherence factor of crumb rubber for exposed skin, $\text{mg}_{\text{crumb rubber}}/\text{cm}^2$
SA_{BW}	Exposed skin surface area normalized to bodyweight, $\text{cm}^2/\text{kg BW}$
EV	Event frequency, events/day

→ Derived from literature data

→ Assume 1 event/day

Dermal: Exposed Skin Surface Area

$$SA_{BW} = \sum_m^n (FTSA_m + \dots + FTSA_n) \times \left(\frac{SA_{total}}{BW} \right)$$

Parameter	Definition
SA_{BW}	Exposed skin surface area normalized to bodyweight, cm ² /kg BW
$FTSA_i$	Fraction of the total body surface area for a specified body part, unitless
SA_{total}	Total body skin surface area available for contact, cm ²
BW	Bodyweight, kg

→ Adopted from US EPA (2011)

→ Derived from US EPA data

Assume whole body is exposed for athletes and child bystanders.

Assume legs and arms (including hands) are exposed for coach, referee, and adult bystander

Dermal: FTSA_i, SA_{total}

Fraction Of The Total Body Surface Area For A Specified Body Part

Gender	Age Group	FTSA _i					
		Head	Trunk	Arms	Hands	Legs	Feet
Female	0<2 years	17%	36%	13%	6%	22%	6%
	2<9 years	7%	40%	14%	5%	27%	6%
	9<16 years	5%	39%	14%	4%	31%	6%
	16-70 years	6%	35%	13%	5%	32%	7%
Male	0<2 years	17%	36%	13%	6%	22%	6%
	2<9 years	7%	40%	14%	5%	26%	7%
	9<16 years	5%	40%	14%	5%	30%	7%
	16-70 years	7%	40%	15%	5%	33%	7%
Combined	0<2 years	17%	36%	13%	6%	22%	6%
	2<9 years	7%	40%	14%	5%	27%	7%
	9<16 years	5%	40%	14%	5%	30%	7%
	16-70 years	6%	38%	14%	5%	33%	7%

SOURCE: US EPA (2011)

Total Body Skin Surface Area Available For Contact

Gender	Age Group	SA _{total} (cm ²)	
		Median	95%
Females	0<2 years	4550	5208
	2<9 years	8900	12300
	9<16 years	12950	17550
	16-70 years	18088	22859
Males	0<2 years	9078	12056
	2<9 years	13300	17900
	9<16 years	20647	24997
	16-70 years	9078	12056
Combined	0<2 years	4646	5333
	2<9 years	8978	12167
	9<16 years	13100	17700
	16-70 years	19389	24222

SOURCE: US EPA (2011)



Dermal: Dermal Load

$$DL = AF_{\text{weighted}} \times SA_{\text{BW}} \times EV$$

Parameter	Definition
DL	Daily dermal skin load of particles, $\text{mg}_{\text{crumb rubber}}/\text{kg BW-day}$
AF_{weighted}	Weighted adherence factor of crumb rubber for exposed skin, $\text{mg}_{\text{crumb rubber}}/\text{cm}^2$
SA_{BW}	Exposed skin surface area normalized to bodyweight, $\text{cm}^2/\text{kg BW}$
EV	Event frequency, events/day

→ Derived from literature data

Dermal: Weighted Adherence Factor

$$AF_{\text{weighted}} = \sum_m^n \frac{(AF_m \times FTSA_m) + \dots + (AF_n \times FTSA_n)}{FTSA_m + \dots + FTSA_n}$$

Parameter	Definition
AF_{weighted}	Weighted adherence factor of crumb rubber for exposed skin, $mg_{\text{crumb rubber}}/cm^2$
AF_i	Adherence factor of crumb rubber to skin for a specified body part, $mg_{\text{crumb rubber}}/cm^2$
$FTSA_i$	Fraction of the total body surface area for a specified body part, unitless

→ Adopted from Kissel et al. 1996

Dermal: AF_i , $AF_{weighted}$

Adherence Factor Of Crumb Rubber To Skin For A Specified Body Part

Body Part	AF_i (mg/cm ²)
Hands	0.037
Arms	0.005
Legs	0.036
Face	0.015
Feet	0.037

SOURCE: Kissel et al. 1996

Weighted Adherence Factor Of Crumb Rubber For Exposed Skin

	Gender	Age Group	$AF_{weighted}$ (mg _{crumb rubber} /cm ²)
Athlete Child Bystander	Female	0<2 years	0.028
		2<9 years	0.030
		9<16 years	0.031
		16-70 years	0.030
	Male	0<2 years	0.028
		2<9 years	0.030
		9<16 years	0.031
		16-70 years	0.033
	Combined	0<2 years	0.028
		2<9 years	0.030
		9<16 years	0.031
		16-70 years	0.031
Coach Referee Adult Bystander	Female	9<16 years	0.013
		16-70 years	0.014
	Male	9<16 years	0.013
		16-70 years	0.015

Values are calculated from data from Kissel et al. 1996 and USEPA (2011)

Exposure Assessment Summary

Exposure Dose:

Exposure Pathway	Non-Cancer Dose	Cancer Dose
Inhalation	$C_{\text{air-adj}}$	Dose_{inh}
Ingestion	$\text{Dose}_{\text{NC-ing}}$	$\text{Dose}_{\text{C-ing}}$
Dermal	$\text{Dose}_{\text{NC-der}}$	$\text{Dose}_{\text{C-der}}$

Questions

1. Do you have any comments or concerns on the general approach?
2. Any input on the use of the Time Activity Study data, e.g., how to deal with extreme values?
3. Have any parameters been left out or are not needed?
4. Are assumptions made reasonable?
5. Any input on the use of survey versus video data, e.g., in deriving exertion levels?

