

Sulfur Dioxide

ACGIH (0.25 ppm) , SCOEL (0.5 ppm) SO₂ STELs based on response in asthmatics at:

0.2 - 1.0 ppm

5 or 10 minute exposures

breathing rates 35- 85 L/min

Q: How to relate these studies in sensitive subjects to worker exposure at 15 minutes?

A: Scale asthma response/incidence and breathing rates from asthma studies to population

Scale Asthma Exposure and Incidence to Population:

1. Normalize asthma studies with **Integrated Exposure (IE)**: conc x time x breathing rate:

$$\text{for each study, } IE = (C \times T \times BR)$$

2. Scale asthma response to population response:

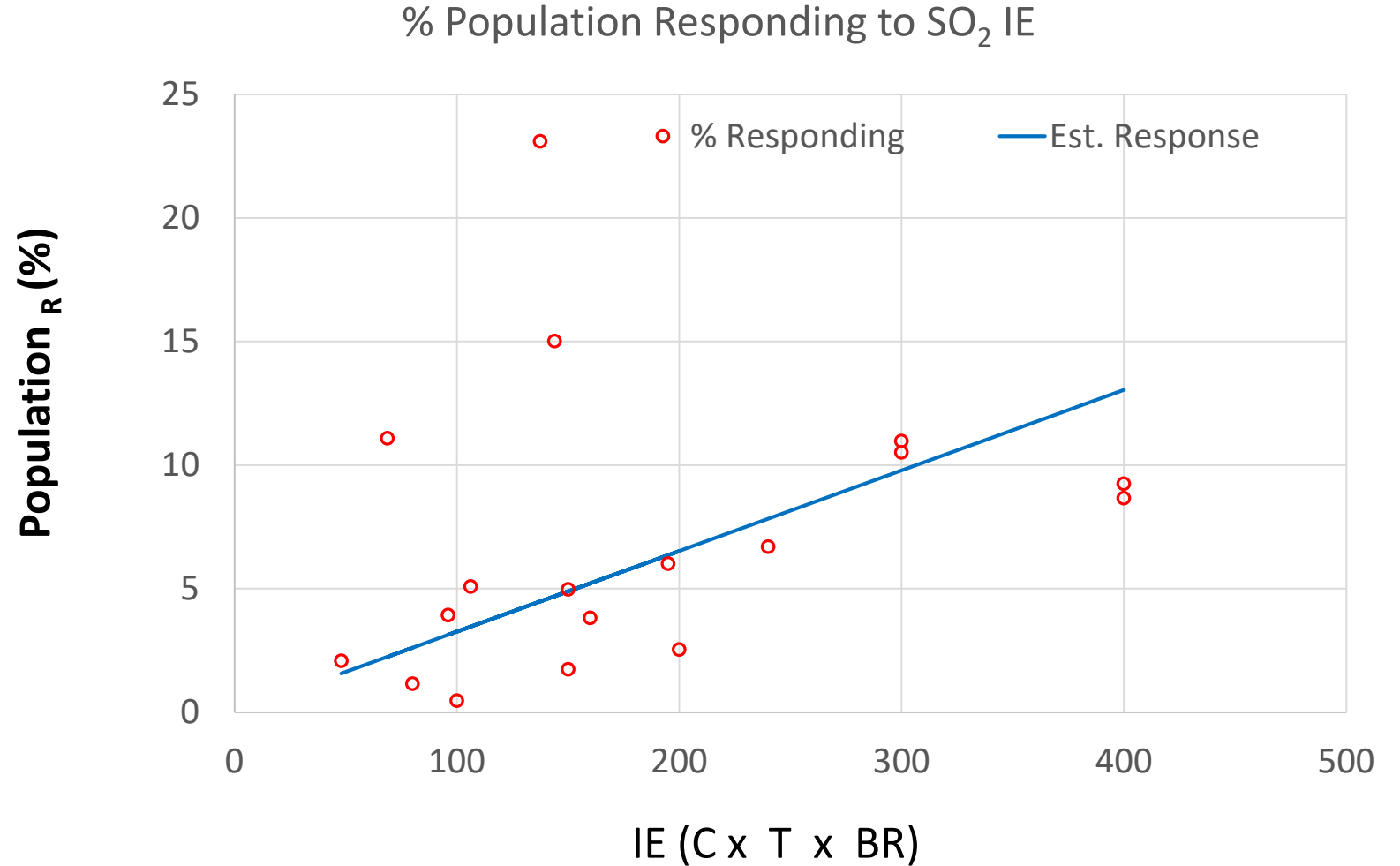
Number of asthmatics in study \div % asthmatics in population (10%) = “number” of population in study

3. Calculate Population_R as: # of asthmatics responding / study population \times 100
4. Determine population response at 15 minutes (Population_{R-15}) with simple conversion: : 15/5, 15/10.
5. Use linear relationship between IE and Population_{R-15} to estimate response at different C and BR

CONC (C)	TIME (T)	BREATHING RATE (BR) <i>mean: 47.7</i>	INTEGRATED EXPOSURE (C x T x BR)	Asthmatics (A _n)	Asthmatics Responding (A _R)	Asthmatics drawn from Population P (10%)	Population _R A _R /P	Population _R at 15 min
0.2	5	48	48.000	23	2	230	0.90	2.7
0.2	10	40	80.000	40	4	400	1.00	1.5
0.25	5	55	68.750	19	9	190	4.80	14.4
0.25	5	85	106.250	9	2	90	2.20	6.6
0.25	10	40	100.000	28	1	280	0.40	0.6
0.3	10	50	150.000	20	3	200	1.50	2.25
0.3	10	50	150.000	21	9	210	4.30	6.45
0.4	5	48	96.000	23	4	230	1.70	5.1
0.4	10	40	160.000	40	13	400	3.30	4.95
0.5	5	55	137.500	10	10	100	10.00	30
0.5	10	40	200.000	28	6	280	2.20	3.3
0.5	10	39	195.000	45	23	450	5.20	7.8
0.6	5	48	144.000	23	15	230	6.50	19.5
0.6	10	40	240.000	40	23	400	5.80	8.7
0.6	10	50	300.000	20	19	200	9.50	14.25
0.6	10	50	300.000	21	19	210	9.10	13.65
1	10	40	400.000	28	21	280	7.50	11.25
1	10	40	400.000	10	8	100	8.00	12

INTEGRATED EXPOSURE (C x T x BR)	Population _R at 15 min
48.000	2.7
80.000	1.5
68.750	14.4
106.250	6.6
100.000	0.6
150.000	2.25
150.000	6.45
96.000	5.1
160.000	4.95
137.500	30
200.000	3.3
195.000	7.8
144.000	19.5
240.000	8.7
300.000	14.25
300.000	13.65
400.000	11.25
400.000	12

Fit to $y = mx$;



Population_R = 0.0142 IE

Using equation, calculate **Population_R** for different concentrations and fixed breathing rates at 15 min.

What conditions result in **Population_R > 5%**

CONC (ppm)	TIME (min)	Breath	Integrated Exposure	Population_R (%)
0.2	15	20	60	2.5
		30	90	3.8
		40	120	5.1
		50	150	6.4
0.25	15	20	75	3.2
		30	112.5	4.8
		40	150	6.4
		50	187.5	7.9
0.3	15	20	90	3.8
		30	135	5.7
		40	180	7.6
		50	225	9.5
0.4	15	20	120	5.1
		30	180	7.6
		40	240	10.2
		50	300	12.7

from Compendium of Physical Activities, 2011:

MET (Metabolic Equivalent):
 The ratio of the work metabolic rate to the resting metabolic rate. One MET is defined as 1 kcal/kg/hour and is roughly equivalent to the energy cost of sitting quietly. A MET also is defined as oxygen uptake in ml/kg/min with one MET equal to the oxygen cost of sitting quietly, equivalent to 3.5 ml/kg/min

ATUS Occupational Code (TRDOCC1)	CPS Occupational Code	Summary MET value
1 Management	0010 - 0430	1.73
2 Business and Financial	0500 - 0950	1.67
3 Computer and Mathematical	1000 - 1240	1.58
4 Architecture and Engineering	1300 - 1560	1.64
5 Life, Physical, and Social Science	1600 - 1960	2.02
6 Community and Social Services	2000 - 2060	2.08
7 Legal	2100 - 2150	1.50
8 Education, Training, and Library	2200 - 2550	2.50
9 Arts, Design, Entertainment, Sports, Media	2600 - 2960	2.13
10 Healthcare Practitioner and Technical	3000 - 3540	2.22
11 Healthcare Support	3600 - 3650	2.83
12 Protective Service	3700 - 3950	2.56
13 Food Preparation and Serving Related	4000 - 4160	2.58
14 Bldg & Grounds Cleaning, Maintenance	4200 - 4250	3.58
15 Personal Care and Service	4300 - 4650	2.53
16 Sales and Related Occupations	4700 - 4960	2.00
17 Office and Administrative Support	5000 - 5930	1.83
18 Farming, Fishing, and Forestry	6000 - 6130	3.67
19 Construction and Extraction	6200 - 6940	4.29
20 Installation, Maintenance, and Repair	7000 - 7620	3.19
21 Production	7700 - 8960	2.67
22 Transportation and Material Moving	9000 - 9750	2.51

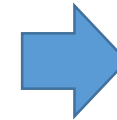
<https://epi.grants.cancer.gov/physical/MET/#ocs>

<https://sites.google.com/site/compendiumofphysicalactivities/corrected-mets>

Determine breathing rates from physical activity surveys or metabolic studies

Table 3.4b. One-Hour Breathing Rates for SB352 School Sites in M³/60 min (Males and Females Combined)

	0<2 Years	2<6 years	6<11 years	11<16 years	16-70 years
Sedentary & Passive Activities (METS ≤ 1.5)					
Mean	0.23	0.27	0.29	0.33	0.32
95 th Percentile	0.34	0.36	0.39	0.45	0.42
Light Intensity Activities (1.5 < METS ≤ 3.0)					
Mean	0.58	0.68	0.68	0.76	0.75
95 th Percentile	0.81	0.86	0.91	1.03	0.97
Moderate Intensity Activities (3.0 < METS ≤ 6.0)					
Mean	1.06	1.25	1.30	1.50	1.62
95 th Percentile	1.54	1.63	1.73	2.05	2.26
High Intensity Activities (METS ≥ 6.0)					
Mean	-	2.24	2.49	2.92	3.01
95 th Percentile	-	2.98	3.51	4.18	4.39



MET	Breathing Rate (L/min)	
	Mean	95th %tile
<1.5	5.3	7.0
1.5 - 3	12.5	16.2
3-6	27.0	37.7
>6	50.2	73.2

OEHHA, Technical Support Document for Exposure Assessment and Stochastic Analysis, 2011. <https://oehha.ca.gov/media/downloads/cnr/110711exposuresd.pdf>

What Asthma incidence to use?

Since 1997, the NHIS has gathered information about **lifetime asthma** and asthma attacks or episodes from the Sample Adult Core and Sample Child Core questionnaires. A positive response to the question: “Has a doctor or other health professional ever told you that you had asthma?” determined lifetime asthma. To determine the prevalence of asthma episodes or attacks, persons answering “yes” to the lifetime asthma question were then asked, “During the past 12 months, have you had an episode of asthma or an asthma attack?” Since 2001, current asthma status has also been collected. To determine **current asthma, persons answering “yes” to the lifetime asthma question were then asked, “Do you still have asthma?”**

U.S. LIFETIME asthma (%)											
	All ages Total	Children Age <18	Adults Age 18+	0-4	5-14	15-34	15-19	20-24	25-34	35-64	65+
Total:	13.3	13.0	13.4	5.6	14.9	15.7	18.2	15.5	15.0	13.1	11.1
Male	12.6	15.1	11.8	8.3	16.5	16.3	21.0	15.6	14.8	10.2	9.6
Female	14.0	10.9	14.9	2.7	13.2	15.1	15.3	15.4	15.2	15.9	12.4
U.S. CURRENT asthma (%)											
	All ages Total	Children Age <18	Adults Age 18+	0-4	5-14	15-34	15-19	20-24	25-34	35-64	65+
Total:	7.9	8.4	7.7	4.4	9.7	8.0	9.4	7.3	7.6	8.1	7.0
Male	6.4	9.5	5.4	6.8	10.3	6.9	9.6	6.9	5.5	5.2	5.2
Female	9.3	7.3	9.8	2.0	9.1	9.1	9.3	7.7	9.7	10.9	8.5

California: Lifetime: 11,370 **12.8** 0.39 (12.1–13.6) Current: 11,340 **7.8** 0.31 (7.2–8.4)

Using METs, breathing rates for different occupations can be used to calculate Population_R.

At 0.25 ppm SO₂, **Population_R** of 5% exceeded only with highly sensitive or under very heavy exertion (>6).

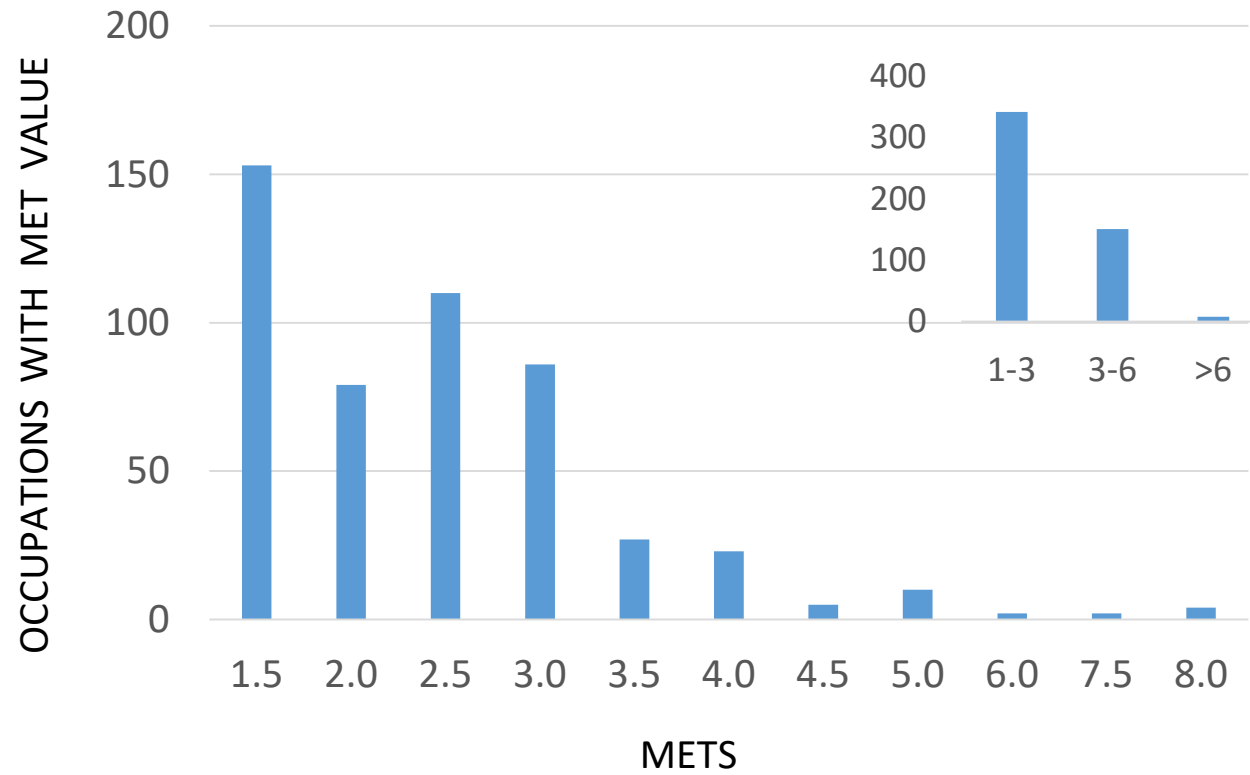
At 0.5 ppm SO₂, **Population_R** of 5% exceeded in a third of occupations.

MET	Breathing Rate (L/min)	
	Mean	95th %tile
<1.5	5.3	7.0
1.5 - 3	12.5	16.2
3-6	27.0	37.7
>6	50.2	73.2



CONC (ppm)	Exposure (min)	MET	Breathing Rate (L/min) mean; 95%	Integrated Exposure	Population _R 10% Asthma	Population _R 7.8% Asthma
0.25	15	<1.5	5.3	19.9	0.8	0.6
			7	26.3	1.1	0.9
		1.5 - 3	12.5	46.9	2	1.5
			16.2	60.8	2.6	2.0
		3 - 6	27	101.3	4.3	3.3
37.7	141.4		6	4.6		
0.5	15	>6	50.2	188.3	8	6.1
			73.2	274.5	11.6	9.0
		<1.5	5.3	39.8	1.7	1.3
			7	52.5	2.2	1.7
		1.5 - 3	12.5	93.8	4	3.1
			16.2	121.5	5.1	4.0
		3 - 6	27	202.5	8.6	6.6
			37.7	282.8	12	9.2
>6	50.2	376.5	16	12.3		
	73.2	549	23.3	17.9		

TOTAL OCCUPATIONS IN EACH MET



Sulfur dioxide

Other organizational sources and their recommendations (Prepared by CDPH/HESIS for HEAC summary document)

Source and date	Findings/Recommendations	Basis/source/ref(s)	Discussion and Assessment
OEHHA (2011)	Developmental toxicity; Acute REL 660 µg/m ³	OEHHA's Developmental And Reproductive Toxicity (DART) committee - State's Qualified Experts mechanism (OEHHA, 2011); acute REL based on respiratory irritation (OEHHA, 1999).	(i) adverse effects on male reproductive system such as decreased sperm quality and fecundability in humans; increased frequencies of chromosomal damage in lymphocytes of exposed workers; and adverse birth outcome among families of exposed workers; (ii) adverse effects in testes including DNA damage in male animals; (iii) decreased odds of live birth in humans; and (iv) alteration in estrous cycle, changes in pregnancy frequency and duration, and changes in offspring growth in female animals. Included under State of California-proposition 65 list as known to the state to cause reproductive toxicity.
US EPA (2017)	Respiratory effects; Reproductive and developmental effects; and cancer	Respiratory effects- strong causal relationship for short-term and suggestive causal relationship for long-term exposure; Reproductive and developmental effects - suggestive but not sufficient to infer a causal relationship; and cancer – suggestive but not sufficient to infer a causal relationship (US EPA, 2017).	Respiratory effects - bronchoconstriction (decreased lung function and increased respiratory symptoms) in exercising individuals with asthma in controlled human studies for short term exposure and in recent epidemiologic and animal toxicological studies for long-term exposure; Reproductive and developmental toxicity - some uncertainties and Little coherence or consistency among the epidemiologic and toxicological studies; Cancer - inconsistent evidence from epidemiologic and toxicological studies as well as from mode of action for genotoxicity.
NTP	-	-	-
ATSDR (1998)	Respiratory effects; some evidence of reproductive and developmental effects; and cancer.	Respiratory effects - Bronchoconstriction in exercising asthmatics and in experimental animals; Reproductive and developmental effects - some evidence in humans and animals; decreased infant birth weight; Cancer - genotoxic effects and increase in lung cancer risk (ATSDR, 1998).	Association between high exposure levels in air and adverse effects on sperms in adult males; reduction in birth weight of newborn by an exposed pregnant women; increase in chromosomal aberrations and sister chromatid exchanges in exposed workers; some evidence of elevated risk of lung cancer in exposed workers and in experimental animals.
IARC (1992)	Not classifiable as to its carcinogenicity to humans (Group 3).	Inadequate evidence for the carcinogenicity in humans and limited evidence for the carcinogenicity in experimental animals (IARC, 1992).	No independent effect of sulfur dioxide seen in several cohort studies of copper smelters; no excess risk of lung cancer in a case-control study; one animal study showed significant increase in lung tumor incidence. Evaluated as Group 3.