TEELs
(Temporary Emergency Exposure Limits)
for
Simple Asphyxiants

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What we'll cover today…..

- **Rationale for Simple Asphyxiant TEELs**
  - **Based on Oxygen (O_2) depletion**
  - **Normal air composition**
  - **Normal air at altitude**
  - **Calculating asphyxiant ppm given $\%O_2$**
  - **Physiological changes at decreasing $\%O_2$**
  - **Air O_2 vs. Alveolar O_2 vs Blood O_2**
  - **Matching health effects to TEEL definitions**
  - **Acclimatization mechanisms at altitude**
  - **Final revised TEELs**

“SIMPLE” Asphyxiant

- **Oxygen (O_2) displacement by asphyxiant**
  - **Resulting in O_2 depletion**
- **Little or no direct toxic effect of its own**
- **Physiological effects of O_2 depletion**

Normal Air

- **Composition**
  - **21% Oxygen**
  - **78% Nitrogen**
  - **1% Other**

- **Example … let's simplify to …**
  - **20% O_2**
  - **80% N_2**

Normal Air at Altitude per cubic x: Hypothetical Example

- **30,000 ft**
  - **2 O_2 + 8 N_2 = 10 Air → 20% O_2**
- **14,000 ft**
  - **20 O_2 + 80 N_2 = 100 Air → 20% O_2**
- **5,000 ft**
  - **200 O_2 + 800 N_2 = 1000 Air → 20% O_2**
- **Sea Level**
  - **2000 O_2 + 8000 N_2 = 10,000 Air → 20% O_2**
- **Percent composition remains constant**
- **Partial pressure O_2 (pp O_2) decreases**

Asphyxiant ppm Calc given %O_2

- ***Co = (1- Cx) 0.209***
- ***Cx = 1 - (Co / 0.209)***

  where

  ***Co* = Oxygen remaining in air, unitless fraction**

  ***Cx* = Introduced asphyxiant gas, unitless fraction (e.g. 500,000 ppm = 0.5)**

  ***0.209* = Oxygen fraction in normal air**

- **Example: x ppm asphyxiant → 16% O_2**

  Cx = 1- (0.16 / 0.209) = 1 – 0.77 = 0.23

  Cx = 0.23 (1,000,000 ppm) = 230,000 ppm

TEEL-0 & TEEL-1: Effects vs. %O_2 Levels

Equiv. O_2 at sea level (%)	Atmospheric pressure (mmHg)	Ambient atmospheric ppO_2	ppO_2 of freshly inspired air in the		Blood O_2 saturation (%)	Equivalent altitude (ft)	Effects
			Upper lung (mmHg)	Alveolar (mmHg)			
20.9	760	159	149	110	96	Sea level	Normal
19.0	689	145	135	95	94	2 500	Some adverse physiological effects occur, but they are unnoticeable.
16.0	581	121	114	70	92	7 500	Increased pulse and breathing rates. Impaired thinking and attention. Reduced coordination.
14.0	523	110	100	60	90	10 000	Abnormal fatigue upon exertion. Emotional upset. Faulty coordination. Poor judgment.
12.5	450	96	85	48	83	14 000	Very poor judgment and coordination. Impaired respiration that may cause permanent heart damage. Nausea and vomiting
<10	<387	<81	<71	<33	<70	>18 000	Inability to perform vigorous movement. Loss of consciousness. Convulsions. Death.

Source: ANSI Z88.2, "Respiratory Protection", Table A.1

TEEL-0 & TEEL-1: Effects vs. %O_2 Levels

Equiv. O_2 at sea level (%)	Effects
19.0	Some adverse physiological effects occur, but they are unnoticeable.

Source: ANSI Z88.2, "Respiratory Protection", Table A.1

OSHA--

1. Confined Space Entry (29 CFR 1910.146)

2. Respiratory Protection (29 CFR 1910.134)

Lower Limit: 19.5% O_2 w/o respiratory protection

TEEL-2: Effects vs. %O_2 Levels

Equiv. O_2 at sea level (%)	Atmospheric pressure (mmHg)	Ambient atmospheric ppO_2	ppO_2 of freshly inspired air in the		Blood O_2 saturation (%)	Equivalent altitude (ft)	Effects
			Upper lung (mmHg)	Alveolar (mmHg)			
20.9	760	159	149	110	96	Sea level	Normal
19.0	689	145	135	95	94	2 500	Some adverse physiological effects occur, but they are unnoticeable.
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Source: ANSI Z88.2, "Respiratory Protection", Table A.1

TEEL-2: Effects vs. %O_2 Levels

Equiv. O_2 at sea level (%)	Effects
16.0	Increased pulse and breathing rates. Impaired thinking and attention. Reduced coordination.

Source: ANSI Z88.2, "Respiratory Protection", Table A.1

TEEL-3: Effects vs. %O_2 Levels

Equiv. O_2 at sea level (%)	Atmospheric pressure (mmHg)	Ambient atmospheric ppO_2	ppO_2 of freshly inspired air in the		Blood O_2 saturation (%)	Equivalent altitude (ft)	Effects
			Upper lung (mmHg)	Alveolar (mmHg)			
20.9	760	159	149	110	96	Sea level	Normal
19.0	689	145	135	95	94	2 500	Some adverse physiological effects occur, but they are unnoticeable.
16.0	581	121	114	70	92	7 500	Increased pulse and breathing rates. Impaired thinking and attention. Reduced coordination.
14.0	523	110	100	60	90	10 000	Abnormal fatigue upon exertion. Emotional upset. Faulty coordination. Poor judgment.
12.5	450	96	85	48	83	14 000	Very poor judgment and coordination. Impaired respiration that may cause permanent heart damage. Nausea and vomiting
<10	<387	<81	<71	<33	<70	>18 000	Inability to perform vigorous movement. Loss of consciousness. Convulsions. Death.

Source: ANSI Z88.2, "Respiratory Protection", Table A.1

TEEL-3: Effects vs. %O_2 Levels

Equiv. O_2 at sea level (%)	Effects
<10	Inability to perform vigorous movement. Loss of consciousness. Convulsions. Death.

Source: ANSI Z88.2, "Respiratory Protection", Table A.1

Blood O_2 vs Alveolar O_2 vs Air O_2

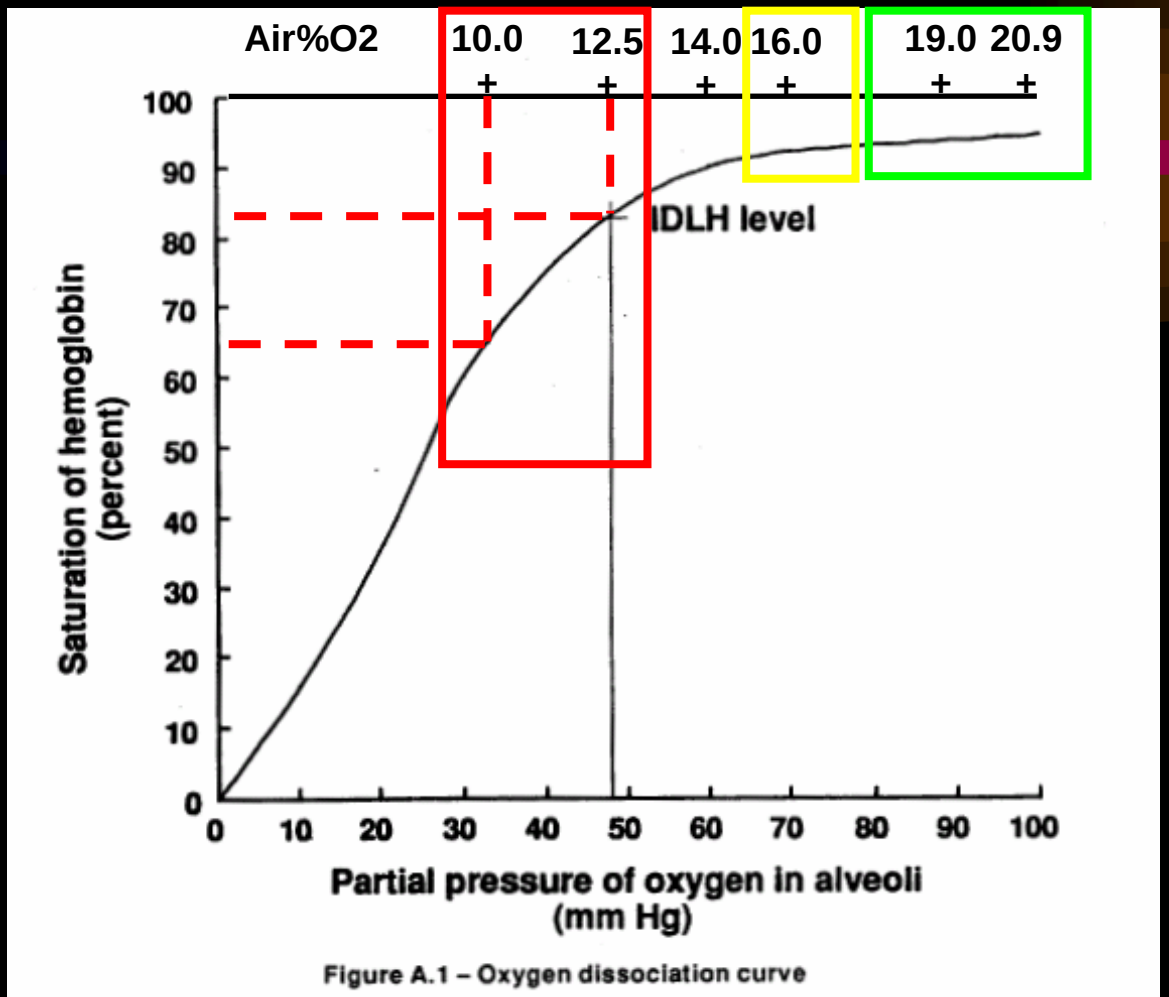

Figure A.1 – Oxygen dissociation curve

Source: ANSI Z88.2-1992

Acclimatization Mechanisms

- Increase in depth of respiration
- Pulmonary artery blood pressure increase
  - Forces blood into parts of the lung not normally used in breathing at sea level
- More red blood cells produced
- Enzyme produced
  - Enhances oxygen release from red blood cell hemoglobin to body tissues
- Takes about 4 weeks

Sources: 1. Princeton University, Outdoor Action Program, 1995
2. ANSI Z88.2-1992, "Respiratory Protection"

- Result:
  - OSHA allows work up to 14,000 ft w/o resp prot

Simple Asphyxiant TEELs "Revised" vs "Former"

- **Based on %O_2 physiological effects**
  - **TEEL-0 = 65,000 ppm, ~ 19.5% O_2 [was 19.5%]**
    - **OSHA confined space entry limit**
  - **TEEL-1 = 65,000 ppm, ~ 19.5% O_2 [was 18%]**
    - **OSHA confined space entry limit**
  - **TEEL-2 = 230,000 ppm, ~ 16% O_2 [was 15%]**
    - **Impaired coordination, perception, judgment (ANSI)**
  - **TEEL-3 = 400,000 ppm, ~ 12.5% O_2 [was 10%]**
    - **Unconsciousness, death (ANSI)**
- **Will appear in TEELs Rev 22 ~ Sept/Oct 2006**