

Carbon Dioxide Study

This study is to demonstrate the amount of carbon dioxide expelled in an atmospheric pressure area with no restrictions. This study does not take into consideration the amount of carbon dioxide sequestered into the ground or air moisture. There are no wind, temperature, or topography variables in this study. This study is on a **worst-case scenario**, which emergency first responders will follow, that the pipeline burst and created a port to the top of the soil. PSI has no effect on the volume that can be held within the pipe, it only acts as a propellant to discharge the pipe during a break.

Data Baselines

1. Pipe Volumes Formula: $volume = \pi \times \frac{d^2}{4} \times length$

THE VALUES SHOWN BELOW ARE FOR PER FOOT OF PIPE					
4" ID	150.8 cu. inches	2.47 liters	12" ID	1,357.20 cu. inches	22.24 liters
6" ID	339.29 cu. inches	5.56 liters	16" ID	2,412.70 cu. inches	39.54 liters
8" ID	603.19 cu. inches	9.88 liters	20" ID	3,769.90 cu. inches	61.78 liters

2. Carbon Dioxide Constants

Expansion Rate of liquid CO2 to Gas: 535:1

3. Area Baseline

Based using one square acre (208.71'x208.71') at 6' of elevation. This measurement is based on all human breathing and vehicle air intake is at or below 6'.

Total Area per Acre: $208.71^2 \times 6 = 261,359.18 \text{ ft}^3$

Converted to $m^3 = 7,400.86 \text{ m}^3$

4. Oxygen Necessary for Human Breathing and Equipment Operation

- Human Breathing: 19.5% atmospheric oxygen level is the minimum for normal body function. Anything lower than that will cause harm and possibly death.
- Gasoline Operated Equipment: 11.6% atmospheric oxygen level is the minimum for internal combustion gasoline engines to operate, not well, but operate. (Diesel is not included in the baseline as this study is based on the Gruver Fire Department coverage area which would utilize gasoline powered response vehicles.)

5. Oxygen Depletion Formula: $\%Oxygen = 100 \times \frac{.2095 \times (Vr - Vg)}{Vr}$

Vr = Area Volume

Vg = Volume of CO2 Gas

1 liter of Liquid CO2 gas using its expansion rate of 535:1 converts to $.535 \text{ m}^3/\text{liter}$

Formula Example for a 4" x 20 mile section of line.

Vr will equal $7,400.86 \text{ m}^3 \times 20 \text{ acres} = 148,017.2 \text{ m}^3$

Vg will equal $2.47 \text{ liters} \times 105,600' (20 \text{ mile pipeline}) = 260,832 \text{ liters} \times .535 \text{ m}^3 = 139,545.12 \text{ m}^3$

$$100 \times \frac{.2095 \times (148,017.2 \text{ m}^3 - 139,545.12 \text{ m}^3)}{148,017.2 \text{ m}^3} = 1.20 \% \text{ Oxygen}$$

4" Inner Diameter Pipeline

PER 20 MILE PIPELINE RUN BETWEEN SHUTOFF VALVES				
Pipeline ID: 4"	CO2 Gas Volume per 20 miles		139,545.12m ³	
Vr in Acres	Vr in m ³	Oxygen %	Red Zone Level	Red Zone Foot Radius
20	148017.2	1.20	Immediate Death	660'
40	296034.4	11.07	Engines Stall	934'
270	2368275.2	19.48	Human Function Decline	2,426' (.46 mile)

6" Inner Diameter Pipeline

PER 20 MILE PIPELINE RUN BETWEEN SHUTOFF VALVES				
Pipeline ID: 6"	CO2 Gas Volume per 20 miles		314,117.76m ³	
Vr in Acres	Vr in m ³	Oxygen %	Red Zone Level	Red Zone Foot Radius
45	333,038.7	1.20	Immediate Death	990'
90	666,077.4	11.07	Engines Stall	1400'
600	4440516	19.48	Human Function Decline	3615' (.68 mile)

8" Inner Diameter Pipeline

PER 20 MILE PIPELINE RUN BETWEEN SHUTOFF VALVES				
Pipeline ID: 8"	CO2 Gas Volume per 20 miles		558,180.48m ³	
Vr in Acres	Vr in m ³	Oxygen %	Red Zone Level	Red Zone Foot Radius
80	592,068.8	1.20	Immediate Death	1320'
160	1,184,137.6	11.07	Engines Stall	1866' (.34 mile)
1080	7,992,928.8	19.48	Human Function Decline	4,850' (.90 mile)

12" Inner Diameter Pipeline

PER 20 MILE PIPELINE RUN BETWEEN SHUTOFF VALVES				
Pipeline ID: 12"	CO2 Gas Volume per 20 miles		1,256,471m ³	
Vr in Acres	Vr in m ³	Oxygen %	Red Zone Level	Red Zone Foot Radius
180	1,332,154.8	1.20	Immediate Death	1980'
360	2,664,309.6	11.07	Engines Stall	2800' (.52 mile)
2,430	17,984,089	19.48	Human Function Decline	7276' (1.4 mile)

16" Inner Diameter Pipeline

PER 20 MILE PIPELINE RUN BETWEEN SHUTOFF VALVES				
Pipeline ID: 16"	CO2 Gas Volume per 20 miles		2,233,851.84m ³	
Vr in Acres	Vr in m ³	Oxygen %	Red Zone Level	Red Zone Foot Radius
320	2,368,275.2	1.20	Immediate Death	2640'
640	4,736,550.4	11.07	Engines Stall	3734' (.7 mile)
4320	31,971,715.2	19.48	Human Function Decline	9700' (1.8 mile)

20" Inner Diameter Pipeline

PER 10 MILE PIPELINE RUN BETWEEN SHUTOFF VALVES				
Pipeline ID: 20"	CO2 Gas Volume per 20 miles		3,490,322.88m ³	
Vr in Acres	Vr in m ³	Oxygen %	Red Zone Level	Red Zone Foot Radius
500	3,700,430	1.19	Immediate Death	3,300'
1000	7,400,860	11.07	Engines Stall	4,666' (.88 mile)
6750	49,955,805	19.48	Human Function Decline	12,124 (2.4 mile)

Red Zone Foot Radius

Notes: These radius measurements do not take wind direction or speed into consideration; this is if there is zero wind speed. Wind will change the spread of CO2 drastically; this is to give a very broad expectation of the Red Zone Area.

For a First Responder outlook, the row of "Human Function Decline" is the minimum distance from the scene that SCBA (self-contained breathing apparatus) must be worn by the first responders. The row "Engines Stall" is the minimum distance from the scene that the first responder gasoline vehicle can come to the scene.

Disclaimer

This study is in no relation to Heartland Greenway (Navigator) or Summit Carbon Solutions and is not sponsored by any other entity. These findings have not been applied into real world applications and are to be used as a demonstration of a worst-case scenario only. This study may not be used for legal purposes and must not be held as concrete evidence regarding a potential CO2 pipeline breach due to not including ecological variables.