A Monte Carlo Approach to Developing Area Source Oil and Gas Emissions Inventories

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Approach and Caveats

- Data source: The 2020 Nonpoint Oil and Gas Emission Estimation Tool, Version 1.3
- One county only: Kingfisher County, Oklahoma

Parameter	Value
Crude Oil Production	29,350,750 bbl
Crude Oil Wells	1,584
VOC Emissions (Working, Breathing, and Flashing) from Crude Oil Tanks	2,976.4 tons

- This is a proof of concept.
- Not actually a Monte Carlo simulation! A simple data set with all possible combinations rather than sampling.
- Only one source category evaluated and only one pollutant: VOC emissions from Crude Oil Tanks.

3.5 Crude Oil Tanks

Crude oil tanks are used to store liquid product at a well pad or central tank battery prior to transfer downstream to a refinery. Figure 3-4 shows a central tank battery (circled) in the Permian Basin adjacent to numerous well pads with pump jacks.²

Crude oil tank emissions are generated by working and breathing processes. The methodology for estimating oil tank venting emissions is shown in Equations 11-12. This methodology is based on a combined working and breathing losses VOC emissions factor on a per unit throughput basis (mass emissions per barrel of oil).



EPA Oil and Gas - Production Activities X

EPA Oil and Gas Tool, 2020 NEI Version 1.1 - Production Activities Module

Welcome to the U.S. Environmental Protection Agency (EPA) Oil and Gas Tool - Production Activities Module. This Module allows the User to generate county-level emission estimates of criteria and hazardous air pollutants (CAPs and HAPs) for oil and gas source categories related to production activities. When finished, data can be exported to Emission Inventory System (EIS) Staging tables.

To begin, first link to the EIS Staging tables in the area bridgetool.accdb database. When finished, please cl below to make your geographic and source category selections.



8 40019 ОК

40123 OK

40085 OK

16 40151 ОК

17 40087 ОК

18 40037 OK

19 40015 ОК

20 40133 OK

40047 OK

22 40129

23 40139 OK

25 40053 ОК

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Equation 11)

$$E_{oil,tanks,VOC} = P_{oil} \times \frac{EF_{oil,tanks,VOC}}{2,000} \times F_{tank} \times \left[1 - F_{VRU} - F_{flare} \times C_{captured} \times C_{efficiency}\right]$$

where:

*E*_{oil,tanks,VOC} is the county-wide annual VOC venting losses from oil tanks [tons-VOC/yr] *P_{oil}* is the annual county-wide oil production [bbl/yr] *EF_{oil.tanks.VOC}* is the VOC emissions factor for total losses from oil tanks [lb-VOC/bb]] F_{tank} is the fraction of oil directed to tanks [%] F_{VRU} is the fraction of oil production controlled by vapor recovery units F_{flare} is the fraction of oil production controlled by flares $C_{captured}$ is the capture efficiency of the flare $C_{efficiency}$ is the control efficiency of the flare 2,000 is the unit conversion factor lb/ton

Well Tanks - Flashing & Stand Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 356 2849573 356 284 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 720 2725699 720 272 377 764 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC 377 7646139 Volatile O Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 1446 1715617 1446 171 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC 302 1759023 Volatile O 302 175 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 625 1393126 625 139 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 409 1601598 409 160 434 1568304 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 434 156 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 102 1352505 102 135 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 316 907128 316 90 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 208 1119692 208 111 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 462 891728 462 89 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 117 1086331 117 108 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 57 635805 57 63 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 130 542294 0 130 54 Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 262 2645274 262 264 2310010200 Oil & Gas Expl & Prod /Crude Petroleum /Oil Well Tanks - Flashing & Standing/Working/Breathing CRUDE OIL TANKS VOC Volatile O 221 546085 221 54

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1	Count	Activity	Emission Factor	Conversion Factor	Control Factor		E oil tanks VOC			
2	1	305,737.0	1.552078	2000	0.316285403		75.04			
3	2	220,810.0	1.552078	2000	0.316285403		54.20			
4	3	135,883.1	1.552078	2000	0.316285403		33.35			
5	4	67,941.6	1.552078	2000	0.316285403		16.68			
6	5	50,956.2	1.552078	2000	0.316285403		12.51			
7	6	33,970.8	1.552078	2000	0.316285403		8.34			
8	7	305,737.0	1.120946	2000	0.316285403		54.20			
9	8	220,810.0	1.120946	2000	0.316285403		39.14			
10	9	135,883.1	1.120946	2000	0.316285403		24.09			
11	10	67,941.6	1.120946	2000	0.316285403		12.04			
12	11	50,956.2	1.120946	2000	0.316285403		9.03			
13	12	33,970.8	1.120946	2000	0.316285403		6.02			
14	13	305,737.0	0.689813	2000	0.316285403		33.35			
15	14	220,810.0	0.689813	2000	0.316285403		24.09			
16	15	135,883.1	0.689813	2000	0.316285403		14.82			
17	16	67,941.6	0.689813	2000	0.316285403		7.41			
18	17	50,956.2	0.689813	2000	0.316285403		5.56			
19	18	33,970.8	0.689813	2000	0.316285403		3.71			
20	19	305,737.0	0.344906	2000	0.316285403		16.68			
21	20	220,810.0	0.344906	2000	0.316285403		12.04			
22	21	135,883.1	0.344906	2000	0.316285403		7.41			
23	22	67,941.6	0.344906	2000	0.316285403		3.71			
24	23	50,956.2	0.344906	2000	0.316285403		2.78			
25	24	33,970.8	0.344906	2000	0.316285403		1.85			
26	25	305,737.0	0.258680	2000	0.316285403		12.51			
27	26	220,810.0	0.258680	2000	0.316285403		9.03			
28	27	135,883.1	0.258680	2000	0.316285403		5.56			
29	28	67,941.6	0.258680	2000	0.316285403		2.78			
20		50.056.0	0.050600	2000	0.04 0005 400		2.00			

## Data Analysis

А	В		С	D		
E_oil_tanks_VOC		Stat	istics			
75.04						
73.28		Mea	an	13.78		
69.76		Med	dian	7.75		
69.76		Mod	de	3.44		
66.24		Max	timum	75.04		
64.48		Min	imum	0.80		
54.20						
54.20						
52.93						<b>a</b> .
52.93				INT OF BIN R	ange	Count
50.38					78.75	5 1
					71.25	3
					63.75	5 2
					56.25	5 4
					48.75	5 8
					41.25	5 2
					33.75	5 12
					26.25	5 8
					18.75	5 16
					11.25	5 54
					3.75	5 106



# **Additional Element**

- Field inspections have shown a tendency for high production wells to overwhelm their vapor collection systems.
- Reduce capture efficiency for the 9% of wells with emissions 171 tons (per year) or more.

### Simulated Super-Emitters:

Baseline emissions: 2,976 tons Emissions with simulated superemitters: 3,385 tons

Percent increase: 13.7%

	D	E	F	G	Н	I.	J	K L	M		N	0	Р	Q					
1	Conversion Factor	<b>Emissions Prior to Control</b>	Alternative Control Factor	Alternative Emissions		<b>Control Factor</b>		E_oil_tanks_VOC											
2	2000	237	0.430112283	102.1		0.316285403		75.04	Previou	s	A	lt	Super-Em	nitter					
3	2000	237	0.42392604	100.6		0.308861911		73.28	Control	Factor	r C_	capture	Control F	actor					
4	2000	237	0.411553553	97.6		0.294014927		69.76	0.31628	85		70	0.430112	2					
5	2000	237	0.411553553	97.6		0.294014927		69.76	0.3088	52		70	0.423926	5					
6	2000	237	0.399181066	94.7		0.279167942		66.24	0.2940	15		70	0.411554	1					
7	2000	237	0.392994822	93.2		0.27174445		64.48	0.2940	15		70	0.411554	1					
8	2000	171	0.430112283	73.7		0.316285403		54.20	0.2791	68		70	0.399181	L					
9	2000	171	0.430112283	73.7		0.316285403		54.20	0.27174	44		70	0.392995	5					
10	2000	171	0.42392604	72.6		0.308861911		52.93											
11	2000	171	0.42392604	72.6		0.308861911		52.93											
12	2000	171	0.411553553	70.5		0.294014927		0.20401402	7				0.0			0 204014027		0.0	6
13	2000	171	0.411553553	70.5		0.294014927		0.23401432	/				0.9	'		0.234014327		0.0	0
14	2000	171	0.411553553	70.5		0.294014927		0.29401492	7				0.9			0.294014927		0.8	36
15	2000	171	0.411553553	70.5		0.294014927		0 27916794	2				0.8			0 279167942		0.8	22
16	2000	171	0.399181066	68.4		0.279167942		0.27510754	2				0.0	'		0.275107542		0.0	2
17	2000	171	0.399181066	68.4		0.279167942		0.2717444	5				0.8			0.27174445		0.8	30
18	2000	171	0.392994822	67.3		0.27174445													
19	2000	171	0.392994822	67.3		0.27174445			_										
20	2000	124	0.316285403	39.1		0.316285403						3	3,385.4					2,976.	.4
21	2000	124	0.308861911	38.2		0.308861911													
22	2000	124	0.294014927	36.4		0.294014927			-										
23	2000	124	0.294014927	36.4		0.294014927			Perce	ent Ir	ncreas	e			13.7%				
24	2000	124	0.279167942	34.5		0.279167942		Chack work sp	200	Dict	tributio	n l	Plot D	ata	Extra Cu	nor Emittore	Cruc	la Oil Braduction k	by Count
25	2000	124	0.27174445	33.6		0.27174445		Check work sp	ace	Dist	inducio		PIOUD	ata	Extra Su	per childers	Cruc	ie on Production i	by coun
26	2000	105	0.216205402	22.4		0.216205402													

# Conclusions

- Applying a Monte Carlo approach to existing emissions inventory data can convert a simple, completely flat data distribution into a heavy-tailed distribution.
- With no additional computational changes, the total emissions will remain the same.
- Simple computational changes (e.g., increasing the risk of control system failure for high emission sources) will allow simulation of higher emissions from the heavy tail of the data distribution.

# **Future Applications**

- Incorporate gas composition data into the Monte Carlo analysis to generate benzene concentrations. Add distance-to-population data and demographics to generate probabilistic risk assessments.
- Generate temporal profiles. Use this approach to design measurement site inspections to refine the data, identify super-emitters, and ground truth this approach.

