

Determination of OB Emission Factors Using an Unmanned Aerial System (“drone”) at Radford Army Ammunition Plant

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Emission Factors

EF = mass of a pollutant emitted/initial mass of ordnance

- Used for operating permit limits on demilitarization processes
- Historically have been determined by extrapolation from small scale BangBox tests and limited airplane plume sampling
- The representativeness and costs of these methods have been issues.
- Often there are simply no direct data upon which to base operational limits.

Since 2010 OB/OD/SF has been sampled at Tooele
Army Ammunition Depot and Camp Dundurn, CAN



Open burning of propellant at Tooele.



Open detonations at Tooele.

Sampling instruments lofted by a helium-filled, tethered aerostat.
Results are published in the peer-reviewed scientific literature by
EPA/ORD.

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Radford: EPA Office of R&D sampler and NASA “drone”



NASA-owned and flown
hexacopter



ORD sensor/sampler
system at Radford

At Radford

- 33 plumes sampled for
 - for particulate matter, metals including Cr VI, chloride, perchlorate, volatile organic compounds, chlorinated dioxins/furans, and nitrogen-based organics

The Radford Site and Tests Undertaken



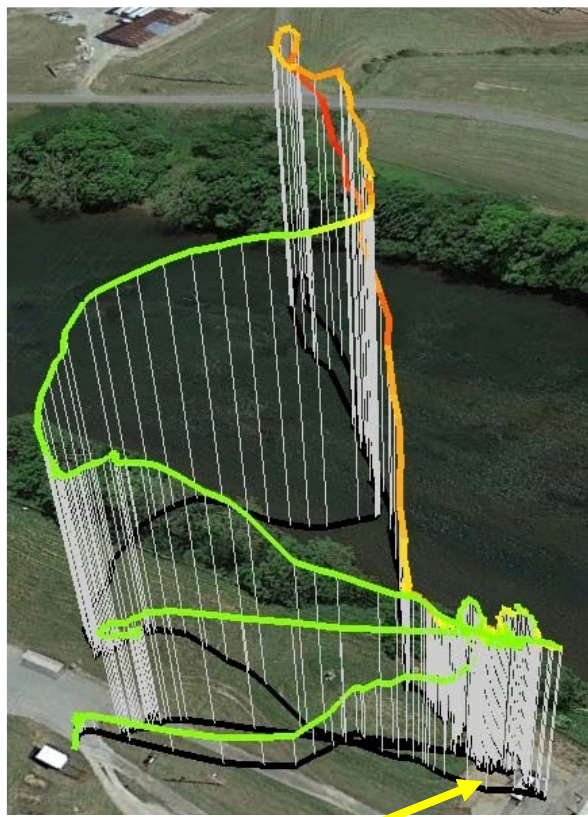
Test Date	Fuel	Amount of burn pans	Amount of Total pan load lb (kg)	Amount of Total waste lb (kg)
09/27/2016	MK-90	5	3,000 (1,364)	3,000 (1,364)
09/28/2016	Skid waste: Type 1	3	3,254 (1,479)	1,620 (736)
09/29/2016	MK-90	5	3,000 (1,364)	3,000 (1,364)
09/30/2016	Skid waste: Type 2	2	1,589 (722)	500 (227)
10/03/2016	MK-90	5	3,000 (1,364)	3,000 (1,364)
10/04/2016	Skid waste: Type 1	3	3,254 (1,479)	1,620 (736)
10/05/2016	MK-90	5	3,000 (1,364)	3,000 (1,364)
10/06/2016	Skid waste: Type 2	2	1,589 (722)	500 (227)

Skid Waste Description

Waste type/ Test Dates	Composition	Carbon Fraction of each component	Carbon fraction in burn pan
Skid waste Type 1 09/28/2016 and 10/04/2016	Pallets 46%	0.502 ^a	0.23
	Cardboard 0.28%	0.46 ^b	0.0013
	Diesel 3.8%	0.86 ^b	0.033
	Pit #1 4.3%	0.017 ^d	0.00074
	Pit #2 13%	0.046 ^d	0.0059
	Pit #3 4.3%	0.41 ^d	0.0018
	Grucci whistles 4.3%	0.16 ^d	0
	MCA-LAP Tracer slum 13%	0.0003 ^d	0.000043
	NRE 1 filters 2.8%	0.013 ^d	0.00035
	NRE tape 0.92%	0	0.00016
	NRE Contaminated 7.1%	0.046 ^d	0.0032
	Total Carbon fraction		0.28
Skid waste Type 2 09/30/2016 and 10/06/2016	Pallets 63%	0.502 ^a	0.32
	Cardboard 0.38%	0.46 ^b	0.0017
	Diesel 5.2%	0.86 ^c	0.045
	Pit #4 5.9%	0.052 ^d	0.0031
	Pit #5 11.8%	0.038 ^d	0.0045
	Pit #6 11.8%	0.056 ^d	0.0066
	NRE Contaminated 1.9%	0.046 ^d	0.00086
	Total Carbon Fraction		0.38

Samples Taken

Analyte	MK-90	Skid waste	Total
PM _{2.5}	5	2	7
Nitrocellulose	2	0	2
Nitroaromatics	4	0	4
PCDD/PCDF	0	4	4
Elements	5	2	7
Cr(VI)	5	3	8
HCl	0	6	6
Perchlorate/chlorate	0	6	6
VOCs	0	4	4



View from South east

Mark [#]	Time [mm:ss]	Height ASL [m]	CO ₂ [ppm]
1	00:00	524	431
2	00:49	542	1851
3	02:25	544	2831
4	02:39	561	3441
5	02:47	572	4085
6	02:54	583	2562
7	03:02	602	2678
8	07:13	586	436

Flight path of NASA UAV with EPA/ORD sampler system.

View from Northeast



Comparison of EFs with HHRA

- 25 of 26 VOCs were less than the HHRA emission factors
- Dioxins were over 1,000x lower than the HHRA
- For MK-90s, 7 of the metal EFs were lower than the RFAAP EFs and four emission factors were higher (As, Cd, Pb, and Ag).
 - Hg, was reported as ND so its ratio (<2.2) is not clearly greater or less than unity.
- For the skid waste burns, ten metals were less than estimated in the HHRA.
- All energetics (MK-90) were non-detect and less than the HHRA EFs

HHRA = Human Health Risk Assessment for Radford operating permit

Sampling Method

- First-ever drone measurements of demil operations
- Most comprehensive air sampling system ever developed for a drone
- Measurements are on the source itself; not a simulation
- Successful deployment: 100% of plumes were sampled
- Cost effective, safe, accurate, and representative measurements
- Relative standard deviations on measurements were low, lending confidence to the methods

EF Conclusions

- PM2.5 and VOC EFs were comparable to previous aerial measurements made by EPA/ORD since 2010
- Dioxin measurements show low EFs, comparable to biomass burning
- No nitroaromatic or nitrocellulose detection at Radford

Overall

The ability to make these measurements safely and efficiently can reduce uncertainty in permitting limits and bring actual source measurements to address public questions about impacts on human health and the environment.