Explosive Destruction of Chemical Munitions

Richard Soilleux

Introduction

- For many years found CW munitions have been destroyed using a ratio of 5:1 explosives to agent.
- The type and amounts of explosive used are based on theoretical calculations which have never been validated experimentally.
- There have been reports that un-burnt CW agent has been detected both in the crater and in the plume following disposal of CW munitions by this method.

Scope of Presentation

- This presentation describes a collaborative programme of experimental work, involving the UK and US, to test the 5:1 explosive destruction method.
- Phase 1 carried out on Dstl Porton Range from 8th February to 17th March. Phase 2 is imminent.
- Surrogate munitions filled with, dimethyl methylphosphonate (DMMP), or nerve agent (10%GB in triethylphosphate (TEP)), were destroyed explosively.
- This work provides the first experimental data on destruction efficiency for the method and also provides accurate input data for computer modelling.

Effects of explosive type

- Theoretical work at Sandia shows that CW agent breakdown occurs in the fireball as the hot gases arising from the detonation burn in air.
- The extent, temperature and duration of the fireball all depend on explosive type and are greatest for explosives that produce a mixture of fuel rich gases.
- C4, plasticized RDX (cyclotrimethylene-trinitramine), produces a fireball that is just sufficiently hot and long to destroy CW agent.
- Explosives containing aluminium burn longer and hotter so should be better.
- C4 was selected for most trials but two were also carried out using PE6, plasticized RDX with 15% aluminium.

Choice of CW agents and simulants

- **Phase 1, simulants**
  - For reasons of safety, phase 1 consisted entirely of CW agent simulant.
  - The simulant chosen was dyed DMMP which is reasonably close chemically to nerve agents, has relatively low toxicity and is readily available.
- **Phase 2, CW agents**
  - The nerve agent trials used a 10% solution of GB (85 – 90% purity) in TEP to mimic the degraded mixture.
  - The trials with H, where decomposition is less, used ~ 99% pure material.

Trial constraints

- For reasons of safety the trials were limited to the central area of the Porton Range within tight meteorological limits.
- Noise constraints limited the explosive charges to 10kg and, for the 5:1 ratio, a limit of 2kg of dilute CW agent or simulant. The trials were therefore limited to single items, scaled down for the larger type (rockets).
- Nerve agent trials were limited to a 10% mixture in TEP because of range edge safety limits. (Fortunately similar to degraded GB).
- The trials were limited to two representative types of CW munition.

(a) Rockets, filled with GB and of 5kg capacity were scaled to 2 litres and constructed from a thin walled (2mm) aluminium tube with welded ends and a filler plug.

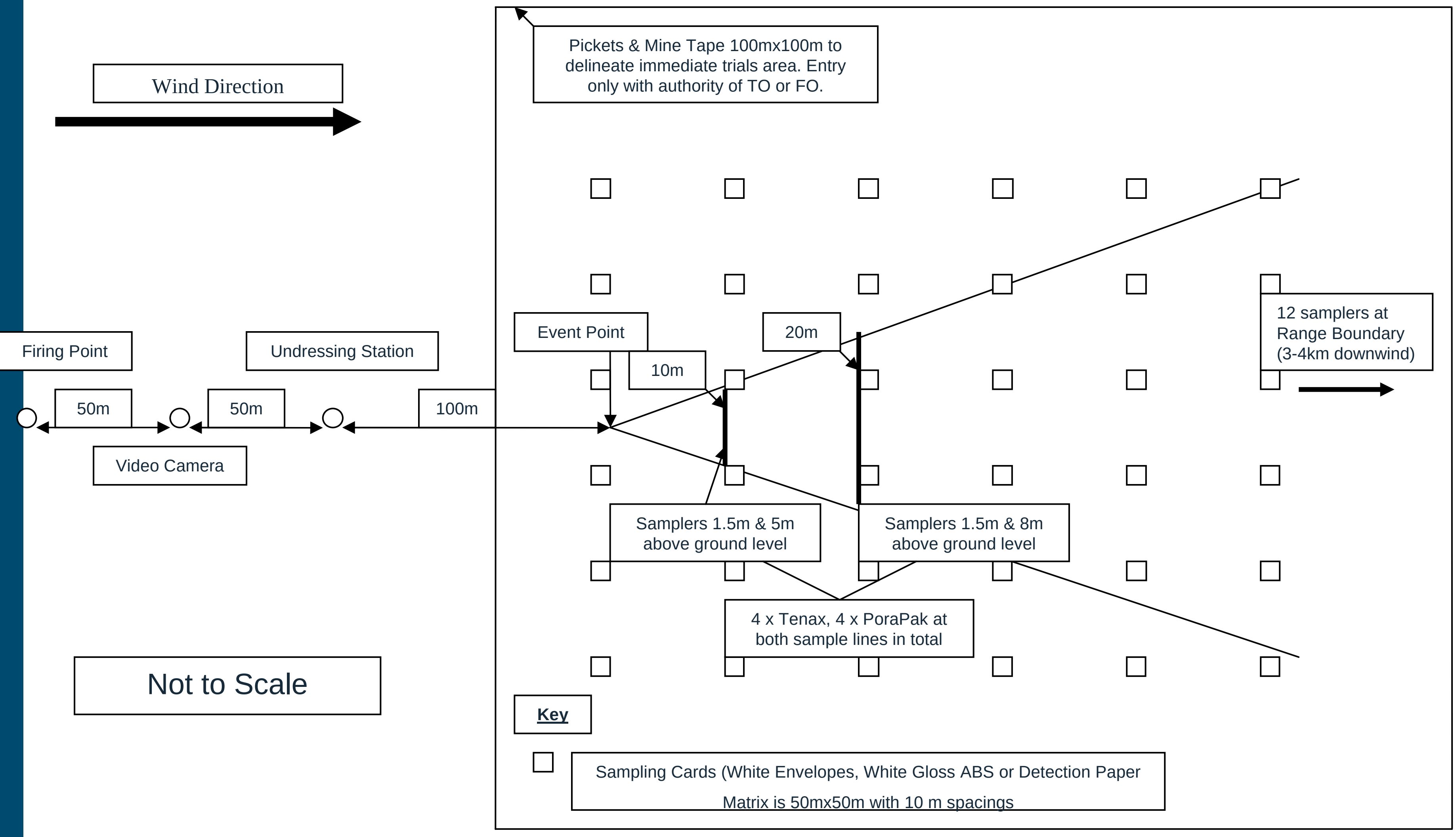
(b) **Mortars**, containing H and of 500ml capacity, were constructed from 100mm diameter steel tube of approximately 5mm wall thickness with welded ends and filler plug. Shown filled with dyed simulant and wrapped with 2.5 kg C4.

Safety considerations

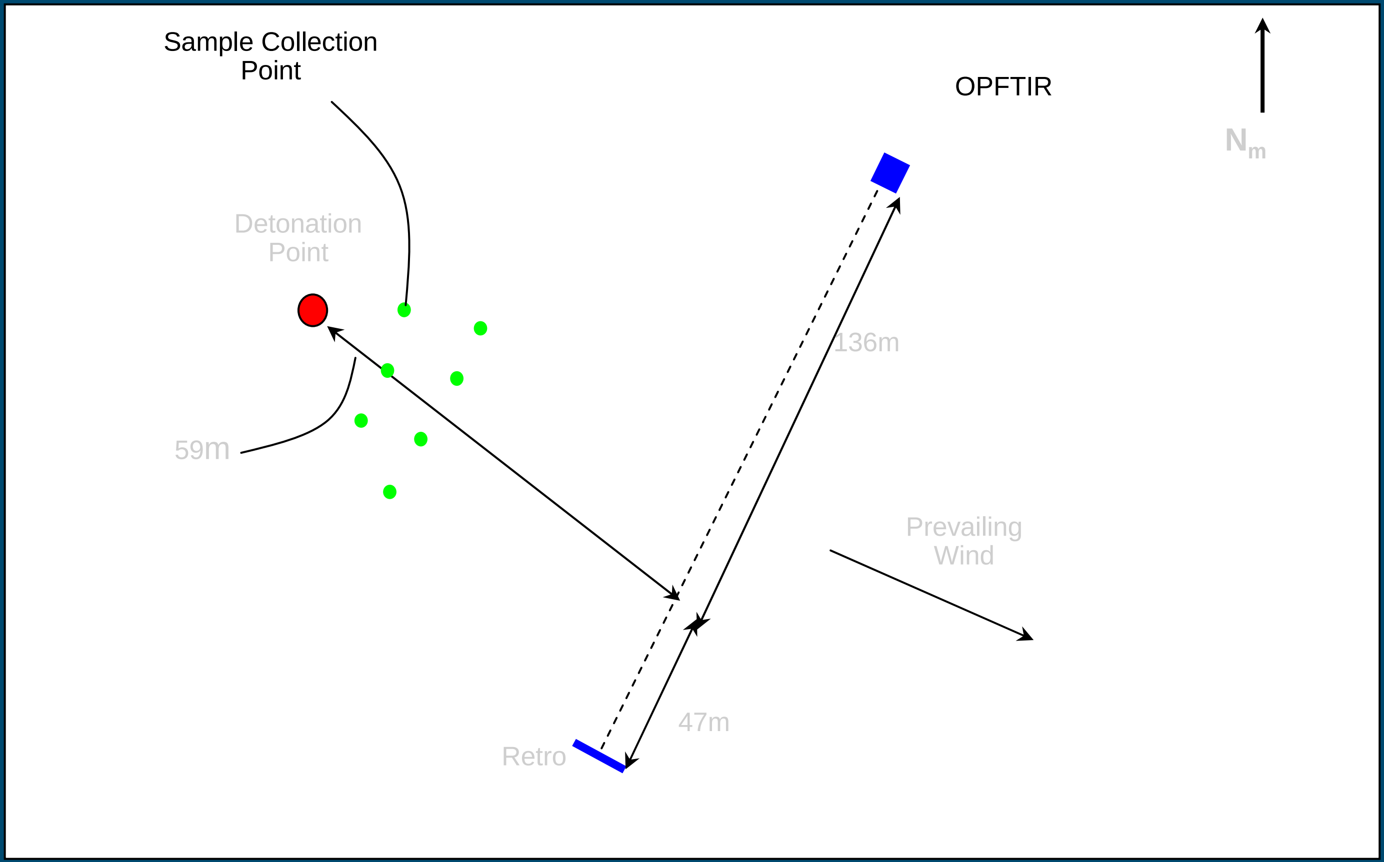
- Prior modelling of a range of scenarios provided estimates of vapour concentrations at various distance down-wind.
- Safe exposure limits used were 0.003 and 3.9 mg.min.m-3 for GB and H, respectively.
- Vapour sampling at the range boundary (approx 4km) confirmed that the public was not exposed to concentrations above these limits.
- Calculations for fragment throw were performed for the “heavy cased” mortar and the safety distance (830m) used for all trials though it would have been much less for the “light cased” rockets.

Sampling

- Vapour samples were collected on poropak/tenax tubes mounted on arrays of masts at heights up to 8m.
- A US operated OPFTIR was arranged downwind with the beam passing through the expected cloud path.
- UK operated scanning IR was used to try to estimate the plume dimensions.
- Liquid samplers used weighted Whatman no1 filter papers.
- Crater and ejected soil was sampled.
- Vapour samples were collected at the range edge.


Pickets & Mine Tape 100mx100m to delineate immediate trials area. Entry only with authority of TO or FO.
Wind Direction
Firing Point
Undressing Station
Event Point
20m
10m
12 samplers at Range Boundary (3-4km downwind)
50m
50m
100m
Video Camera
Samplers 1.5m & 5m above ground level
Samplers 1.5m & 8m above ground level
4 x Tenax, 4 x PoraPak at both sample lines in total
Not to Scale
Key
Sampling Cards (White Envelopes, White Gloss ABS or Detection Paper
Matrix is 50mx50m with 10 m spacings

OPFTIR Layout



Photography and Video

- Photographs were taken as a record of the trial.
- Video recordings were made using 2 cameras one facing down-wind, the other cross-wind.
  - Stills from the videos were used to measure cloud dimensions to give volumes.
  - Cloud transit times through the sampling array were taken from the videos to calculate sampling times/volumes and concentrations.

Fireball Effects: C4

Fireball Effects: brighter with PE6

Serial	Fill (kg)	Transit time (min)	Average collected (µg) (3 sig. fig.)	Average concentration (mg.m^{-3})	80% Confidence Interval
1	2.0 DMMP	0.165	0.527	3.19	(0.196, 1.42)
2	2.0 DMMP	0.140	0.163	1.16	(0.06, 0.439)
3	2.0 DMMP	0.340	0.119	0.35	(0.07, 4.636)
6	0.5 Mortar	0.185	0.445	2.41	(0.187, 1.059)
7	0.2 GB	0.420	0.033	0.08	(0.019, 0.047)
7	1.8 TEP	0.420	0.190	0.45	(0.09, 0.4)

Summary of averaged results from sorption tubes (combined tenax and poropak data)

Serial	Fill	Plume volume (m^3)	Average mass (g)	Average concn ($mg.m^{-3}$)	Destructn Efficiency (%)	80% Confidence Interval	95% Confidence Interval
1	DMMP	1195	3.8	3.19	99.81	99.49,99.93	-
2	DMMP	1813	2.1	1.16	99.89	99.72,99.96	-
3	DMMP	800.1	0.3	0.35	99.99	99.46,99.99	-
6	DMMP	2202	5.3(21.2)	2.41(9.64)	98.94	97.48,99.55	-
7	GB	6889	0.5(5.0)	0.08(0.8)	99.73	-	99.61,99.84
7	TEP	6889	3.1(3.4)	0.45(0.5)	99.83	-	99.64.99.92

Normalised values in brackets.

Destruction efficiencies based on plume volumes and transit times

Vapour sampling results

- Results from the sorption tubes were good.
- OPFTIR results were limited and qualitative because of obscuring effects of smoke and dust but generally confirmed sorption results.
- Scanning IR also limited and qualitative but did tend to confirm sorption results.

Ground contamination

- No liquid droplets were detected on any of the samplers.
- Significant amounts were detected in soil both inside and thrown out from the crater.

Serial	Fill (kg)	Crater dimensions			Conc in soil ($g.kg^{-1}$)	Soil mass* (kg)	Total mass in soil (g)
		d(cm)	h(cm)	v(litres)			
Blank	-	-	-	-	<0.01	-	-
5	2.0 DMMP	160	30	200	0.112	310	35
6	0.5 DMMP	80	30	50	0.689	100	69(276)
7	0.2 GB	160	30	200	<0.001	310	-
7	1.8 TEP	160	30	200	0.05	310	16(18)

•Soil mass from crater plus 30kg of sand. Normalised results in brackets.

Results from soil analysis

Serial	Agent/simulant		Explosive		Fireball		Mass	
	Type	Mass (kg)	Type	Mass (kg)	Width (m)	Height (m)	Plume (g)	Soil (g)
1	DMMP	2.0	C4	10	8.8	4.4	3.8	-
2	DMMP	2.0	C4	10	8.6	3.8	2.1	-
3	DMMP	2.0	PE6	10	10.5	5.0	0.3	-
4	DMMP	2.0	PE6	10	8.8	5.0	-	-
5	DMMP	2.0	C4	10	8.4	3.6	-	35
6	DMMP	0.5	C4	2.5	8.1	4.0	5.3	69
7	GB	0.2	C4	10	10.2	5.6	0.5	-
7	TEP	1.8	C4	10	10.2	5.6	3.1	16

Input data for computer modelling: fireball dimensions and agent/simulant vapour mass

Interim Conclusions

- 5:1 explosive destruction of CW munitions has been shown to destroy, on average, 99.51% according to vapour measurements.
- Soil contamination was 5 to 13 times higher than vapour probably because adsorption provides shielding from the fireball. Destruction efficiencies are then reduced to 85.14% in the worst case.
- Destruction efficiencies for mortars are less (factor of 6 or 7) than for rockets.
- As predicted, the high aluminium explosive PE6 is more efficient (factor of 10) than is the commonly used C4.
- Results for G agents are accurately reproduced using simulants so data from simulant and agent trials are equally valid for this type of trial.
- Estimates are given for computer modelling of burst diameters and residual agent.
- Crater formation, and hence soil contamination, could be avoided and higher destruction efficiencies achieved by placing wrapped CW munitions on a platform.

Recommendations

- The planned toxic trials with GB and H should be completed, and the simulant results confirmed, before the interim conclusions and recommendations are adopted.
- Pending confirmation of the results, disposals using the 5:1 method should avoid crater formation and minimise ground contamination by placing wrapped CW munition on a hard surface or platform.
- It is recommended that further large scale trials should be carried out, with CW agent simulants, to test the effects for full scale disposal operations with multiple munitions.