TECHNICAL NOTE

John D. Twibell,[1] *Ph.D.; S. Lynne Turner;*[1]
Kenneth W. Smalldon,[2] *M.Sc.; and Douglas G. Higgs,*[3] *FRSC*

The Persistence of Military Explosives on Hands

REFERENCE: Twibell, J. D., Turner, S. L., Smalldon, K. W., and Higgs, D. G., "**The Persistence of Military Explosives on Hands,**" *Journal of Forensic Sciences*, JFSCA, Vol. 29, No. 1, Jan. 1984, pp. 284-290.

ABSTRACT: Amounts of military explosives that were transferred to hands on contact have been quantified. Factors affecting the persistence of these residues were studied and it was found that about 90% was removed by a single wash. Subsequent washes were however progressively less efficient. Although cyclonite (RDX) and trinitrotoluene (TNT) could be detected easily after 24 h, their presence could not be established after 48 h on the hands of volunteers who had washed about twelve times.

KEYWORDS: criminalistics, explosives, nitroglycerine

The levels of nitroglycerine (NG) transferred to hands on contact with explosives and their subsequent persistence have been reported previously [*1*]. At the time of the original study (1976 to 1977) terrorist devices in the United Kingdom were almost exclusively constructed from such explosives but, more recently, military explosives such as trinitrotoluene (TNT) and cyclonite (RDX) have been used and it was therefore necessary to study their persistence on hands.

In any persistence study it is difficult to determine the amount initially transferred to the hands without terminating the experiment. It was therefore necessary to determine the levels of explosive that were transferred to hands on handling and then to use a simulation model [*1*] to determine the persistence of known amounts of the explosives.

Experimental Procedure

Purified samples of TNT, RDX, and pentaerythritol tetranitrate (PETN) (Propellants Explosives and Rocket Motors Establishment, Waltham Abbey, Essex, England) were dis-

Received for publication 26 Jan. 1983; accepted for publication 11 April 1983.

[1]Senior scientific officer and Sandwich Course student (University of Bath, England), respectively, Central Research Establishment, Home Office Forensic Science Service, Aldermaston, Reading, Berkshire, England.

[2]Principal scientific officer, Home Office Forensic Science Laboratory, Washington Hall, Euxton, Chorley, Lancs, England.

[3]Principal scientific officer (retired), EM2 Branch, Royal Armament Research and Development Establishment, London.

solved (10 mg/mL) in toluene (TNT) or acetone (RDX and PETN), and used to prepare analytical standards, and solutions for application to hands.

Handling Experiments

The military explosives (Atomic Weapons Research Establishment, Aldermaston, Reading, Berkshire, England) comprised a cast block of TNT (approximately 50 g), a lump of plasticized RDX (approximately 50 g), and some pellets of PETN (250 mg). Volunteers, using their right hands, picked up and gently squeezed a lump of RDX or TNT or five pellets of PETN, passed the sample to the left hand and squeezed it gently before putting it down. The volunteers then rubbed their hands together after which any contamination obvious to the naked eye was removed by an observer. Hands were swabbed immediately or after appropriate delays.

Solution Simulation

Solutions of the explosives (100 μg in 100 μL of toluene, for TNT, and acetone or ethanol for RDX and PETN) were spread over the whole palm area of subjects' hands using a dispensing pipette. After the solvent had evaporated subjects were told to continue their normal duties, but asked not to wash their hands. After appropriate delays the hands were then swabbed.

Swabbing Procedure

Hands were swabbed using pea-sized pieces of viscose wool pulled from "Tender Touch Cleansing Puffs" (Smith and Nephew, Welwyn Garden City, England), held in tweezers. The swabs were dipped into absolute ethanol (4-mL Analytical Reagent (AR) grade) in a small glass vial (10 mL) and excess solvent removed by squeezing the swab against the interior surface of the vial. The whole palm area and pad surfaces of the fingers were swabbed thoroughly three times, the swab being redipped and rinsed each time in the solvent. After the final swabbing, the swab was sealed in the solvent vial for analysis.

Swab solutions were subsequently diluted with ethanol or alternatively concentrated on a water bath (90°C with moderate air jet) to adjust their concentrations to the linear range of the instrument response.

Analysis by Electron Capture Gas Chromatography (GC-ECD)

A Pye 104 gas chromatograph with an electron capture detector (10 mCi Ni63) operated at 275°C was used with a short support-coated open-tubular (SCOT) column (13 m) coated with SP2100. Nitrogen was used both as carrier (2 mL/min) and makup (45 mL/min) gas. The column was operated isothermally at 140°C for TNT and 160°C for RDX and PETN. Injection volumes were 0.5 μL.

Explosives were quantified by comparing their peak areas with calibration graphs produced from injected standards.

Results and Discussion

Contact Levels and Short-Term Persistence

The amounts of the three explosives recovered after handling are shown in Tables 1, 2, and 3. It can be seen that the initial contact levels of the three explosives are markedly different. These differences are far greater than the intersubject variation that occurs with a

TABLE 1—*The amounts of RDX recovered from hands after handling the explosive.*

Subject	RDX Recovered (μg) at Intervals after Handling			
	No Delay		1-h Delay	
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
A left hand	827	552	...	...
A right hand	880	942	...	...
B left hand	...	...	104	37
B right hand	461	662	...	...
C left hand	3.4[a]	5.0[a]	...	...
C right hand	4.0[a]	178	...	...

[a] Hands washed immediately after handling, before swabbing.

TABLE 2—*The amounts of TNT recovered from hands after handling the explosive.*

Subject	TNT Recovered (μg) at Intervals after Handling			
	No Delay		1-h Delay	2½-h Delay
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
A left hand	4.8	44	...	...
A right hand	11	50	...	...
B left hand	25	...	...	2.1
B right hand	...	27	2.9	...
C left hand	1.4[a]	10[a]	...	...
C right hand	...	4.0[a]	0.9	...

[a] Hands washed immediately after handling, before swabbing.

TABLE 3—*The amounts of PETN recovered from hands after handling the explosive.*

Subject	PETN Recovered (μg) at Intervals after Handling	
	No Delay	1-h Delay
A left hand	150	...
A right hand	122	...
B left hand	...	13
B right hand	142	...
C left hand	4.0[a]	...
C right hand	9.0[a]	...

[a] Hands washed immediately after handling, before swabbing.

particular explosive. The greater initial contact levels of RDX compared with PETN or TNT are more likely to result from the physical nature of the material than to its chemical composition. The plasticized RDX had a "soapy" texture and presumably smeared easily onto the hands. The PETN pellets were noticed to disintegrated easily while the TNT block was highly crystalline and had a smooth shiny appearance.

Losses of each explosive over the first hour after contact appeared to be of the order of 90%, which agrees with earlier work on NG [*1*].

Effect of Washing

Tables 1 to 3 also show the effect of washing before swabbing. It can be seen that hand washing removes roughly 93 to 95% of the initial RDX or PETN contamination, but only about 80% of the initial TNT. This suggests that a greater proportion of the TNT contamination resulted from material absorbed by the skin rather than surface contamination which occurs with the other explosives.

Solution Simulation

Short-Term Persistence Without Washing—The above results show that the physical nature of the explosive can influence the results of a persistence study. It was therefore decided to reduce this effect by using the simulation model described previously for NG [*1*]. In this method standard solutions of the explosives were applied to hands so that the starting level of explosives could be established.

Tables 4 to 6 show the quantities of RDX, TNT, and PETN that were recovered from unwashed hands at periods of up to 8 h after the application of 100 μg of the explosives. Persistence curves (Fig. 1) plotted from the mean levels of explosive found at each time interval are compared with the earlier curve obtained for NG [*1*]. It can be seen that in all cases there was a rapid loss of explosive during the first 30 min, which decreased with increasing time. As expected from its volatility relative to the other explosives, TNT was lost more rapidly than RDX or PETN, but more slowly than NG. The results from RDX and PETN appear to be sufficiently similar to justify the use of one curve for both species.

Medium Term Persistence of RDX with Washing—From the above experiments it was decided to study the rate of loss of the most persistent explosive (RDX) over the working day. The explosive was applied to the hands of three laboratory workers. Although the actual handling results indicate that the first wash removes 90%, the simulation trials suggest that subsequent washes are progressively less efficient.

Overnight Persistence—When RDX was applied to subjects' hands just before they retired to bed and the hands swabbed the following morning before washing, higher levels of RDX (Table 4) were detected than in the corresponding daytime period. In longer persistence

TABLE 4—*Recoveries of RDX after 100-μg* solution applied to hands.

Subject	RDX Recovered (μg) at Various Times after Application[a]				
	½ h	1 h	2 h	4 h	8 h
A left hand	7.7	5.3	3.9	4.0	1.8
A right hand	10	5.6	5.2	2.6	0.6
B left hand	11	8.0	5.9	3.2	1.3
B right hand	9.7	8.8	3.6	2.5	1.0
C left hand	...	...	13	...	...
C right hand	...	...	6.5	...	...
D left hand	7.3	5.2	5.5	4.8	19.5[b]
D right hand	10	5.2	5.3	3.8	33.2[b]
E left hand	7.5	7.6	6.9	...	...
E right hand	5.2	4.0	3.9	...	...
F left hand	7.1	3.6	3.5	...	...
F right hand	4.8	1.8	1.2	...	...
Mean	8.0	5.5	5.4	3.5	1.2

[a] Each recovery is from a different experiment carried out on a different day. No reswabbing results are included. Hands were not washed during the persistence period.

[b] Overnight persistence.

TABLE 5—*Recoveries of TNT after 100-μg solution applied to hands.*

Subject	TNT Recovered (μg) at Various Times after Application[a]			
	½ h	1 h	2 h	8 h
B left hand	11	1.5	1.8	...
B right hand	12	1.2	1.5	...
C left hand	12	2.9	2.1	0.2
C right hand	5.3	3.3	1.5	0.4
D left hand	12	3.9	4.1	0.7
D right hand	7.2	3.4	4.2	1.0
E left hand	6.8	2.8	2.9	0.6
E right hand	7.1	1.6	2.4	0.6
G left hand	9.4	9.8	2.0	...
G right hand	7.6	5.1	3.0	...
Mean	9.0	3.6	2.6	0.6

[a] Each recovery is from a different experiment carried out on a different day. No reswabbing results are included. Hands were not washed during the persistence period.

TABLE 6—*Recoveries of PETN after 100-μg solution applied to hands.*

Subject	PETN Recovered (μg) at Various Times after Application[a]				
	½ h	1 h	2 h	4 h	8 h
A left hand	5.1	4.5	...	...	...
A right hand	2.6	6.0	...	...	...
B left hand	6.5	0.9	2.7	3.7	...
B right hand	4.8	4.2	1.6	3.3	...
C left hand	19	1.5	3.3	2.4	1.5
C right hand	10	2.9	3.0	1.6	1.9
D left hand	9.7	5.6	...	...	...
D right hand	6.0	3.3	...	...	...
E left hand	7.5	4.9	1.6	4.5	...
E right hand	5.3	3.7	1.8	2.7	...
Mean	7.7	3.8	2.3	3.0	1.7

[a] Each recovery is from a different experiment carried out on a different day. No reswabbing results are included. Hands were not washed during the persistence period.

experiments which included a sleep period, RDX could still be detected easily after 18 h (Table 7).

Persistence to a Realistic Detection/Confirmation Limit

It is possible to detect nanogram amounts of explosives in handswabs by GC-ECD, or possibly even subnanogram levels with appropriate cleanup techniques [*2,3*]. Without access to such techniques as thermal energy analysis [*4*],[4] it is not currently possible to confirm the identity of such low levels of explosives. In fact it would be difficult to confirm the presence of much less than 100 ng of TNT or 10 ng of RDX[4] by thin-layer chromatography (TLC) and it is therefore important to estimate persistence times to these, rather than to lower, levels.

If the persistence curves (Fig. 1) are extrapolated it would appear that, even with washing,

[4] J. D. Twibell, unpublished results.

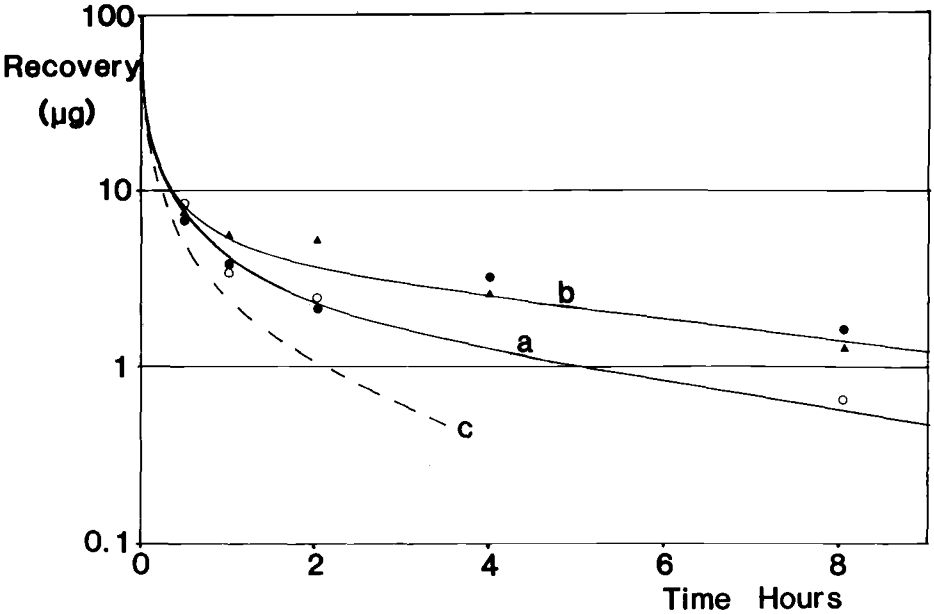

FIG. 1—*Mean persistence curves for* (a) *TNT* (○), (b) *RDX* (▲), *and PETN* (●), *following application of 100 µg of each species, compared with* (c) *that of NG.*

TABLE 7—*Recoveries of RDX after 100-µg solution applied to hands.*

Subject	Number of Hand Washes	RDX Recovered (µg) at Various Times after Application: 8 h	18 h (Overnight)
A left hand	2	...	...
A right hand		1.90	...
B left hand	2	...	...
B right hand		0.14	...
C left hand	6	0.13	...
C right hand		0.08	...
C left hand	3	...	0.13
C right hand		...	0.26
D left hand	4	...	0.59
D right hand		...	0.47

levels of these explosives which are capable of confirmation, should be found even after two to three days. Further experiments were therefore carried out to investigate this theory.

RDX and TNT were applied separately to the hands of laboratory workers and their hands swabbed at 24 or 48 h after application. It was found that for volunteers who had washed about twelve times both were detected at about the 30-ng level after 24 h. However, where hands had been washed 20 or more times it was barely possible to detect either species (less than 10 ng). Neither could be detected after 48 h on swabs from hands which had been washed at least twelve times.

Conclusion

Because of their lower volatility, military explosives persist for longer periods on hands than does NG. Although only low levels of explosives were found after 24 h, and attempts to detect either RDX or TNT after 48 h were unsuccessful, it cannot be concluded that detection after such intervals is not possible.

The results of this limited study serve merely as guidelines for the prediction of the persistence of military explosives on hands. There are so many factors which could affect the persistence that an exhaustive study would be completely impractical. Such a study would be tedious and would require the expenditure of time and operator involvement not commensurate with the small amount of additional information that it would be likely to produce.

References

[1] Twibell, J. D., Home, J. M., Smalldon, K. W., and Higgs, D. G., "Transfer of Nitroglycerine to Hands During Contact with Commercial Explosives," *Journal of Forensic Sciences*, Vol. 27, No. 4, Oct. 1982, pp. 783-791.

[2] Douse, J. M. F., "Trace Analysis of Explosives at the Low Picogram Level by Silica Capillary Column Gas-Liquid Chromatography with Electron Capture Detection," *Journal of Chromatography*, Vol. 208, No. 1, April 1981, pp. 83-88.

[3] Higgs, D. G. and Hayes, T. S., "Post Detonation Traces of Nitroglycerine on Polymeric Materials: Recovery and Persistence," *Journal of Forensic Science Society*, Vol. 22, No. 4, Oct. 1982, pp. 343-352.

[4] Lafleur, A. L. and Morriseau, B. D., "Identification of Explosives at Trace Levels by High Performance Liquid Chromatography with a Nitrosyl Specific Detector," *Analytical Chemistry*, Vol. 52, No. 8, July 1980, pp. 1313-1318.

Address requests for reprints or additional information to
John D. Twibell
Central Research Establishment
Home Office Forensic Science Service
Aldermaston, Reading Berkshire, England, RG7 4PN