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POST-CONTAMINATION VAPOUR HAZARDS FROM MILITARY VEHICLES CONTAMINATED WITH THICKENED AND UNTHICKENED GD (C)

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by

A. Bailey

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Technical Paper No. 249

February 1979

Chemical Defence Establishment,
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CDE TECHNICAL PAPER NO: 249

DATE: FEBRUARY 1979

POST-CONTAMINATION VAPOUR HAZARDS FROM MILITARY VEHICLES CONTAMINATED WITH THICKENED AND UNTHICKENED GD (C)

by

A. BAILEY

SUMMARY

The residual vapour hazards from four types of military vehicles previously contaminated with either thickened or unthickened GD have been measured over periods up to 72 hours. The effects of decontamination procedures, the use of impermeable paint, vehicle design and climatic conditions on the magnitude of these hazards have been investigated and an assessment made of their relevance to contamination control.

It was found that on permeable surfaces, e.g. alkyd paints, liquid GD had disappeared after approximately 30 minutes and decontamination procedures applied 15 minutes after the contamination had been applied were ineffective in reducing the subsequent vapour hazard; the vapour hazard arising from thickened GD contamination was less than that encountered with liquid GD. The employment of decontamination procedures following contamination of in-service military vehicles with thickened and liquid GD produced no significant decrease in the subsequent vapour concentrations.

On impermeable surfaces, e.g. polyurethane paint, liquid GD persisted for longer periods (at least 3 hours) and hence decontamination was relatively more effective in reducing the immediate post-contamination vapour hazard but even in this case weathering alone for 3 hours had the same effect as weathering alone on an alkyd-painted vehicle. In the case of thickened GD on polyurethane-painted vehicles it was observed that the agent persisted on the surface for up to 5 hours. Decontamination during this period would have reduced the immediate vapour hazard but would have had little effect on the

subsequent hazard. [It is suggested that the use of agent impermeable paint may be of little military value in the context of GD attack].

(Sgd). B.C. BARRASS,

Superintendent,
Detection & Analysis Division.

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INTRODUCTION

Laboratory experiments and field trials (e.g. 4, 9) have shown that complete decontamination of military vehicles and equipment with in-service decontamination apparatus is not possible for several reasons including the following: (1) Many of the paints, rubbers and other constructional materials are permeable to CW agents and readily absorb liquid agents. Since present decontaminants do not penetrate such materials the absorbed agent cannot be neutralised; it is subsequently evolved as vapour over a period of time, giving rise to protracted post-contamination vapour hazards. (2) Modern equipments often have components fabricated from unprotected light alloys and hence the use of Chemical Agent Decontaminant (CAD, see Appendix B), which is strongly alkaline and contains reactive chlorine, is not permissible. (3) For successful and effective neutralisation of CW agents, the agent and decontaminant need to be brought into intimate contact; the present decontamination apparatus (Apparatus Decontamination NBC Portable) achieves this by the use of brushes on lances. The design of current military vehicles and equipment is such that often much of the surface of the object to be decontaminated (e.g. the under surfaces of vehicles) is completely inaccessible to the decontamination brushes.

In view of the impossibility of effecting complete decontamination, the philosophy of contamination control, in which decontamination plays only a part, is being developed. The objectives of this approach are to devise procedures, which with the minimum of decontamination, will (a) allow the immediate military mission to be accomplished, (b) prevent the transfer of contamination to clean areas including collective protection, (c) reduce the challenge to the personal protective ensemble, (d) bring about an increase in military operational efficiency (such as by allowing the

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respirator to be doffed) and (e) give the local Commander a knowledge of the magnitude, extent, significance and duration of any remaining hazard (such as by the use of contamination monitors, tables of contamination etc.). This paper reports the results of an extended series of field experiments and laboratory studies conducted over the past three years in which the post-contamination vapour hazards from a number of military vehicles contaminated with GD have been studied as a contribution to the development of this philosophy. These experiments have allowed a number of recommendations to be made regarding the use of impermeable vehicle paints to reduce vapour hazards, the effectiveness of decontamination and the magnitude, duration and military significance of residual vapour hazards. Preliminary studies on the efficiencies of the various Service decontamination procedures have already been reported (4, 9).

EXPERIMENTAL PROCEDURES

A number of redundant military vehicles were obtained from various sources and serviced to a condition in which they could be driven. The vehicles were finished with either conventional matt Army green glycero phthalate (alkyd, GP) paint or with agent impermeable catalytically hardened polyurethane (PU) paint. After contamination with GD (thickened or unthickened), the vehicles were subjected to a variety of decontamination and/or weathering procedures and the subsequent rate of vapour evolution from the vehicles was monitored. A description of the experimental procedures is given in Field Trial Programme 5/73 (reproduced in Appendix A) and amplified where necessary below.

(a) Vehicles

The following vehicles were used:-

(i) "Centurion" main battle tank

(ii) Armoured personnel carrier (Type FV 432)

(iii) Two "Saladin" armoured cars (Type FV 601(C))

(iv) Two Bedford 4-tonne 4 x 4 dropside cargo trucks with canvas tilts (Type FV 13112)

One vehicle of each type was painted with Army matt green GP paint (Specification FVRDE 2012) and a Saladin and a cargo truck were finished with PU paint (Specification DTD 5580). The GP paint films were over one year old and the PU paint films three months old when the experiments began.

(b) Contamination of the Vehicles

(i) Unthickened GD

Details of the experimental procedure are given in the Field Trial Programme 5/73 reproduced in Appendix A. The agent was applied to the front, near side and the top of the vehicle with a hand-held "Killaspray" to a nominal contamination density of 5 g m^{-2}. Agent contamination density was measured by thirteen sampling felts attached to the vehicle (see Appendix A). After the removal of the felts for analysis the vehicle was driven to a clean open area for decontamination and/or weathering. The vehicle was then driven into an enclosed chamber so that any vapour being evolved from the vehicle could be measured.

(ii) Thickened GD

GD containing 5% w/w of thickening agent was prepared by mixing a 10% w/w solution of methacrylate polymer (Rohm and Haas Acryloid K125) in dichloromethane with the pure agent. The co-solvent was then stripped from the solution under reduced pressure using a water-pump. The solution was maintained at a temperature of 30 - 35°C over a water bath during the operation.

Contamination of the vehicle was achieved in a fashion similar to that for unthickened agent except that a domestic electric paint sprayer was used (Wagner Model 320/240). The mass median diameter of the agent drops was in the range 2.5 - 4.0 mm, with "strings" of agent attached to many of the drops.

(c) Decontamination and Weathering

Decontamination was effected using the 'Apparatus Decontamination NBC Portable' filled with the recommended decontaminating solution, the specification of which is reproduced in Appendix B. The solution was applied with brushing at the rate of 200 - 400 ml m^{-2} to the contaminated surfaces of the vehicle. If further hosing with water was required this was provided from a fire tender at the rate of about 10 gallons per minute at a pressure of 50 psi for 15 minutes.

Weathering was achieved by allowing the vehicle to stand in the open air for the required period.

(d) Assessment of the Residual Vapour Hazard

A polythene-lined thermostatted ($\pm$ 2°C) chamber into which vehicles could be driven was erected on the range. The internal volume of the chamber was 460 m^3 (after Trial 32 a new chamber was constructed with internal volume 790 m^3). The rate of disappearance of GD vapour in the chamber was measured and found to decay exponentially with a rate constant of 0.10 h^{-1} (0.18 h^{-1} after Trial 32).

Contaminated vehicles were driven into the chamber and the chamber was then sealed. Several electric fans were used to stir the chamber air and ensure complete mixing. The agent vapour concentration was then monitored for up to 72 hours by the methods outlined in Appendix A. The measured quantities were expressed as dosages (Ct values in mg $h^{-1}m^{-3}$).

RESULTS AND DISCUSSION

1. General Introduction

A total of thirty-nine experiments have been carried out; the data arising from these experiments are presented in Appendix D.

The evolution of vapour from GD absorbed into paintwork and other agent-permeable materials on the vehicle is likely to be diffusion controlled and has therefore been assumed to be a first-order kinetic process. Similarly, agent losses from the vehicle exposure chamber (adsorption on the walls etc.) are likely to be diffusion controlled and have been shown to follow first order kinetics (Section (d) above). Combination of the two rate processes (Appendix C) leads to the equation:-

$$ct = \frac{K_1 m_o}{V(K_2 - K_1)} \left[\frac{1}{K_1}(1 - e^{-K_1 t}) - \frac{1}{K_2}(1 - e^{-K_2 t}) \right]$$

where K_1 is the rate of desorption of GD from the vehicle (h^{-1})

K_2 is the rate of absorption of GD by the chamber (h^{-1})

V is the volume of the chamber (m^3)

m_o is the mass of GD on the vehicle and available for evolution immediately on entry into the chamber (mg)

t is the time elapsed after entry into the chamber (h)

ct is the measured dosage over the sampling period, t (mg $h^{-1}m^{-3}$)

The experimental data have been fitted by an iterative computer method to this equation to derive values of K_1 and m_o. The fitted curves are shown in Figures C1 - 39. All data recorded in Tables 1 - 9 and used in the detailed analysis of these field experiments have been normalised to a standard GD contamination density of 10 g m^{-2} (1(b)) and corrected for any impurity in the agent. This normalisation procedure has been justified experimentally (see Appendix E).

Contamination of vehicles by hand-spraying inevitably leads to considerable variations in the agent contamination density on the vehicle surface. Similarly, the irregularity of vehicle surfaces (hubs, wheels, accessories etc.) also leads to irregularity of contamination level. Experience over a large number of field trials (e.g. reference 3) indicates that the range of contamination levels will be within 50% of the mean level and differences in residual vapour hazard measured in similar experiments can be expected to be of this order. Discussion of the results contained in Tables 1 - 9 have been separated into the five sections below.

2. Conventional Glycerophthalate Painted Vehicles Contaminated with GD

(a) Weathering time

It was found that GD penetrated rapidly into GP paint and other permeable materials on the vehicles and after half an hour it was not possible to detect free liquid agent on the vehicle with single colour detector paper (Detector Paper No.2, Mk.1). This is less than half the expected lifetime of a GD droplet of 200 μm diameter on an impermeable surface (Table 1) calculated by the method of Slack and Cameron (6) but is consistent with laboratory experience. Table 2 summarises the loss of the contamination from the vehicles, the value for m_o being obtained by extrapolation to zero weathering time. The required weathering time (t_R) is that time for which the vehicles must be weathered before it

TABLE 1

LIFETIMES OF GD DROPLETS ON IMPERMEABLE SURFACES

$$\text{Lifetime (hours)} = \frac{1.66r^2\rho}{4DC_o}$$

r = drop radius

ρ = liquid density

D = diffusion coefficient

C_o = saturated vapour concentration

Temp. (°C)	5	10	20
C_o (g l^{-1})	0.75×10^{-3}	1.10×10^{-3}	2.65×10^{-3}
Drop radius (μm)	Drop lifetime (hours)		
200	1.03	0.70	0.29
500	6.41	4.37	1.81
1000	25.66	17.50	7.26

would be safe to work in a typical workshop (5) with the vehicle for an 8 hour shift. The calculation and assumptions are shown in Appendix E. It can be seen that there are considerable differences between the residual hazards from the various vehicles which reflect the differences in their construction. The "required weathering times" range from 20 to over 80 hours and in temperate climates therefore, it seems reasonable to regard vehicles which have been weathered for at least three days as being clear of GD contamination, provided items such as canvas tilts are abandoned. A more extensive Table of required weathering times is given in the conclusions (Table 10).

TABLE 2

VAPOUR HAZARDS FROM GD-CONTAMINATED GP-PAINTED VEHICLES

Vehicle	K_1 (h^{-1})	m_o (mg)	Contaminated surface area (m^2)	$m_o\ m^{-2}$	t_R* (h)
Centurion	0.11	1900	20	32	28
FV 432	0.19	2300	29	80	20
Saladin	0.06	7000	30	250	60
Truck with tilt	0.054	13500	42	320	80+
Truck without tilt	0.045	3000	30	100	58

* t_R is the weathering time required to reduce the rate of desorption from a vehicle initially contaminated with 10 g m^{-2} GD so that if the vehicle was placed in a typical workshop (1000 m^3, one air change per hour) it would be safe to work with it for a full shift (8 hours).

(b) Effect of weathering temperature, wind and rain

Neale has shown (2) that when no free liquid GD is present and when the contamination of paintwork and the subsequent vapour evolution from the paintwork take place at the same temperature, then temperature has little effect on the rate of vapour evolution. A much greater effect was noted for the case of contamination at a low temperature followed by desorption at a higher temperature. The experiments reported here are analogous to former conditions above and an examination of the results shown in Table 3 are consistent with previous findings (2) over the temperature range studied here (approx. 0^oC - 20^oC). Safety considerations prevented experiments being carried out in wind conditions outside a narrow range (2 - 7 ms^{-1}) and in rainy weather, but the laboratory findings of Neale (2) indicate that ventilation rates over contaminated surfaces have little effect in the conditions which pertained during these experiments. On three occasions vehicles were sprayed with water to simulate light rain for a few minutes during the period in which the rate of vapour evolution was being monitored. Any change in desorption rate on spraying was less than the experimental error in monitoring the rate.

TABLE 3

EFFECT OF TEMPERATURE ON AGENT DESORPTION RATE

Vehicle	Temperature (^{o}C)	Weathering Time* t_w (h)	$\frac{dm}{dt}(t_w)$ (mg min^{-1})
Truck with tilt	-0.4	3	10.4
	+2.7	3	13.7
	8.1	3	5.4
	11.8	3	9.2
Truck without tilt	0.7	3	1.5
	7.0	3	2.5
	9.3	3	1.6
FV 432	6.8	0.5	6.1
	13.3	0.5	7.6
	20.8	0.5	6.7
	6.5	3	3.1
	14.6	3	2.6

* t_w is the weathering time (h) which has elapsed before the rate of vapour desorption, $\frac{dm}{dt}(t_w)$, (mg min^{-1}) is measured.

(c) Effect of decontamination

An examination of Table 4 shows that the decontamination procedures, even when commenced only 15 minutes after contamination has taken place, do not have any significant effect in reducing the vapour hazard from a vehicle.

TABLE 4

EFFECT OF DECONTAMINATION ON AGENT DESORPTION RATE

Vehicle	Decontamination	t_w (h)	$\frac{dm}{dt}(t_w)$ (mg min^{-1})
FV 432	No	3	2.6
	Yes	3	3.1
	No	0.5	6.7
	Yes	0.25	7.6
	Yes	0.25	6.1
Truck with tilt	No	0.5	18.0
	No	0.5	7.8
	Yes	0.25	31.1
	Yes	0.25	29.4

N.B. The decontamination operation takes fifteen minutes to perform, thus it is thirty minutes before the rate of vapour desorption from the vehicle can be measured. Hence in these experiments, for the case of no decontamination, the rate of vapour desorption at t_w = 0.5 h is compared with the rate of vapour evolution at t_w = 0.25 h for the decontaminated case.

(d) Vapour desorption rates from GP painted vehicles

Table 5 lists the initial desorption rates for GD from each vehicle calculated using the constants listed in Table 1 for the situation with no free liquid on the vehicle surface; the desorption rates from simple painted metal plates (4, 9) are included for comparison.

It can be seen that the observed vapour desorption rates from two of the conventionally painted vehicles used in these experiments are considerably smaller than those from similarly prepared 1 m^2 plates used in the laboratory. A short investigation to be reported separately revealed that paint weathered outdoors for two months was far more agent-resistant than similar painted surfaces which had been kept indoors. An additional and more marked effect was also observed in that painted surfaces which had been decontaminated with CAD were far more resistant to subsequent agent contamination and the residual

TABLE 5

INITIAL DESORPTION RATES FROM VEHICLES

Vapour Source	Desorption rate ($mg\ m^{-2}h^{-1}$)
Centurion (MBT)	3.5
FV 432 (APC)	15.2
Saladin (AC)	15.0
Cargo truck	4.5
Cargo truck with canvas tilt	17.3
Painted plate (weathered after contamination for one hour)	11.5
Painted plate (decontaminated with CAD after one hour)	11.9

vapour hazard from surfaces treated in this way was reduced eight-fold. The two vehicles used in these experiments had been used in previous agent trials and had been decontaminated using CAD. This fact probably accounts for the differences between the plate and vehicle results in Table 5. The results obtained from these experiments are probably typical of vehicles which have been in service for six or more months but it is likely that the hazard from a contaminated freshly painted vehicle could be at least five times that measured in these experiments. It would appear from these incidental observations that subjecting painted surfaces to a relatively simple treatment may significantly enhance their resistance to chemical agent penetration and markedly reduce after-attack hazards.

3. Contamination of Conventional GP-painted Vehicles with Thickened GD

A cargo truck and a Saladin armoured car were contaminated with thickened GD and weathered for three hours before the residual vapour hazard was monitored. The results are tabulated in Table 6. It was observed that all free liquid on the vehicle surface had disappeared by absorption or evaporation by the end of the weathering period.

The Table shows that for equivalent contamination levels, the hazard from the thickened agent is less than one-fifth of that from pure GD. The reason for this is probably because the greatly restricted spreading of the thickened agent over the paintwork reduces the amount of agent which can penetrate into

the paint by reducing the area available for penetration; thus less agent in total is subsequently available for desorption. These observations are consistent with those from laboratory experiments (4).

If, as has been reported (7), the likely contamination level for thickened GD is 0.3 g m^{-2} (as opposed to the NATO figure of 10 g m^{-2}) (1), then the evaporation rate from these vehicles will be sufficiently low after three hours weathering to allow a full 8 hour shift to be worked on the vehicles in a 1000 m^3 workshop without decontamination.

TABLE 6

THE CONTAMINATION OF GP PAINTED VEHICLES WITH THICKENED AND UNTHICKENED GD

Vehicle	Agent	t_w (h)	$\frac{dm}{dt}(t_w)$ (mg min^{-1})
Cargo truck Without tilt	GD	3	1.5, 2.5, 1.6
	Thickened GD	3	0.39
Saladin	GD	3	5.9
	Thickened GD	3	0.63

4. PU Painted Vehicles Contaminated with GD

A cargo truck and a Saladin armoured car were painted with a CW agent-impermeable polyurethane finish (8). The vehicles were then contaminated with GD and the effects of various post-contamination regimes examined.

(a) Weathering

Examination of Table 7 shows that after vehicle contamination has taken place there is a much higher rate of agent evolution from PU painted vehicles. After about 3 hours the rate of vapour evolution has fallen below that from a similarly contaminated GP-painted vehicle. A significant, though small, vapour hazard persisted for about 24 hours in the case of the cargo truck and for about 10 hours for the Saladin (Figures, Appendix C). It was likely that this vapour was evolving from permeable materials and not from the PU paintwork (tyres, rubber seals, grease etc.) and from liquid trapped in cracks and crevices. The differences in the hazard durations of the two vehicles

may well reflect the cleaner construction lines of the armoured vehicle.

TABLE 7

COMPARISONS OF VAPOUR HAZARDS FROM PU AND GP PAINTED VEHICLES CONTAMINATED WITH UNTHICKENED GD (NO DECONTAMINATION)

Vehicle	t_w (h)	$\frac{dm}{dt}(t_w)$ PU (mg min^{-1})	$\frac{dm}{dt}(t_w)$ GP (mg min^{-1})
Cargo truck without tilt	0.2	52.5	(5.9)*
	0.5	7.0	(2.5)*
	3	1.1, 1.3, 0.89	1.5, 1.6, 2.5
Saladin	0.25	-	20.2
	0.5	21.4	7.3
	3	1.00	5.9

* The bracketted figures are from experiments with a similar but not identical truck.

(b) Decontamination

A marked reduction in post-contamination hazard was brought about by the application of decontamination procedures to the Saladin (Table 8). The improvement was not sufficient to allow immediate unmasking in the vicinity of the vehicle or to enable immediate workshop repairs to begin. It is estimated that the required weathering time (t_R) would be reduced from over 60 hours to about 8 hours (Table 10).

TABLE 8

VAPOUR HAZARDS AFTER DECONTAMINATION OF A PU PAINTED SALADIN AFTER CONTAMINATION WITH UNTHICKENED GD

	t_w (h)	$\frac{dm}{dt}(t_w)$ (mg min^{-1})
Decontaminated*	0.25	3.2
Not decontaminated	0.5	21.4

* See footnote to Table 4.

5. PU Painted Vehicles Contaminated with Thickened GD

In contrast with the case of a GP-painted Saladin, where the vapour hazard after 3 hours weathering was lower for thickened GD than for unthickened agent, with the PU painted Saladin, the vapour hazard was somewhat greater after contamination with thickened GD (Table 9). The explanation of this observation probably lies in the fact that there is little loss of agent by penetration into paintwork for the PU painted vehicle, hence agent losses are mainly by evaporation. With unthickened agent, there was no detectable free liquid on the vehicle surface after 3 hours weathering, evaporation being complete; with the thickened GD, free liquid could still be detected and was still evaporating. In these circumstances a reduction in both vapour and contact hazard would have been possible by the application of standard decontamination procedures (4).

TABLE 9

CONTAMINATION OF A PU PAINTED SALADIN WITH GD (NO DECONTAMINATION)

Agent	t_w (h)	$\frac{dm}{dt}(t_w)$ (mg min^{-1})	m_o
GD	3	1.00	299
Thickened GD	3	1.54	2019

Advantages and disadvantages of GP and PU paints

With GP paints, free unthickened GD has disappeared from the surface of the paint in about 30 minutes, hence there is no contact hazard after this time; on PU paint, the agent and therefore the contact hazard lasts for about 3 hours. If no decontamination is carried out, the vapour hazard associated with the PU painted vehicle will be considerably higher than for the GP painted vehicle for the first 3 hours after attack; thereafter, the vapour hazard will be lower. For a PU painted Saladin the vapour hazard will persist for about 8 hours and for a GP painted Saladin about 60 hours. Decontamination applied before free liquid has disappeared will remove the contact hazard but is not effective in reducing the residual vapour hazard.

Thickened agents persist on GP paint for less than 3 hours but for at least 5 hours on PU paint. The vapour hazard was lower than from unthickened agents for both paints and the differences in residual vapour hazard from the paints much less marked.

The choice of paint will be determined by the balance between the increased duration of the contact hazard period and the shortened residual vapour hazard and whether the higher cost of the PU system is justified by any advantage gained by its use.

6. Vehicle Design

The value of m_o given in Table 2 for each vehicle represents the amount of GD retained by the vehicle and available for desorption after the free liquid GD on the various surfaces had disappeared. By measuring the silhouette areas projected by the top, side and front of each vehicle, a nominal figure for the amount of retained agent per unit area ($m_o\ m^{-2}$) for each vehicle was calculated and is reported in Table 2.

The vehicle which retained most agent was, as might have been expected, the cargo truck fitted with its tilt. It took well in excess of 80 hours for the evaporation of agent from the tilt to fall to a safe level. There was a marked difference in the desorption rate constant, (K_1) for the two armoured tracked vehicles compared with the rubber-tyred wheeled vehicles, the former having a much greater decay-rate and therefore becoming 'safe' more rapidly. It is also worthy of note that the Centurion main battle tank, with its cleaner lines and shielded tracks, presented less opportunity for the agent to gain the shelter of cracks and crevices and enabled ready evaporation. This was reflected in the Centurion having the lowest ($m_o\ m^{-2}$)

figure of all the vehicles tested.

The above considerations demonstrate that post-contamination vapour hazards can be minimised not only by using the minimum of absorbent materials but also by the design of vehicles with clean uncomplicated surfaces and with the minimum of non-flush mounted accessories.

7. Post-Contamination Hazards from Vehicles Contaminated with Mustard

The conclusions drawn from the work reported in this paper about the contamination control of the relatively non-persistent agent, GD, will require tempering by some consideration of the problems likely to arise following the application of persistent mustard contamination. No experiments with mustard were undertaken in this work but a summary of the literature dealing with post-contamination hazards from mustard contaminated vehicles is being carried out and will be reported subsequently.

CONCLUSIONS

(a) Conventionally painted vehicles

1. The contact hazard from an unthickened GD attack in temperate climates (above $0^{o}C$) has disappeared from permeable surfaces within 1 hour and the vapour hazard in a confined space after 3 days weathering.

2. After a GD attack, decontamination of conventionally painted vehicles, even if carried out only 15 minutes after the attack, is ineffective in reducing the subsequent vapour hazard.

3. Following attack with thickened GD, the contact hazard had disappeared after 3 hours and the residual vapour hazard was less than one-fifth of that from a similar attack with pure GD.

4. Weathering of vehicles outdoors and/or treatment of vehicle surfaces with a solution of package (G) of the CAD pack renders the paintwork considerably less permeable to GD and greatly reduces the longer term vapour hazard following GD contamination.

(b) Polyurethane-painted vehicles

5. During the first three hours after GD attack the vapour hazard from PU painted vehicles is greater than from GP painted vehicles; thereafter the hazard is less.

6. Decontamination effects a reduction in the vapour and contact hazard from PU painted vehicles. The reduction is not sufficient to permit

immediate unmasked safe working in confined spaces for high initial contamination densities (above 1 g m^{-2}).

7. The duration and severity of the vapour hazard from a thickened GD attack on PU painted vehicles is greater than in the case of GP painted vehicles.

(c) General

8. Suitable vehicle design will considerably reduce vapour hazards from contaminated vehicles.

9. A summary Table of required weathering times can be compiled (Table 10).

TABLE 10

REQUIRED WEATHERING TIMES (t_R HOURS) FOR VARIOUS VEHICLES

Vehicle	Vehicle paint type			
	GP		PU	
	Contaminating agent			
	GD	TGD*	GD	TGD*
Centurion	28	-	-	-
Saladin	60	(24)	(8)	(16)
FV 432	20	-	-	-
Truck with tilt	80+	-	-	-
Truck without tilt	58	(24)	8	-

The figures in brackets are derived from one experiment only.

* TGD is thickened GD.

Influence of decontamination on the above times:

(a) Glycerophthalate paint/unthickened GD - no effect

(b) Glycerophthalate paint/TGD - not determined

(c) Polyurethane paint/unthickened GD - reduces t_R by 4 hours

(d) Polyurethane paint/TGD - not determined

It is expected from laboratory experiments that for case (b) there will be little effect but for case (d) decontamination will be very effective.

ACKNOWLEDGEMENTS

The author acknowledges the invaluable assistance of Messrs. B.J. Purser, M.L. Wheeler, W.G. Wills and K. Sinclair in carrying out many of the trials reported here.

REFERENCES

1. a) UK Service Requirement, NGASR 3040.
   b) NATO Document AC/196 (WP7) D.100.
2. H.E.R. Hartley, E.H. Letts, R.D. Lynch and E. Neale, CDE TP 13.
3. J.L. Clipson, CDE FTR 12.
4. A. Bailey, CDE TN 313.
5. N. Thompson, CDE/IL.1061/1370/73, page 58.
6. G. Slack and P. Cameron, CDE TN 91.
7. B. Thurston, CDE TN 289.
8. H.E.R. Hartley and E. Neale, CDE TN 147.
9. W.C. Evans, CDE FTR 30.

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APPENDICES

APPENDIX A	-	Field Trial Programme No.5/73
APPENDIX B	-	Chemical Agent Decontaminant (CAD)
APPENDIX C	-	Vapour Evolution Rates in a Chamber. Figures C1 - 39
APPENDIX D	-	Tabulated Data
APPENDIX E	-	Normalisation of Contamination Density
APPENDIX F	-	Calculation of the Required Weathering Time

APPENDIX A

PROGRAMME NO. 5/73

EVALUATION OF THE VAPOUR HAZARD FROM A CONTAMINATED APC IN A NIGHT HIDE SITUATION

PART II. EXAMINATION OF VARIABLES

Circulation:-

Participants:	HAS (3)	STCD (5)	SCD (5)	SERD (2)
	HRS (4)	S.Met.D.	EMO	S.Med.D.
For information:	Director	AFEO		
	DD(D)	USASR (4)		
	TSO(D)	Tech.Reg. (2)		
	HTIRS			
	NEO	DRES (2)		
	SMO	Weapons 8 (2)		
		Field Trials Sub-Committee (8)		

Project No: 3407

File No: TD.6000

INTRODUCTION

1. Measurements of vapour evolution from painted surfaces contaminated with various CW agents have been made in laboratory experiments. In addition, in 1969, the vapour hazard arising from a contaminated APC in a 'Night Hide' situation was evaluated. The results of the latter trial showed that a long-term hazard could arise, even when the surface showed no detectable contamination, but that exposure of men to military significant dosages could be very much reduced by careful use of vapour detection devices. The scope of the 'Night Hide' Trial was limited and additional trials are required to examine the effects of weathering and/or decontamination.

OBJECT

2. To measure the long-term vapour hazard within the 'Night Hide' situation arising from a contaminated vehicle after it has been exposed to various weathering and decontamination processes.

SITE AND TIME

3. Spraying will be carried out in an area agreed between personnel carrying out the spraying and HRS. Weathering will be carried out in an exposed position. Vapour evolution will be measured in an enclosure set up within the range area. Early Summer 1973 through Winter 1973 - 1974.

METEOROLOGICAL CONDITIONS

4. Wind speed < 7 m/s (for spraying operation).

No precipitation during spraying.

NUMBER OF TRIALS

5. Thirty (estimated).

SCOPE

6. The scope of the trials will examine some of the following variables. The number carried out will depend on the results of preceding trials.

Trial	Decontamination**	Weathering Time*
1	No	≯ 30 min
2	No	1 hr
3	No	2 hr
4	No	4 hr
5	No	6 hr
6	No	8 hr
7	No	12 hr
8	Yes	≯ 30 min
9	Yes	1 hr
10	Yes	2 hr
11	Yes	4 hr
12	Yes	6 hr
13	Yes	8 hr
14	Yes	12 hr

The above, or a selection of the above, will be repeated using thickened agents. Some trials will be required under both Summer and Winter conditions.

FOOTNOTE

* Weathering	Weathering will be the simple exposure of the vehicle to ambient conditions in an exposed position, i.e. not shaded from the sun or wind by trees etc.
** Decontamination	The vehicle will be decontaminated using Chemical Agent Decontaminant as directed in the instructions for the use of the Decontamination equipment.

EQUIPMENT AND MATERIALS

7.	Rotary sequential samplers	16 SCD
	Bubblers (Neale) with 1 litre/min critical orifices	192 SCD
	Sampler posts with sampling positions at 0.3 m and 1.67 m	8 HRS
	The Vehicle APC FV 432 Mk.1 (or other suitable A class vehicle)	HRS or SMO
	Sampling felts	13 HRS
	Thermometer or thermistors for surface temperature measurement	SCD
	Pumps, batteries, leads etc. as required	HRS
	Polythene sheet	HRS
	GD (dyed 0.5% Brilliant Fast Red B and 0.1% SWN) (500 ml/Trial) (Estimated max. 15 l)	STCD
	Thickened GD as above	STCD
	Spray devices for dissemination of above	STCD
	Bins for contaminated felts	
	Protective clothing as required, consisting of PVC suits, CB suits, rubber boots, neoprene gloves, CB hoods, respirators (S6), socks, boiler suits, pyjamas and underwear	HRS
	Range Chamber (construction to be decided by ERD) Preferred size 38' x 18' x 14' high	SERD
	Fans and heaters for enclosure	SERD
	Decontamination equipment	SERD
	Generator 27 KVA	SERD
	Platform for spraying	HRS
	Audible safety warning	HRS

LAYOUT

8. See Figures 1 and 2. The felts will be positioned on the vehicle as shown. The vapour sampling layout consists of an array of bubbler posts at a distance of 1 m from the vehicle at heights of 0.3 m and 1.67 m. Each rotary sequential sampler will operate 12 Neale bubblers containing 2 ml of cyclohexanol. The vapour sampling will be carried out in a range chamber, the structure of which will be determined by availability of materials. Provision will be made in any chamber for ventilation, air circulation and maintenance of temperature at 22°C.

PROCEDURE

9. Spraying Operations The vehicle will be driven to the prepared clearing or other agreed spraying site where sampling felts and thermometer or thermistors will be attached (see Fig.1) and the door will be covered with a polythene sheet. A crew of "2 men" will be dressed in full protective clothing and will remain in the vehicle during the spraying operation. The crew within the vehicle will be provided with an audible safety warning (RS). The surface temperature of the vehicle will be recorded and spraying will be carried out using a suitable spray apparatus as required by the agent's characteristics, i.e. thickened or unthickened. Contamination density should be between 5 and 10 g/m^2 on the top front and one side of the vehicle. On completion of spraying, felts will be collected for subsequent analysis. The polythene sheet will be removed. Precautions will be taken to ensure that the vehicle surface is not exposed to sunlight before spraying.

10. Movement of Vehicle After contamination the vehicle will be moved to the weathering or decontamination position and the necessary activities indicated in paragraph 6 (Scope) will take place. After weathering etc. the vehicle will be moved to the sampling chamber. The sampling posts will be in position with the exception of those required to allow entry of the vehicle to the layout. The crew will dismount through the rear door and the sampling arc will be completed. All sampling equipment will be connected in preparation for vapour sampling. The chamber will be closed and the circulating fans and thermostatted heaters switched on.

11. Vapour Sampling Vapour sampling will commence at a specified time (see Scope, para.6) after spraying and will be carried out according to the schedule below:

S S+X*	(S+X) + 1	(S+X) + 2	(S+X) + 3	(S+X) + 6	(S+X) + 9
	(S+X) + 12	(S+X) + 15	(S+X) + 18	(S+X) + 21	
	(S+X) + 24	(S+X) + 36 hours			

In addition to the above, RVD tests will be carried out when required at the discretion of HAS representatives.

ANALYSIS

12. The content of the bubblers will be analysed for GD. The sampling felts will be analysed for dyestuff. (A sample will be sent to CD for reference purposes).

METEOROLOGICAL OBSERVATIONS

13. At the spraying site:

Wind speed and direction at 2 m.

---

* X is the time between spraying and vapour sampling which will be for decontamination and/or weathering.

At the weathering site in appropriate trials:

Wind and direction at 2 m

Temperature of the surface of the vehicle

Air temperature

Relative humidity

Weather diary

PROTECTION AND SAFETY

14. Staff engaged in spraying agent and those who could, by accident, be contaminated will wear PVC suit, impregnated boiler suit or CB suit, rubber boots, neoprene gloves and respirator over under-clothing and woollen stockings. Staff liable to exposure to small quantities of agent and vapour will wear a CB suit, hood, rubber boots, gloves and respirator over under-clothes and woollen stockings.

Those staff wearing PVC suits will report to the Medical Officer or HRS if they feel signs of becoming a heat casualty.

All staff working in the contaminated area will rinse boots and gloves in bleach slurry before undressing. The CDE undressing team will carry out all undressing operations.

All staff working directly with agents will take oxime tablets one hour before spray and be subject to blood cholinesterase determinations after the trial. EMO will be present for each spraying operation.

RESPONSIBILITIES

16.

STCD	Provision of GD and thickened GD
	Spraying operation
HRS	Preparation of layout
	Administrative control and safety
	Provision and placing of sampling felts, vacuum pumps, power supplies, sampling lines, sampling posts to hold bubbler nests and bleach
	Slurry in trays
	Provision of protective clothing
	Provision of polythene sheet
SCD	Provision of bubblers
	Provision of rotary sequential samplers
	Provision and positioning of thermometer or thermistors
	Operation of the above
	Chemical analysis of felts and bubbler contents
EMO	Attendance at trial
	Provision of ambulance to deal with nerve agent casualties

S.Med.D.	Blood cholinesterase determinations
	Provision of oxime tablets
SERD	Preparation of a suitable range chamber. Arrangements for power supplies, heaters and fans. Provision of decontamination equipment
HAS	Preparation of a report
S.Met.D.	Meteorological observations as required

Project Control Officer K. Sinclair, ERD

(Sgd). K. Sinclair, for SERD

(Sgd). W.E.B. Whatley, HRS

(Sgd). W.G. Wills, for DD(D)

FIG.1 POSITION OF FELTS

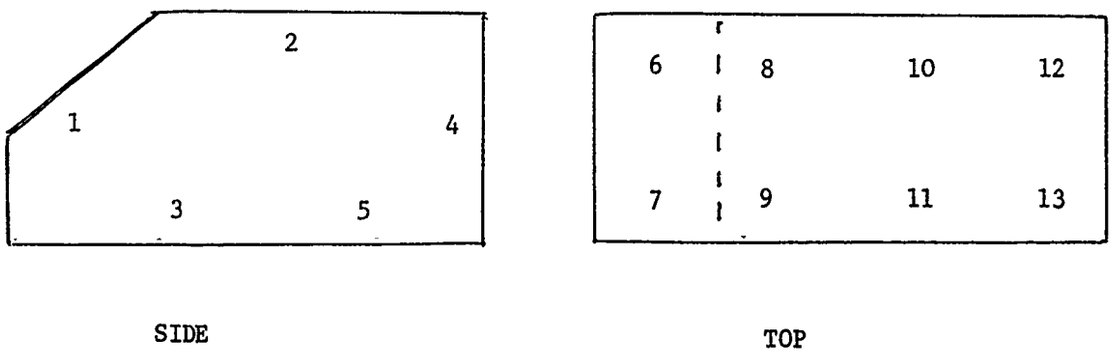
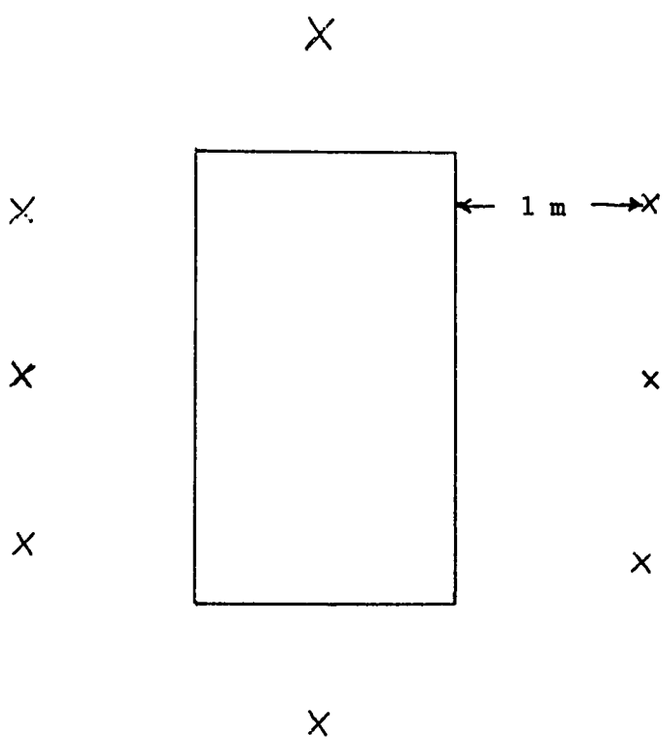


FIG.2 POSITION OF SAMPLERS



PROGRAMME NO.5/73

ADDENDUM A

EVALUATION OF THE VAPOUR HAZARD FROM A CONTAMINATED APC IN A NIGHT HIDE SITUATION

Circulation:-

Participants:	HAS (3)	STCD	SCD	SERD (2)
	HRS (4)	S.Met.D.	EMO	
For Information:	Director	AFEO		
	DD(D)	USASR		
	TSO(D)	Tech.Reg. (2)		
	HTIRS	DRES		
	NEO	Weapons 8 (2)		
	SMO	Field Trials Committee (9)		

Project No.3407
File No. TD.6000

INTRODUCTION

1. Programme 5/73 was raised to continue the investigation of 'Night Hide' hazards commenced in 1969. The Decontamination Project Team has requested that the trials be extended to assess the effects of rain or drizzle on the vapour evolution from contaminated vehicles.

OBJECT

2. To determine the vapour hazard arising from a contaminated vehicle after wetting.

EQUIPMENT AND MATERIALS

3. 4-Oaks or Nu Swift apparatus filled with water and fitted with constant pressure liquid valve - 1 SERD

PROCEDURE

4. As in main programme except for the following:-

   (a) After contamination, the vehicle will be weathered for three hours.

   (b) After vapour sampling for twenty-one hours the vehicle will be 'lightly' sprayed with water while in the chamber. Vapour sampling will be continued up to the end of the 36 hour sampling period.

SAFETY

5. Personnel entering the range chamber will wear full protective (CB) clothing.

RESPONSIBILITIES

6. SERD Provision, filling and use of water spray.

(Sgd). W.G. WILLS,
for DD(D).

6.11.73

APPENDIX B

UK CHEMICAL AGENT DECONTAMINATING SOLUTION FOR USE WITH THE PORTABLE NBC DECONTAMINATION APPARATUS

The solution is prepared by dissolving the following substances in water:-

1.	Sodium dichloroisocyanurate (FiClor 60S)	to make a 5% solution
2.	Sodium hydroxide (Caustic Soda)	to make a 2.5% solution
3.	Boric anhydride	to make a 1.5% solution
4.	Santomers detergent	to make a 0.01% solution

When the above chemicals are supplied in the standard 2 lb. tins, package V contains item 1, package G contains item 2 and package H contains items 3 and 4; the contents of the three packages should be dissolved in 2 gallons (9 litres) of water.

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APPENDIX C

VAPOUR EVOLUTION RATES IN A CHAMBER

The desorption of agent from the paintwork and other permeable materials of construction and the absorption of agent by chamber walls are likely to be diffusion processes; the data obtained in these field experiments have been analysed on the assumption that the rates of build-up and decay of agent vapour in the chamber could be described by Fickian diffusion.

$$\frac{-dm}{dt} = K_1 m$$

$$\frac{dc}{dt} = \frac{K_1 m}{V} - K_2 c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

m	is mass of agent on vehicle
c	is vapour concentration in the chamber
V	is the chamber volume
K_1, K_2	are the rates of desorption and adsorption of the agent

Differentiation gives $\frac{d_2 c}{dt^2} = -K_1\left(\frac{dc}{dt} + K_2 c\right) - K_2 \frac{dc}{dt}$

which on rearrangement gives the expression

$$\frac{d^2c}{dt^2} = (K_1 + K_2)\frac{dc}{dt} + K_1 K_2 c = 0$$

from which $c = Ae^{-K_1 t} + Be^{-K_2 t} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$

At $t = 0$, $c = 0$, so that $A = -B$ and $c = A(e^{-K_1 t} - e^{-K_2 t})$.

Since $m = m_o e^{-K t}$ it follows from (1) that

$$\frac{dc}{dt} = \frac{K_1 m_o e^{-K_1 t}}{V} - K_2 c$$

and from (2) $\frac{dc}{dt} = A(K_1 e^{-K_1 t} - K_1 e^{K_1 t})$.

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When t = 0, c = 0 and it follows that

$$\frac{K_1 m_o}{V} = A(K_2 - K_1)$$

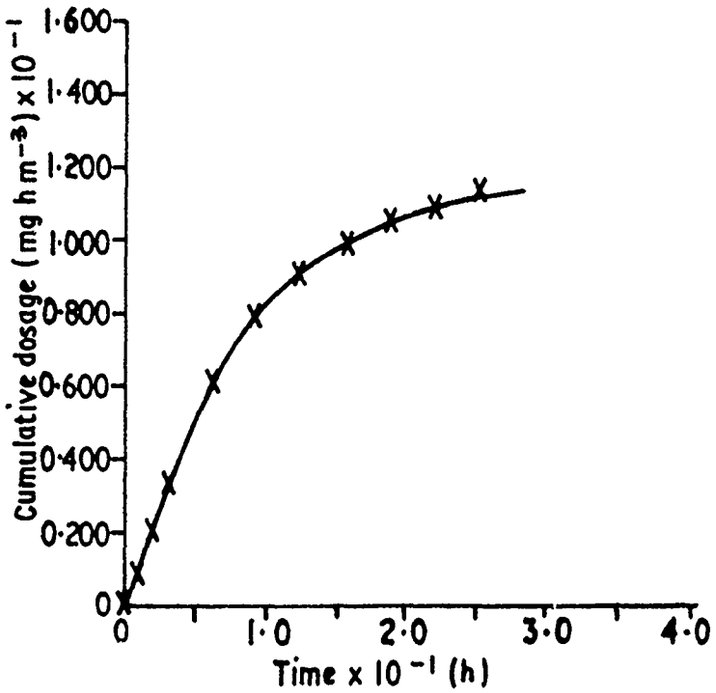
$$\text{Thus} \quad c = \frac{K_1 m_o}{V(K_2 - K_1)} (e^{-K_1 t} - e^{-K_2 t})$$

$$\text{and} \quad ct = \int_o^t c(t)dt$$

$$ct = \frac{K_1 m_o}{V(K_2 - K_1)} \left[\frac{1}{K_1} (1 - e^{-K_1 t}) - \frac{1}{K_2} (1 - e^{-K_2 t}) \right] \quad \text{.....(3)}$$

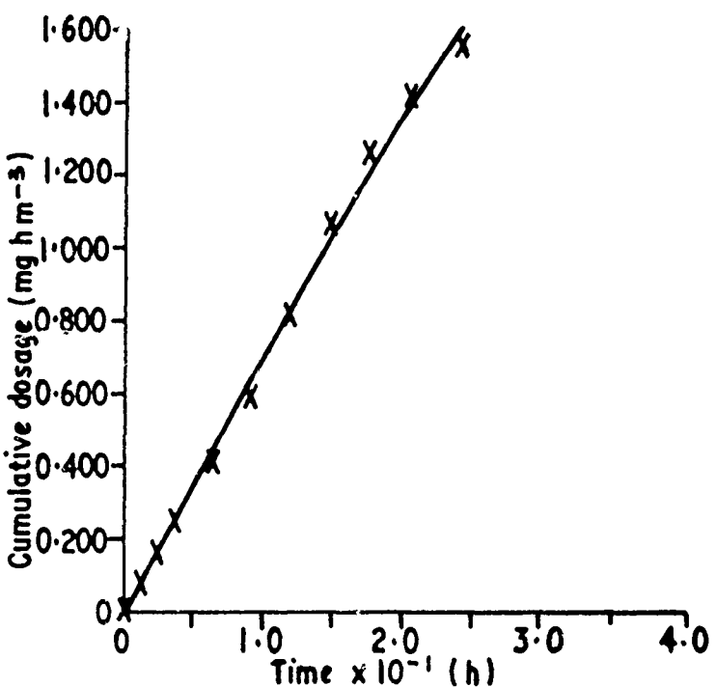
The experimental measurements can be used directly in this equation. A curve-fitting computer programme was used to obtain the values of K_1, K_2 and m_o which gave the best fit to the experimental measurements.

The curves are reproduced in Figures C1 - 39 and the numerical values of K_1 and m_o are recorded in Tables 1 - 8 as appropriate.



TRIAL I GD ON FV 432 ½ h WEATHERING

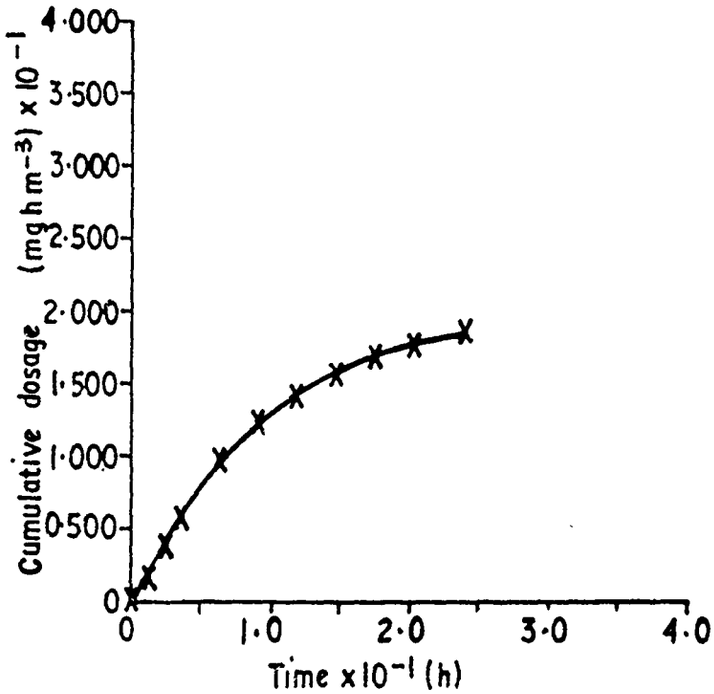
FIG. C I.



TRIAL.2. GD ON FV432 12 h WEATHERING

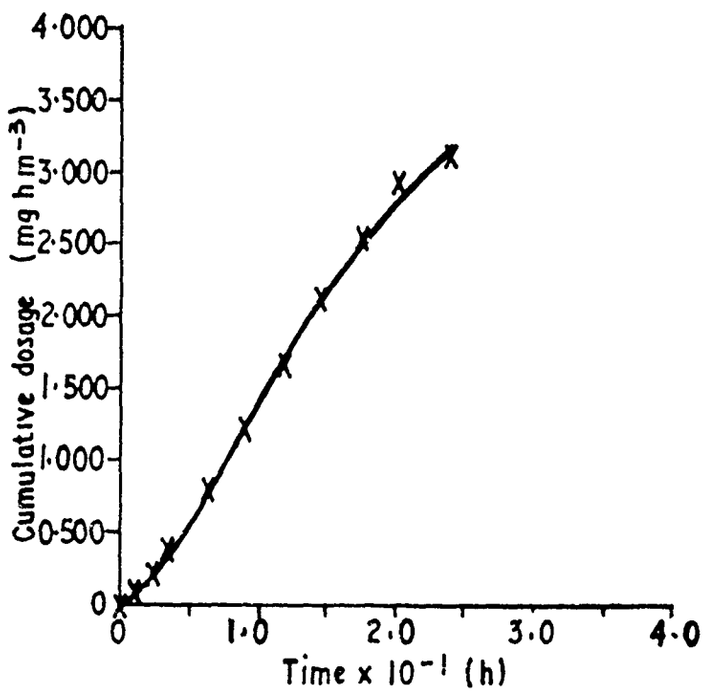
FIG. C 2.

TP 249 | PT 7480



TRIAL 3 GD ON TRUCK WITH TILT $\frac{1}{2}$ h WEATHERING

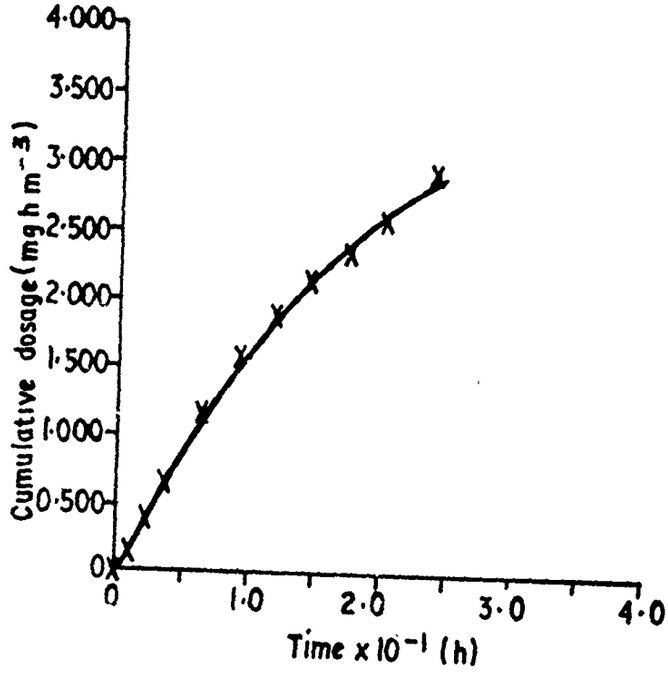
FIG.C.3.



TRIAL 4 GD ON TRUCK WITH TILT 12 h WEATHERING

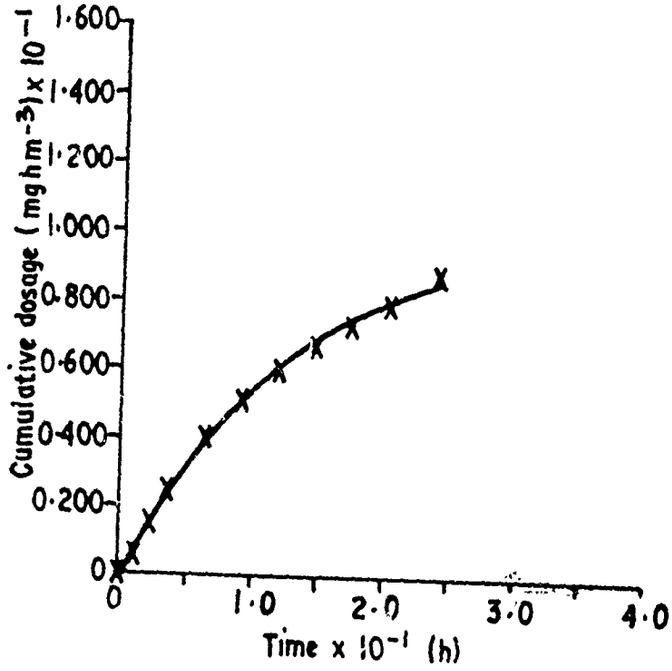
FIG. C 4.

TP 249 | PT 7481



TRIAL 5 GD ON FV432 3h WEATHERING

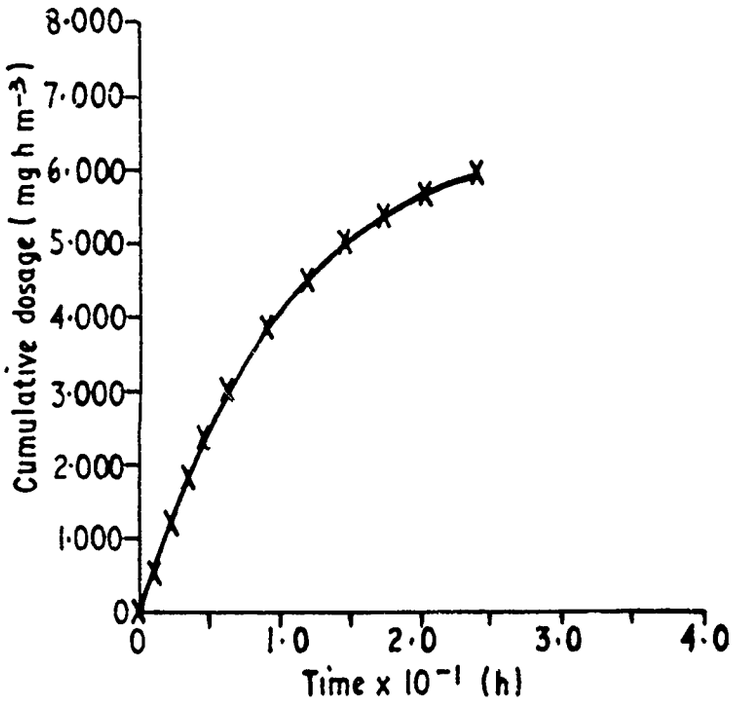
FIG. C.5.



TRIAL 6 GD ON TRUCK WITH TILT 3h WEATHERING

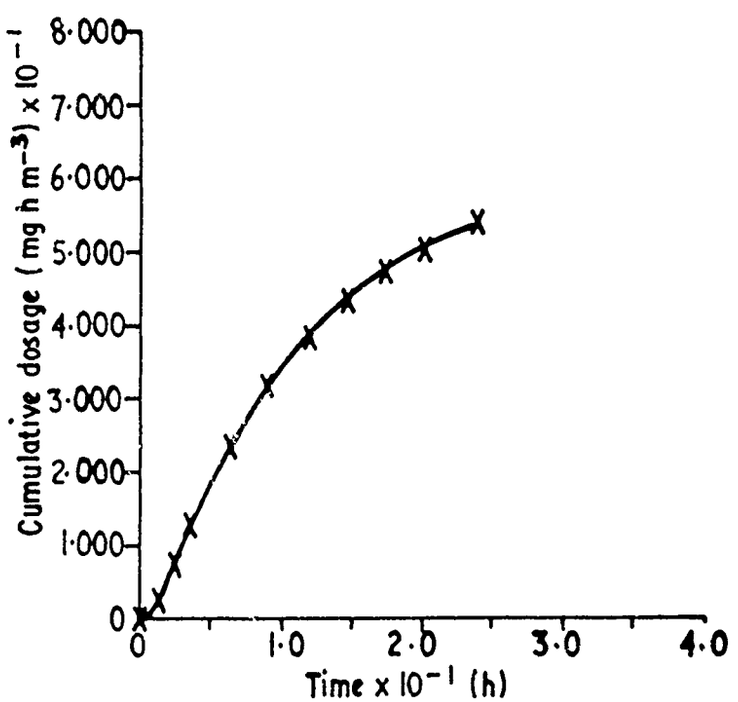
FIG. C.6.

TP 249 PT 7482



TRIAL 7 GD ON FV 432 ¼ WEATHERING AND DECONTAMINATION

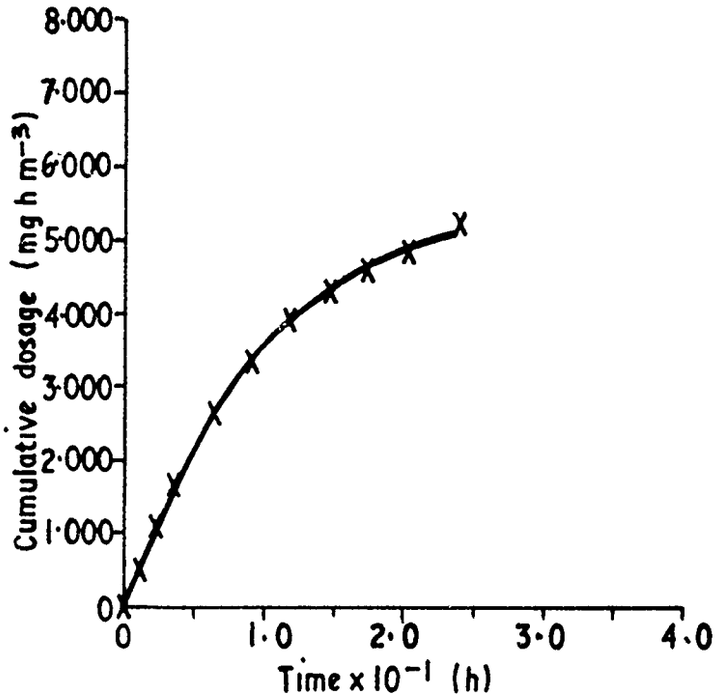
FIG.C.7.



TRIAL 8 GD ON A TRUCK WITH TILT ¼ WEATHERING AND DECONTAMINATION

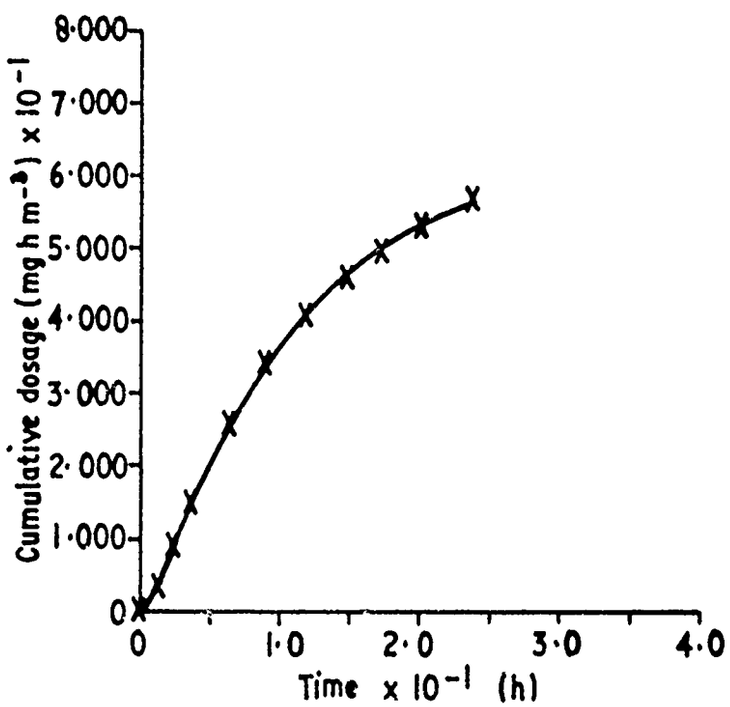
FIG.C.8.

TP 249 PT 7483



TRIAL 9 GD ON FV 432 $\frac{1}{4}$ h WEATHERING AND DECONTAMINATION

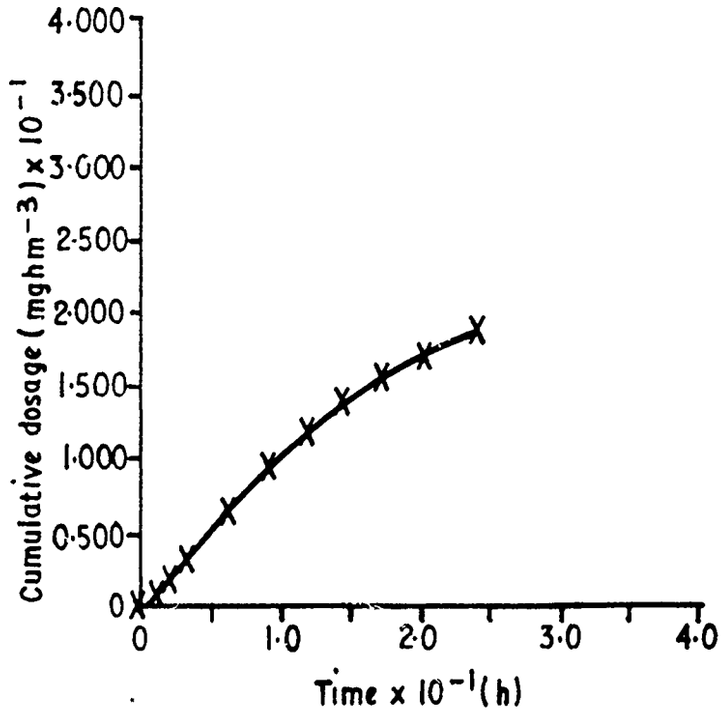
FIG.C.9.



TRIAL 10 GD ON A TRUCK WITH TILT $\frac{1}{4}$ h WEATHERING AND DECONTAMINATION

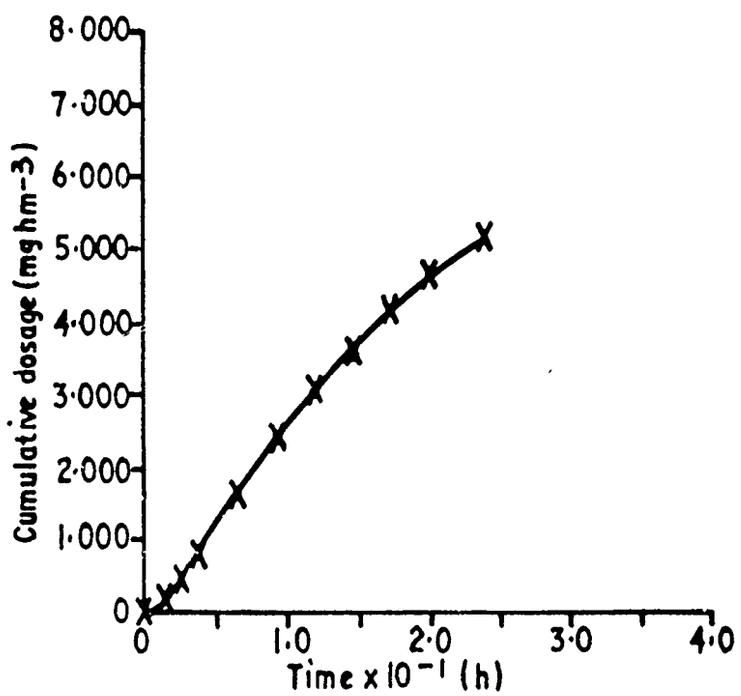
FIG.C.10.

TP 249 PT 7484



TRIAL 11 GD ON A TRUCK WITH TILT 3h WEATHERING

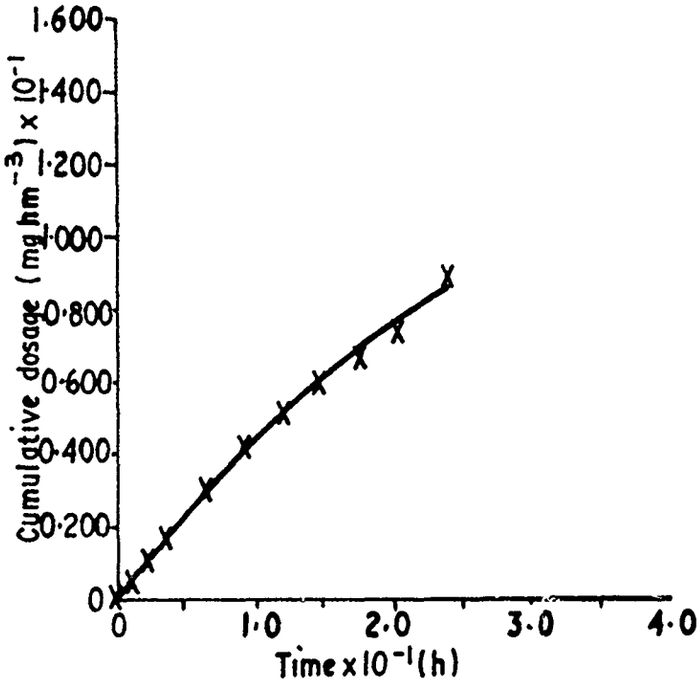
FIG. C. 11.



TRIAL 12 GD ON A TRUCK WITHOUT TILT 3h WEATHERING

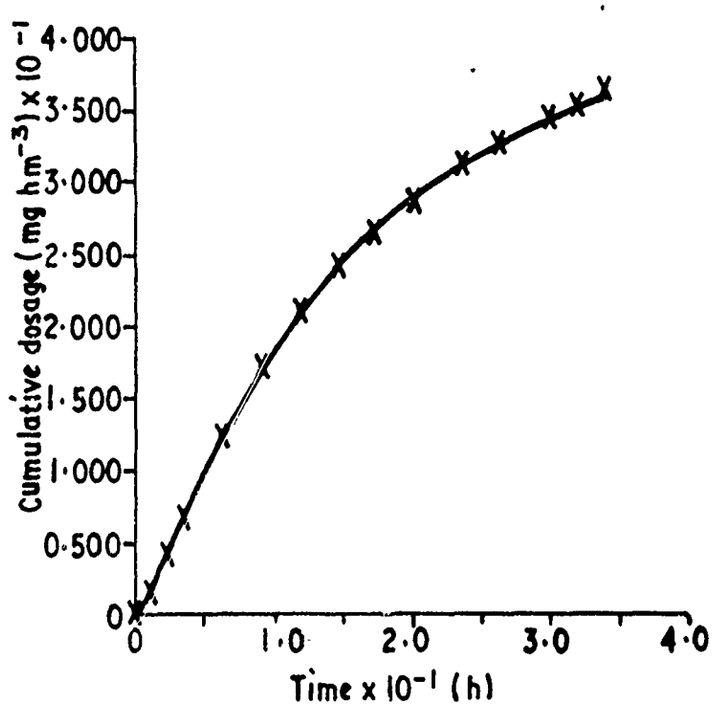
FIG. C. 12.

TP 249 | PT 7485



TRIAL 13 GD ON A TRUCK WITHOUT TILT 3h WEATHERING

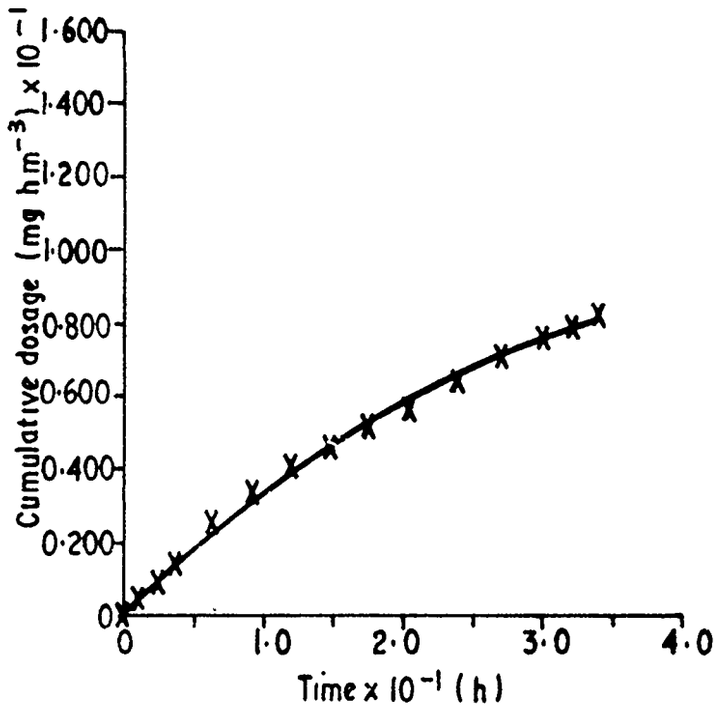
FIG.C.13.



TRIAL 14 GD ON A TRUCK WITH TILT 3h WEATHERING

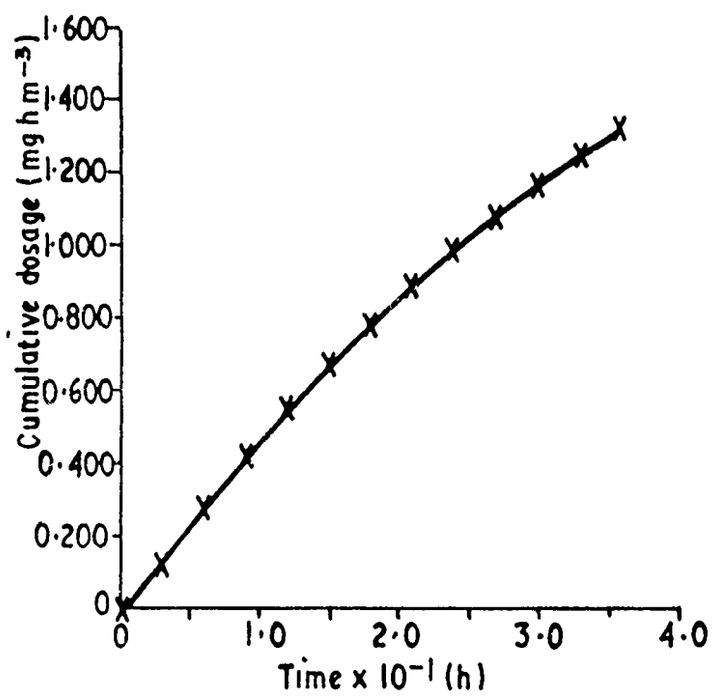
FIG.C.14.

TP 249 PT 7486



TRIAL 15 GD ON FV432 3h WEATHERING AND DECONTAMINATION

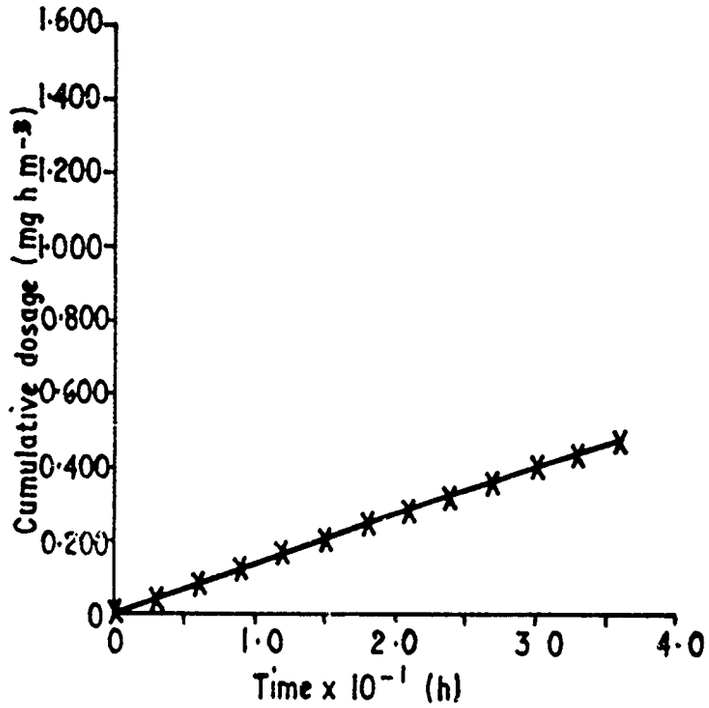
FIG. C. 15.



TRIAL 16 GD ON A TRUCK WITH TILT 72 h WEATHERING

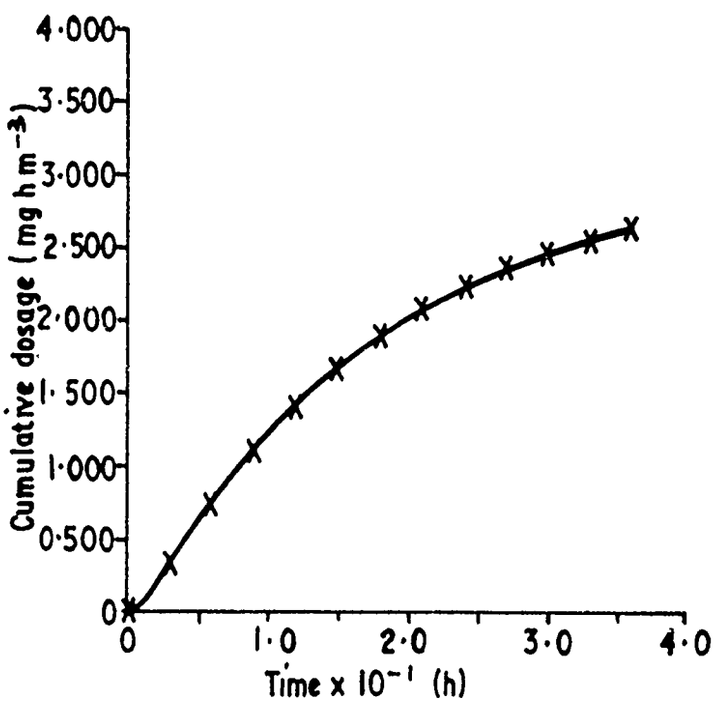
FIG. C. 16.

TP 249 | PT 7487



TRIAL 17 GD ON CENTURION 72 h WEATHERING

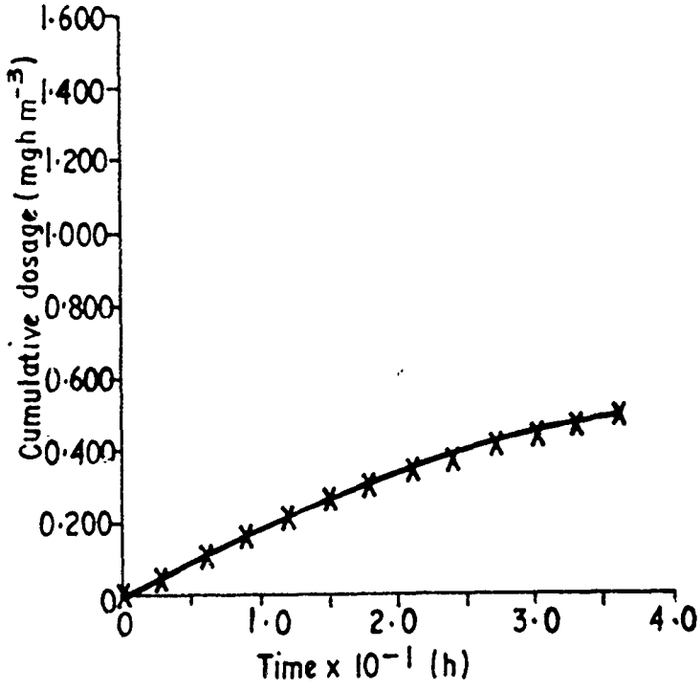
FIG. C. 17



TRIAL 18 GD ON CENTURION 12 h WEATHERING

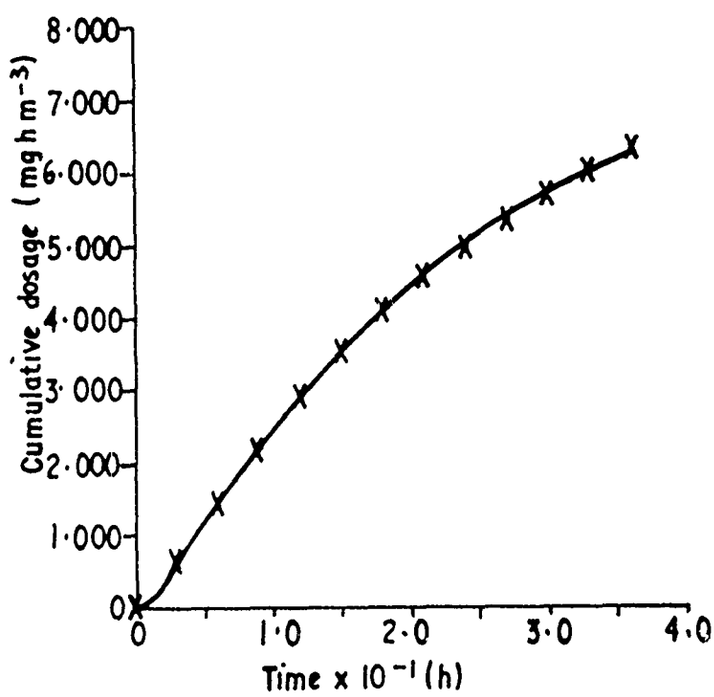
FIG. C. 18.

TP 249 PT 7488



TRIAL 19 GD ON A TRUCK WITHOUT A TILT 72 h WEATHERING

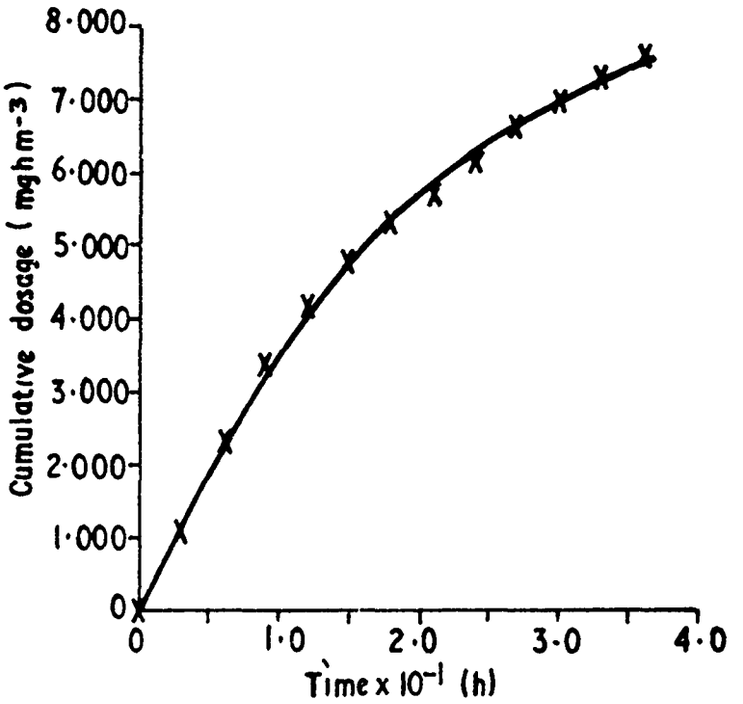
FIG.C.19.



TRIAL 20 GD ON A SALADIN 12 h WEATHERING

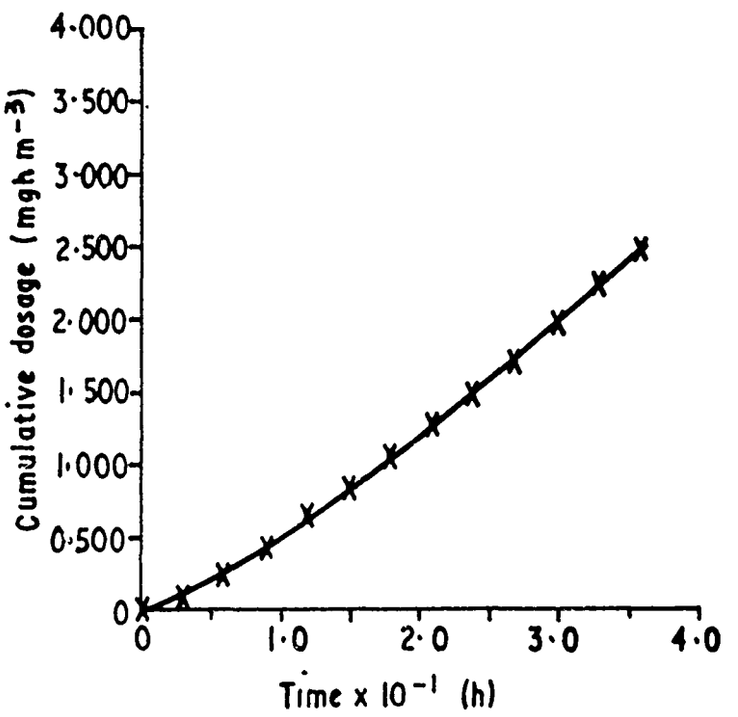
FIG.C.20.

TP 249 PT 7489



TRIAL 21 GD ON A SALADIN 3h WEATHERING

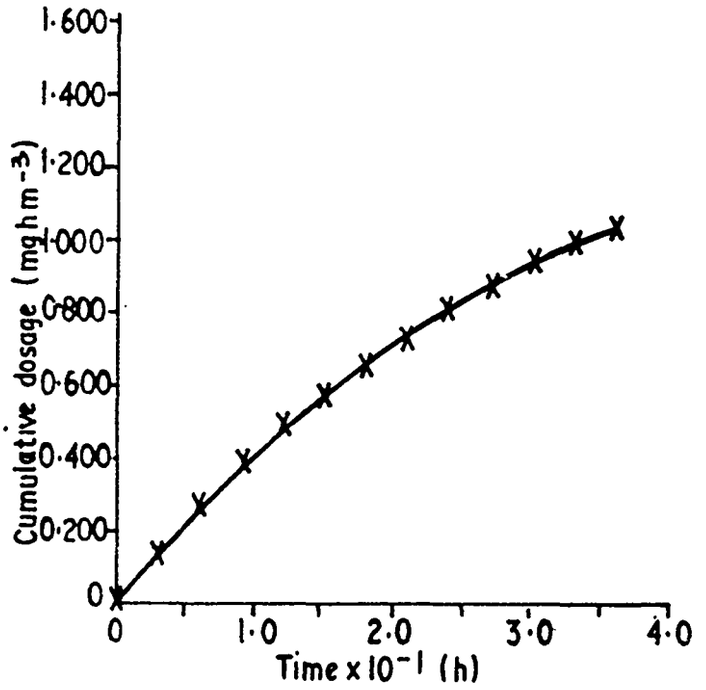
FIG. C. 21



TRIAL 22 GD ON A SALADIN 72 h WEATHERING

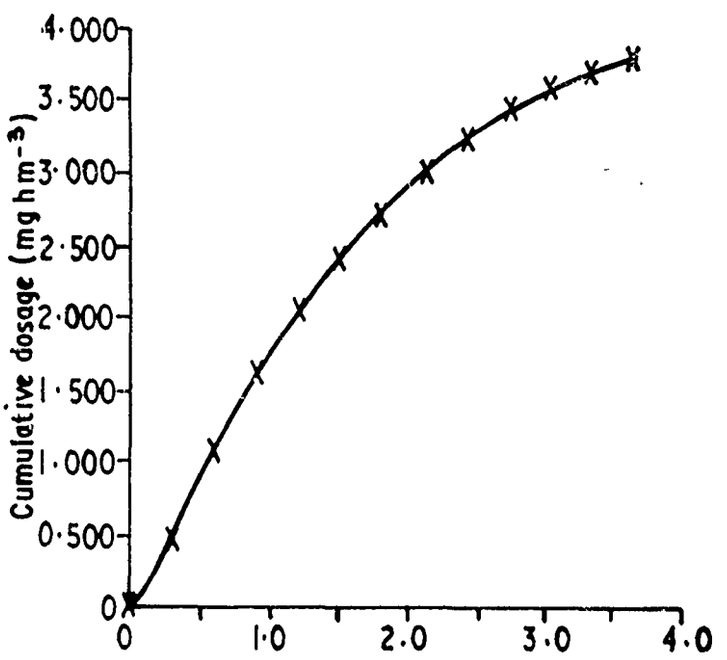
FIG.C.22.

TP 249 | PT 7490



TRIAL 23 GD ON A PU PAINTED TRUCK WITHOUT A TILT
3 h WEATHERING

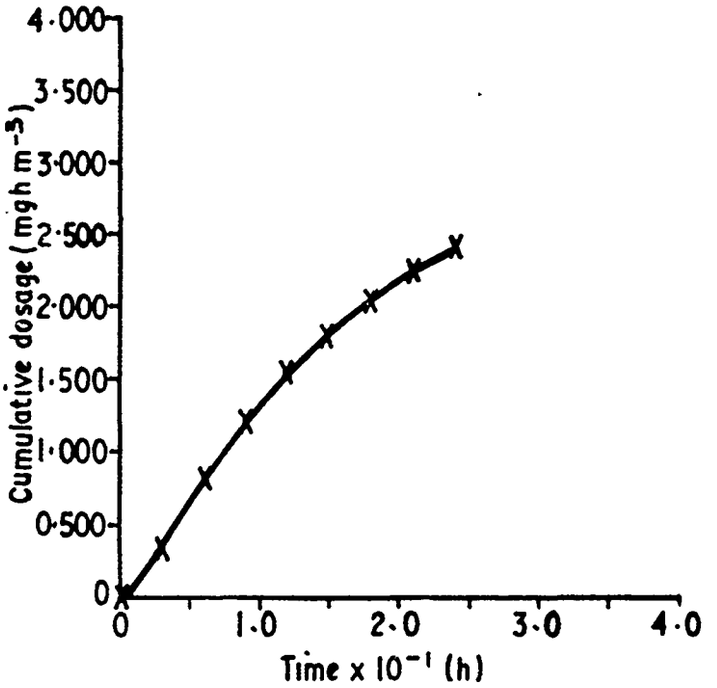
FIG. C.23.



TRIAL.24. GD ON A PU PAINTED SALADIN 3 h WEATHERING

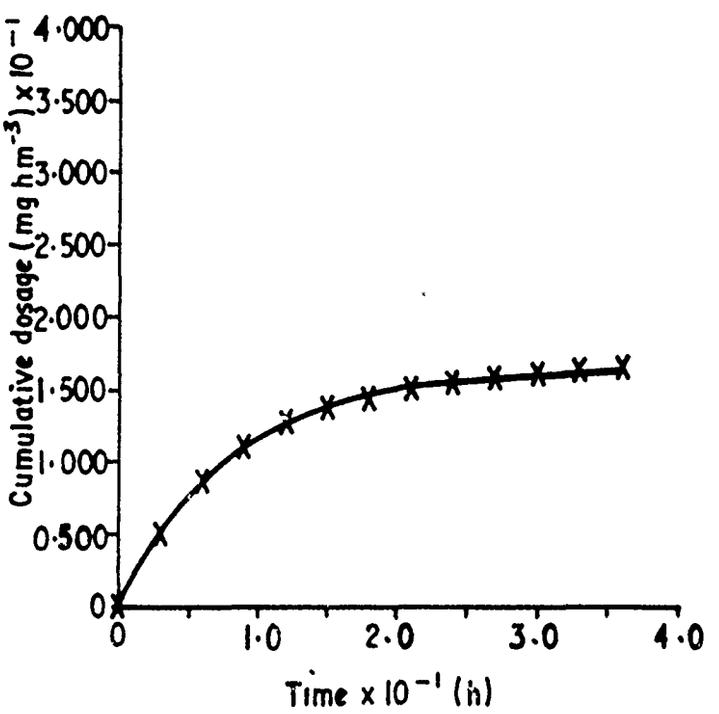
FIG .C.24.

TP 249 | PT 7491



TRIAL 25 GD ON PU PAINTED TRUCK WITHOUT TILT
3 h WEATHERING

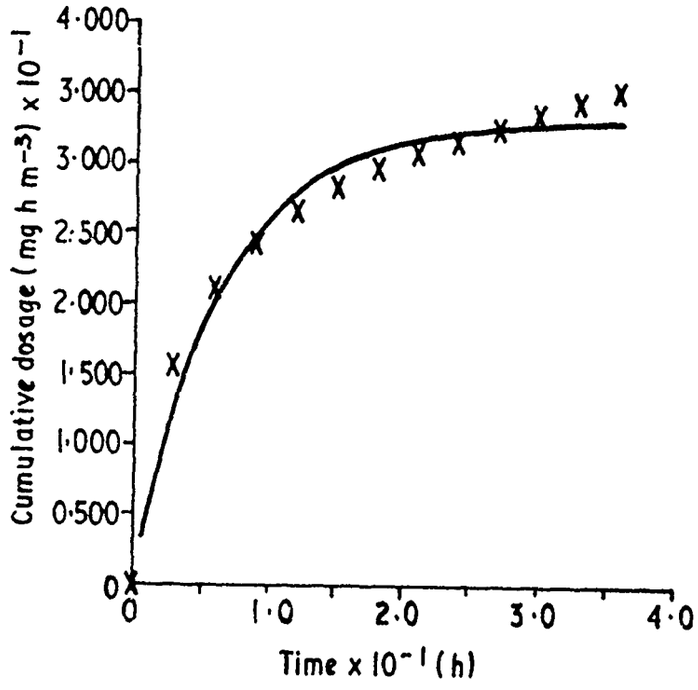
FIG.C.25.



TRIAL 26 GD ON A PU PAINTED SALADIN 0·5h WEATHERING

FIG.C.26

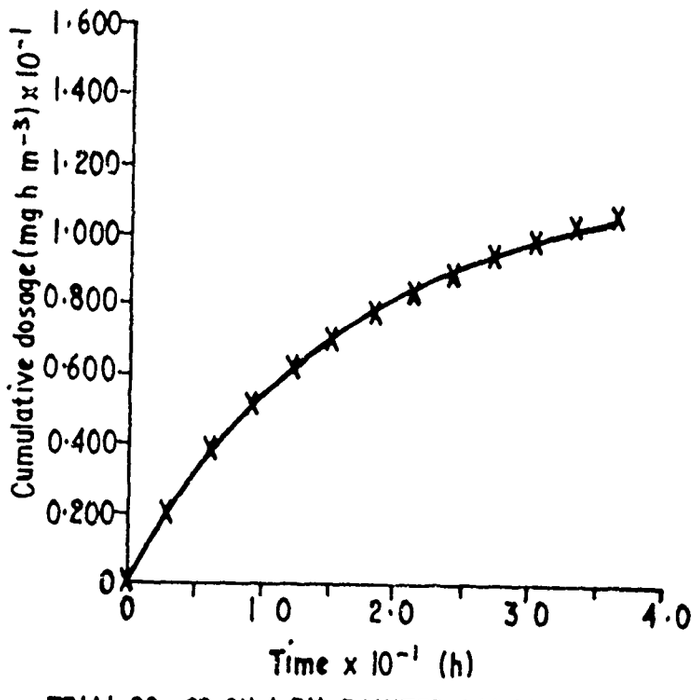
TP 249 PT 7492



TRIAL 27 GD ON A PU PAINTED TRUCK WITHOUT A TILT

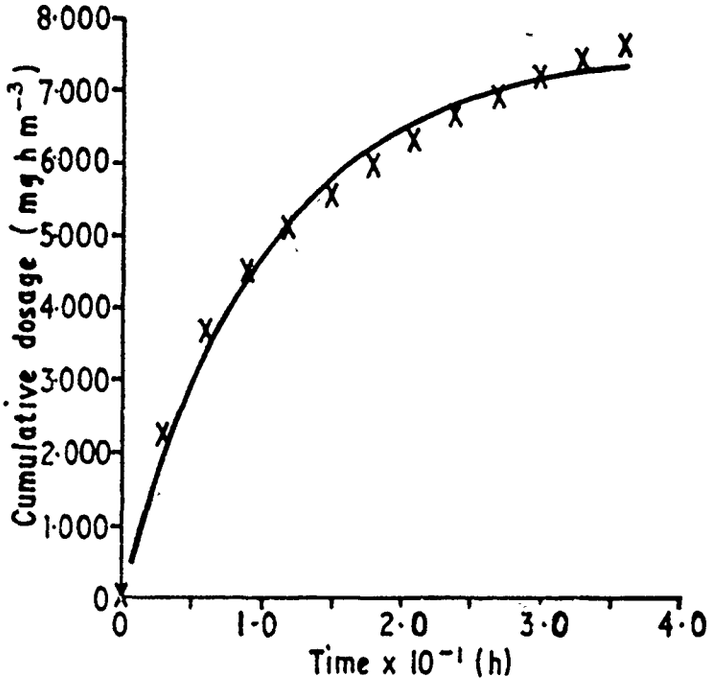
0·25 h WEATHERING

FIG.C.27



TRIAL 28 GD ON A PU PAINTED SALADIN 0·25 h WEATHERING

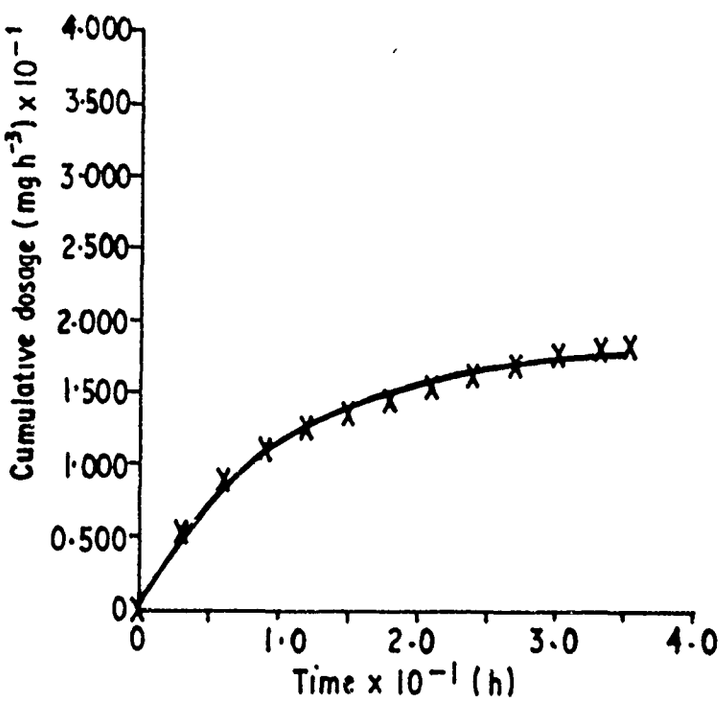
FIG.C.28.



TRIAL 29 GD ON A PU PAINTED TRUCK WITHOUT A TILT

0·25 h WEATHERING

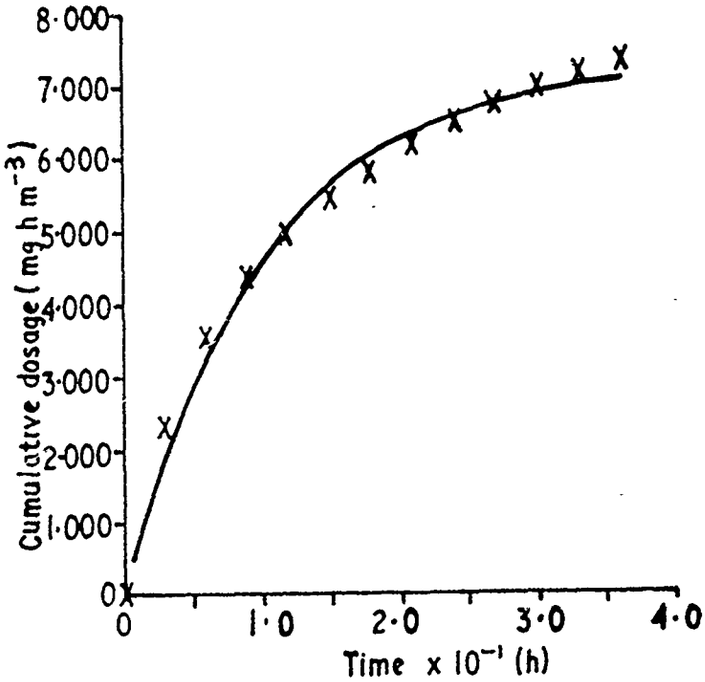
FIG. C 29



TRIAL 30 GD ON A SALADIN 0·5 h WEATHERING

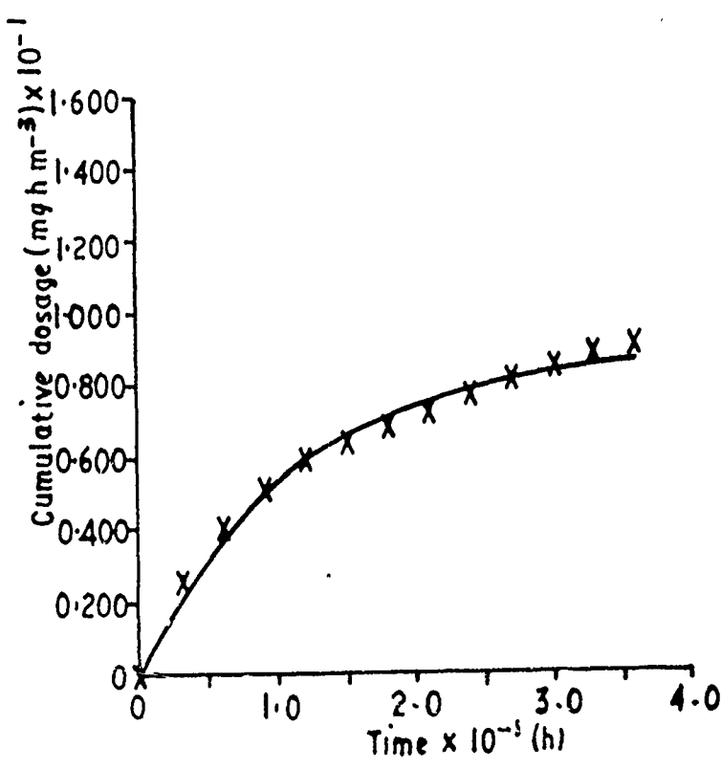
FIG. C 30

TP 249 PT 7494



TRIAL 31 GD ON A TRUCK WITH A TILT 0·5 h WEATHERING

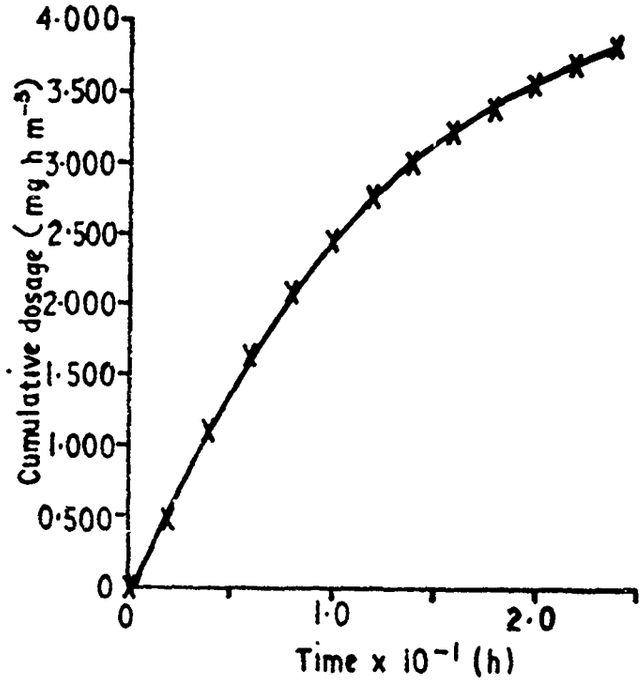
FIG. C 31



TRIAL 32 GD ON A SALADIN 0·5 h WEATHERING

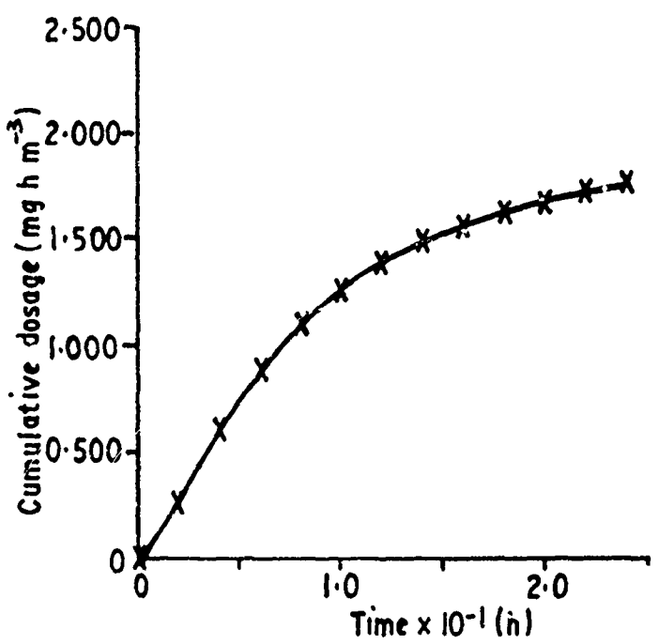
FIG. C 32

TP 249 | PT 7495



TRIAL 33 GD ON A TRUCK WITHOUT A TILT 3 h WEATHERING

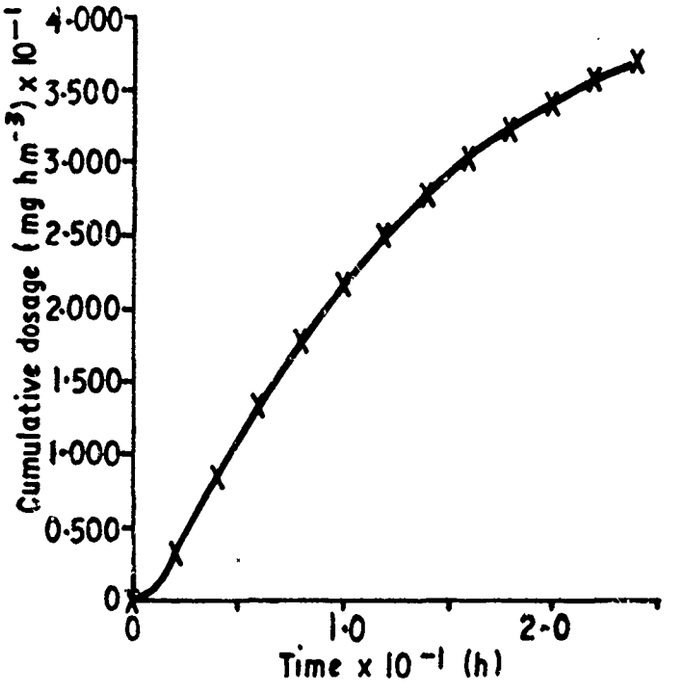
FIG. C33



TRIAL 34 GD ON A PU PAINTED TRUCK WITHOUT A TILT

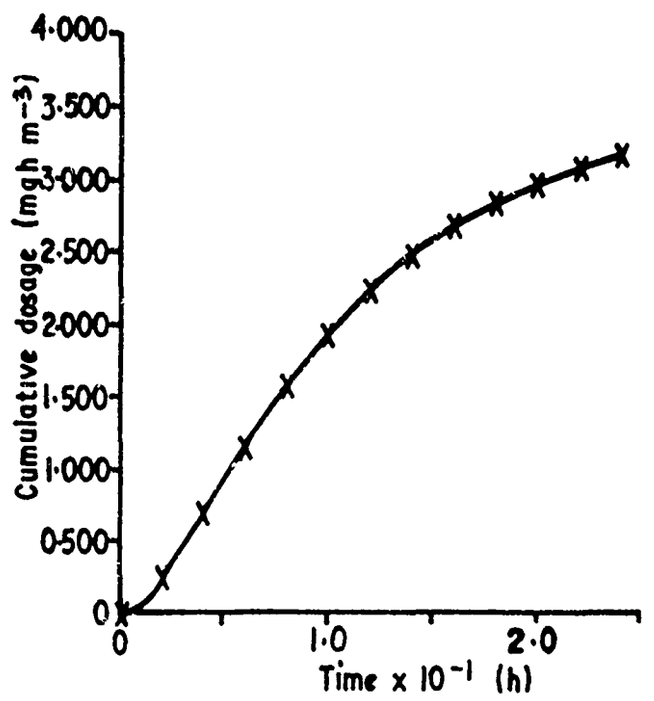
3 h WEATHERING

FIG. C 34



TRIAL 35 GD ON A TRUCK WITH TILT 3 h WEATHERING

FIG. C 35

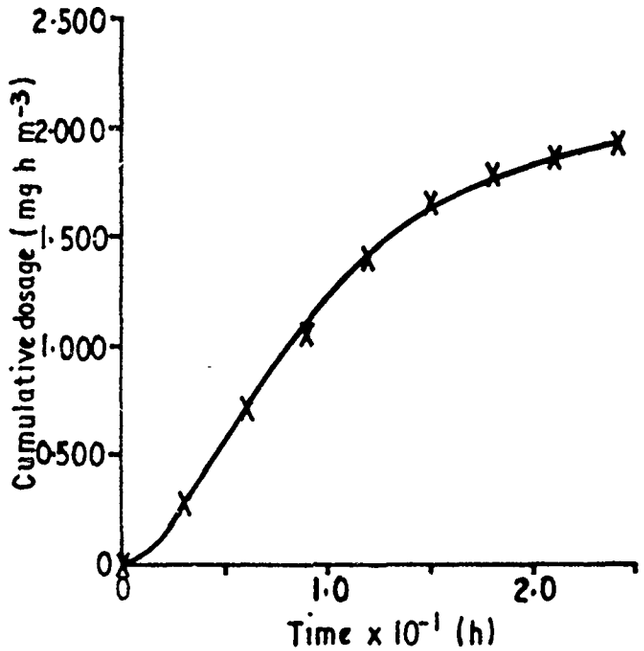


TRIAL 36 GD ON A TRUCK PAINTED WITH PU WITHOUT A TILT

6 h WEATHERING

FIG. C 36

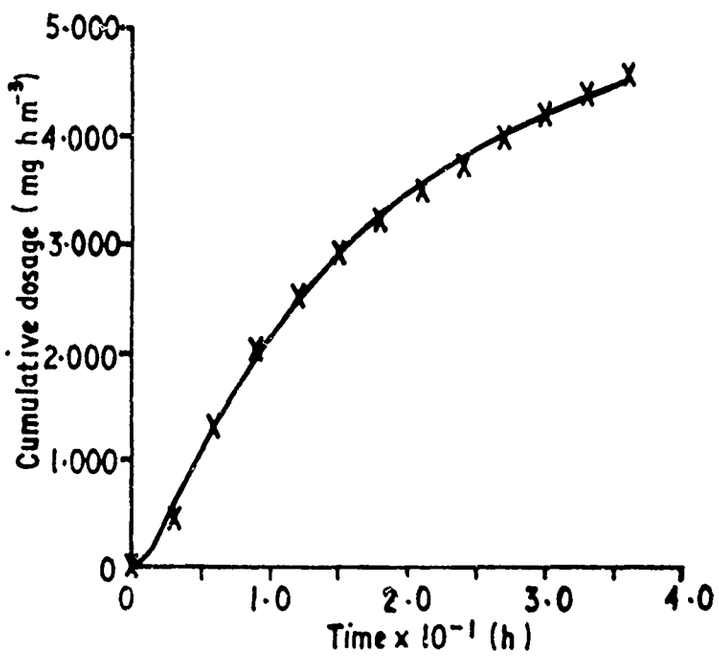
TP 249 PT 7497



TRIAL 37 THICKENED GD ON A TRUCK WITHOUT A TILT

3 h WEATHERING

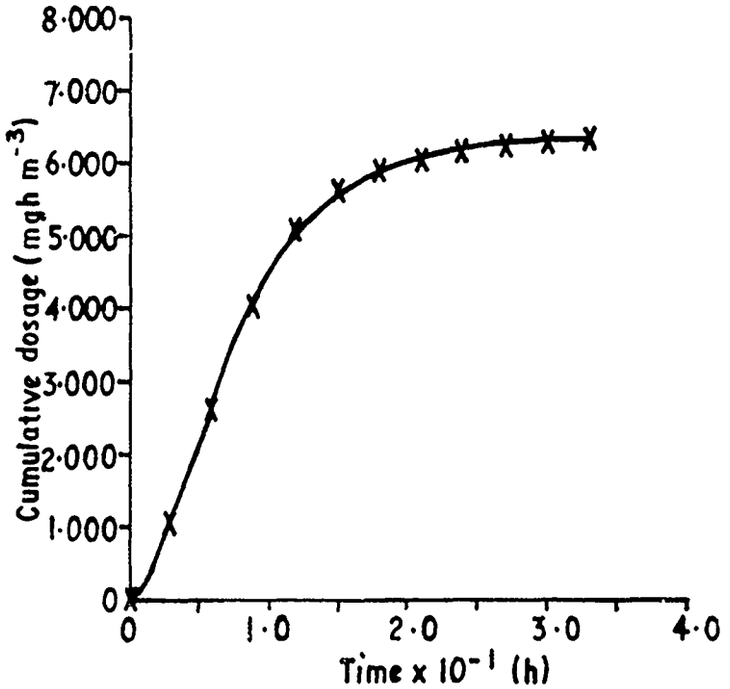
FIG.C 37



TRIAL 38 THICKENED GD ON A SALADIN 3 h WEATHERING

FIG.C 38

TP 249 | PT 7498



TRIAL 39 THICKENED GD ON A PV PAINTED SALADIN
3 h WEATHERING

FIG C 39

APPENDIX D

TABULATED DATA

NOTE: The 'Ct' values tabulated here are the Means of eight separate but simultaneous measurements

TRIAL NO.1 DATE 20.8.73

Vehicle type:- FV 432 Decontamination:- No

Paint:- GP Washdown:- No

Weathering time:- 0.5 hours

Mean weathering temperature:- 20.8°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1	47
1 - 2	73
2 - 3	82
3 - 6.2	167
6.2 - 9.4	104
9.4 - 12.6	69
12.6 - 15.8	49
15.8 - 19.00	36
19.00 - 22.2	30
22.2 - 25.4	28
30 - 33	20
33 - 36	16

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	16.9	5.1	7.6	5.5	9.1	19.7	9.8
	8	9	10	11	12	13	14
	9.1	17.2	11.5	10.5	5.1	6.9	-

Agent purity:- 87%, Corrected mean contamination density 9.0 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.2 DATE 28.8.73

Vehicle type:- FV 432

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 12 hours

Mean weathering temperature:- 18.2°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	5
1.2 - 2.4	5
2.4 - 3.6	5
3.6 - 6.4	10
6.4 - 9.2	10
9.2 - 12.0	14
12.0 - 14.8	15
14.8 - 17.6	12
17.6 - 20.4	9
20.4 - 24.0	9
30 - 33	6
33 - 36	6

Contamination Density (g m^{-2})							
	1	2	3	4	5	6	7
	5.9	7.0	7.4	7.5	4.4	1.7	4.7
	8	9	10	11	12	13	14
	1.1	2.4	2.8	4.3	8.9	4.3	-

Agent purity:- 87%, Corrected mean contamination density 4.2 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.3 DATE 3.9.73

Vehicle type:- Truck with tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 0.5 hours

Mean weathering temperature:- 21.4°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	85
1.2 - 2.4	129
2.4 - 3.6	130
3.6 - 6.4	240
6.4 - 9.2	157
9.2 - 12.0	106
12.0 - 14.8	81
14.8 - 17.6	70
17.6 - 20.4	57
20.4 - 24.0	64
30 - 33	48
33 - 36	31

Contamination Density ($g\ m^{-2}$)							
	1	2	3	4	5	6	7
	5.9	7.0	7.4	7.5	4.4	1.7	5.7
	8	9	10	11	12	13	14
	1.1	2.4	2.8	4.3	8.9	4.3	-

Agent purity:- 88%, Corrected mean contamination density 4.2 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.4 DATE 10.9.73

Vehicle type:- Truck with tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 12 hours

Mean weathering temperature:- 15.3°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	5
1.2 - 2.4	9
2.4 - 3.6	10
3.6 - 6.4	24
6.4 - 9.2	24
9.2 - 12.0	27
12.0 - 14.8	28
14.8 - 17.6	26
17.6 - 20.4	22
20.4 - 24.0	11
30 - 33	5
33 - 36	8

Contamination Density ($g\ m^{-2}$)							
	1	2	3	4	5	6	7
	5.0	5.5	8.7	6.5	9.1	5.2	6.9
	8	9	10	11	12	13	14
	2.6	2.1	3.6	2.8	1.4	3.5	-

Agent purity:- 86%, Corrected mean contamination density 4.1 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.5 DATE 17.9.73

Vehicle type:- FV 432

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 14.6°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	8
1.2 - 2.4	14
2.4 - 3.6	17
3.6 - 6.4	31
6.4 - 9.2	24
9.2 - 12.0	18
12.0 - 14.8	14
14.8 - 17.6	12
17.6 - 20.4	16
20.4 - 24.0	22
30 - 33	11
33 - 36	7

Contamination Density ($g\ m^{-2}$)							
	1	2	3	4	5	6	7
	0.44	6.1	1.7	1.6	2.9	9.0	2.9
	8	9	10	11	12	13	14
	1.8	5.3	2.9	1.1	3.2	2.2	-

Agent purity:- 84%, Corrected mean contamination density 2.7 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.6 DATE 1.10.73

Vehicle type:- Truck with tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 11.8°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	26
1.2 - 2.4	59
2.4 - 3.6	59
3.6 - 6.4	94
6.4 - 9.2	66
9.2 - 12.0	51
12.0 - 14.8	43
14.8 - 17.6	37
17.6 - 20.4	37
20.4 - 24.0	56
30 - 33	22
33 - 36	18

Contamination Density (g m^{-2})							
	1	2	3	4	5	6	7
	5.6	3.4	3.8	6.3	2.9	2.6	5.1
	8	9	10	11	12	13	14
	2.0	1.2	5.1	3.2	2.0	1.2	-

Agent purity:- 73%, Corrected mean contamination density 2.5 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.7 DATE 10.10.73

Vehicle type:- FV 432

Paint GP

Weathering time:- 0.25 hours

Mean weathering temperature:- 13.3°C

Decontamination:- Yes

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	30
1.2 - 2.4	40
2.4 - 3.6	39
3.6 - 6.4	69
6.4 - 9.2	51
9.2 - 12.0	40
12.0 - 14.8	30
14.8 - 17.6	21
17.6 - 20.4	17
20.4 - 24.0	20
30 - 33	11
33 - 36	8

Contamination Density ($g\ m^{-2}$)							
	1	2	3	4	5	6	7
	6.2	3.9	2.8	3.6	4.1	4.9	6.2
	8	9	10	11	12	13	14
	3.6	4.1	8.4	0.6	4.2	1.4	-

Agent purity:- 84%, Corrected mean contamination density 3.5 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.8 DATE 16.10.73

Vehicle type:- Truck with tilt

Decontamination:- Yes

Paint:- GP

Washdown:- No

Weathering time:- 0.25 hours

Mean weathering temperature:- 7.6°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	149
1.2 - 2.4	287
2.4 - 3.6	314
3.6 - 6.4	642
6.4 - 9.2	520
9.2 - 12.0	389
12.0 - 14.8	287
14.8 - 17.6	213
17.6 - 20.4	180
20.4 - 24.0	260
30 - 33	130
33 - 36	67

Contamination Density (g m^{-2})							
	1	2	3	4	5	6	7
	6.0	10.4	4.0	6.9	8.2	8.5	3.3
	8	9	10	11	12	13	14
	5.2	4.3	4.2	3.6	1.7	1.7	-

Agent purity:- 86%, Corrected mean contamination densith 4.5 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.9 DATE 22.10.78

Vehicle type:- FV 432 Decontamination:- Yes

Paint:- GP Washdown:- Yes

Weathering time:- 0.25 hours

Mean weathering temperature:- 6.8°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	27
1.2 - 2.4	38
2.4 - 3.6	35
3.6 - 6.4	59
6.4 - 9.2	44
9.2 - 12.0	31
12.0 - 14.8	23
14.8 - 17.6	18
17.6 - 20.4	17
20.4 - 24.0	24
30 - 33	16
33 - 36	13

Contamination Density (g m^{-2})							
	1	2	3	4	5	6	7
	3.7	3.6	3.9	1.4	3.4	2.9	2.3
	8	9	10	11	12	13	14
	6.1	10.4	5.1	7.0	5.8	7.0	-

Agent purity:- 82%, Corrected mean contamination density 3.9 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.10 DATE 29.10.73

Vehicle type:- Truck with tilt

Decontamination:- Yes

Paint:- GP

Washdown:- Yes

Weathering time:- 0.25 hours

Mean weathering temperature:- 11.0°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	196
1.2 - 2.4	354
2.4 - 3.6	366
3.6 - 6.4	629
6.4 - 9.2	500
9.2 - 12.0	398
12.0 - 14.8	295
14.8 - 17.6	234
17.6 - 20.4	187
20.4 - 24.0	249
30 - 33	111
33 - 36	87

Contamination Density (g m^{-2})							
	1	2	3	4	5	6	7
	11.8	7.9	8.7	5.1	2.6	4.0	4.0
	8	9	10	11	12	13	14
	4.7	4.9	11.7	4.0	10.0	3.6	-

Agent purity:- 88%, Corrected mean contamination density 5.6 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.11 DATE 5.11.73

Vehicle type:- Truck with tilt

Decontamination:- No

Paint GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 8.1°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	22
1.2 - 2.4	65
2.4 - 3.6	85
3.6 - 6.4	202
6.4 - 9.2	178
9.2 - 12.0	153
12.0 - 14.8	111
14.8 - 17.6	94
17.6 - 20.4	92
20.4 - 24.0	108
30 - 32	26
32 - 34	23

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	1.7	6.9	3.0	5.8	2.2	6.5	5.2
	8	9	10	11	12	13	14
	2.7	4.1	5.0	4.1	4.6	1.8	-

Agent purity:- 88%, Corrected mean contamination density 3.6 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.12 DATE 14.11.73

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 9.3°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	8
1.2 - 2.4	17
2.4 - 3.6	21
3.6 - 6.4	51
6.4 - 9.2	46
9.2 - 12.0	39
12.0 - 14.8	33
14.8 - 17.6	30
17.6 - 20.4	27
20.4 - 24.0	32
30 - 32	11
32 - 34	13

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	3.4	5.0	9.6	5.6	4.8	3.6	5.6
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 85%, Corrected mean contamination density 4.5 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.13 DATE 20.11.73

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 7.0°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	21
1.2 - 2.4	38
2.4 - 3.6	39
3.6 - 6.4	83
6.4 - 9.2	68
9.2 - 12.0	57
12.0 - 14.8	49
14.8 - 17.6	44
17.6 - 20.4	44
20.4 - 24.0	89
30 - 32	27
32 - 34	24

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	12.7	3.5	11.8	7.1	4.6	8.8	31.6
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 91%, Corrected mean contamination density 7.4 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.14 DATE 27.11.73

Vehicle type:- Truck with tilt

Decontamination:- No

Paint GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 2.7°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	88
1.2 - 2.4	157
2.4 - 3.6	161
3.6 - 6.4	337
6.4 - 9.2	293
9.2 - 12.0	225
12.0 - 14.8	185
14.8 - 17.6	137
17.6 - 20.9	122
20.4 - 24.0	155
24.0 - 26.5	95
26.5 - 30.0	106
30 - 32	56
32 - 34	59

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	6.7	17.7	7.6	6.4	4.7	5.1	4.0
	8	9	10	11	12	13	14
	7.1	10.2	3.8.	5.4	1.1	-	-

Agent purity:- 85%, Corrected mean contamination density 5.7 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.15 DATE 3.12.73

Vehicle type:- FV 432 Decontamination:- Yes

Paint:- GP Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 6.5°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 1.2	19
1.2 - 2.4	31
2.4 - 3.6	33
3.6 - 6.4	64
6.4 - 9.2	50
9.2 - 12.0	42
12.0 - 14.8	35
14.8 - 17.6	30
17.6 - 20.4	30
20.4 - 24.0	44
24 - 27	39
27 - 30	34
30 - 32	18
32 - 34	14

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	3.6	6.7	4.5	4.0	4.0	9.8	5.6
	8	9	10	11	12	13	14
	6.2	5.6	8.1	6.1	6.5	14.1	-

Agent purity:- 83%, Corrected mean contamination density 5.4 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.16 DATE 18.1.74

Vehicle type:- Truck with tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 72 hours

Mean weathering temperature:- 11.2°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	6
3 - 6	10
6 - 9	9
9 - 12	8
12 - 15	7
15 - 18	6
18 - 21	6
21 - 24	6
24 - 27	6
27 - 30	6
30 - 33	5
33 - 36	4

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	3.6	2.1	2.9	4.8	4.9	5.3	3.3
	8	9	10	11	12	13	14
	1.4	10.2	4.9	1.8	4.3	0.5	-

Agent purity:- 86%, Corrected mean contamination density 3.3 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.17 DATE 25.1.74

Vehicle type:- Centurion battle tank

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 72 hours

Mean weathering temperature:- 8.4°C

Sampling Time (hours)	Mean Ct (mg.min m^{-3})
0 - 3	2
3 - 6	2
6 - 9	3
9 - 12	3
12 - 15	2
15 - 18	2
18 - 21	2
21 - 24	2
24 - 27	3
27 - 30	3
30 - 33	2
33 - 36	2

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	4.1	3.7	4.4	3.8	3.0	2.7	4.8
	8	9	10	11	12	13	14
	1.8	4.0	1.9	1.2	3.8	1.4	1.4

Agent purity:- 84%, Corrected mean contamination density 2.5 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.18 DATE 18.2.74

Vehicle type:- Centurion battle tank

Paint:- GP

Weathering time:- 12 hours

Mean weathering temperature:- 6.3°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	2.0
3 - 6	2.4
6 - 9	21
9 - 12	19
12 - 15	16
15 - 18	13
18 - 21	10
21 - 24	9
24 - 27	8
27 - 30	6
30 - 33	5
33 - 36	6

Contamination Density (g m^{-2})							
	1	2	3	4	5	6	7
	5.2	4.1	1.9	3.2	3.1	5.9	1.9
	8	9	10	11	12	13	14
	1.0	6.1	1.6	4.4	0.8	1.2	7.6
	15	16	17	18	19	20	-
	7.1	10.6	3.4	2.7	2.6	8.5	-

Agent purity:- 74%, Corrected mean contamination density 3.0 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.19 DATE 22.2.74

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 72 hours

Mean weathering temperature:- 8.5°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	2
3 - 6	4
6 - 9	3
12 - 15	3
15 - 18	2
18 - 21	2
21 - 24	2
24 - 27	2
27 - 30	2
30 - 33	2
33 - 36	2

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	3.3	5.8	2.7	3.3	2.0	5.2	3.0
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 89%, Corrected mean contamination density 3.2 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.20 DATE 5.3.74

Vehicle type:- Saladin

Paint:- GP

Weathering time:- 12 hours

Mean weathering temperature:- 4.0°C

Decontamination:- No

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	37
3 - 6	48
6 - 9	45
9 - 12	44
12 - 15	38
15 - 18	33
18 - 21	28
21 - 24	25
24 - 27	23
27 - 30	20
30 - 33	19
33 - 36	19

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	3.5	1.0	1.5	2.8	1.8	1.1	4.6
	8	9	10	11	12	13	14
	1.1	1.9	2.5	6.3	3.4	0.8	-

Agent purity:- 83%, Corrected mean contamination density 1.7 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.21

DATE 25.3.74

Vehicle type:- Saladin

Paint:- GP

Weathering time:- 3 hours

Mean weathering temperature:- 9.0°C

Decontamination:- No

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	62
3 - 6	78
6 - 9	62
9 - 12	48
12 - 15	36
15 - 18	29
18 - 21	25
21 - 24	28
24 - 27	28
27 - 30	23
30 - 33	18
33 - 36	17

Contamination Density (g m^{-2})							
	1	2	3	4	5	6	7
	1.8	1.2	6.9	1.3	2.3	0.4	1.8
	8	9	10	11	12	13	14
	0.5	1.2	1.7	0.3	1.9	4.0	-

Agent purity:- 79%, Corrected mean contamination density 1.5 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.22

DATE 29.3.74

Vehicle type:- Saladin

Paint:- GP

Weathering Time:- 72 hours

Mean weathering temperature:- 8.5°C

Decontamination:- No

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	5
3 - 6	9
6 - 9	12
9 - 12	13
12 - 15	12
15 - 18	12
18 - 21	12
21 - 24	13
24 - 27	15
27 - 30	16
30 - 33	16
33 - 36	13

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	2.8	7.0	1.8	4.2	1.2	4.0	9.4
	8	9	10	11	12	13	14
	2.0	5.4	2.6	8.2	0.9	4.9	-

Agent purity:- 84%, Corrected mean contamination density 3.5 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.23 DATE 9.9.74

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- PU

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 3.1°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	7
3 - 6	9
6 - 9	8
9 - 12	6
12 - 15	5
15 - 18	4
18 - 21	5
21 - 24	5
24 - 27	4
27 - 30	4
30 - 33	3
33 - 36	2

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	1.6	1.4	0.2	1.9	0.6	0.8	0.9
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 87%, Corrected mean contamination density 0.92 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.24 DATE 17.9.74

Vehicle type:- Saladin

Decontamination:- No

Paint:- PU

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 4.0°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	28
3 - 6	36
6 - 9	34
9 - 12	26
12 - 15	21
15 - 18	18
18 - 21	18
21 - 24	14
24 - 27	13
27 - 30	9
30 - 33	6
33 - 36	5

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	3.6	4.3	3.0	3.0	5.5	8.2	8.3
	8	9	10	11	12	13	14
	4.0	6.8	1.6	4.3	1.2	6.8	-

Agent purity:- 85%, Corrected mean contamination density 4.0 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.25 DATE 26.9.74

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- PU

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 9.2°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	20
3 - 6	28
6 - 9	24
9 - 12	20
12 - 15	16
15 - 18	14
18 - 21	11
21 - 24	10
24 - 27	-
27 - 30	-
30 - 33	-
33 - 36	-

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	3.6	2.6	2.6	3.3	1.1	1.7	3.8
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 81%, Corrected mean contamination density 2.2 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.26 DATE 3.10.74

Vehicle type:- Saladin

Decontamination:- No

Paint:- PU

Washdown:- No

Weathering time:- 0.5 hours

Mean weathering temperature:- 7.8°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	317
3 - 6	220
6 - 9	138
9 - 12	91
12 - 15	52
15 - 18	43
18 - 21	38
21 - 24	30
24 - 27	27
27 - 30	22
30 - 33	21
33 - 36	20

Contamination Density (g m^{-2})							
	1	2	3	4	5	6	7
	4.1	3.2	3.5	3.1	1.8	5.3	3.4
	8	9	10	11	12	13	14
	2.0	1.0	2.1	1.8	4.1	2.0	-

Agent purity:- 86%, Corrected mean contamination density 2.1 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.27 DATE 7.10.74

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- PU

Washdown:- No

Weathering time:- 0.25 hours

Mean weathering temperature:- 6.1°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	929
3 - 6	329
6 - 9	192
9 - 12	142
12 - 15	100
15 - 18	76
18 - 21	59
21 - 24	52
24 - 27	61
27 - 30	66
30 - 33	51
33 - 36	39

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	3.4	2.6	2.1	4.0	0.1	3.6	4.4
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 86%, Corrected mean contamination density 2.5 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.28

DATE 14.10.74

Vehicle type:- Saladin

Paint:- PU

Weathering time:- 0.25 hours

Mean weathering temperature:- 7.9°C

Decontamination:- Yes

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	116
3 - 6	114
6 - 9	83
9 - 12	62
12 - 15	49
15 - 18	41
18 - 21	35
21 - 24	35
24 - 27	34
27 - 30	29
30 - 33	24
33 - 36	20

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	7.4	5.0	7.7	5.5	5.3	3.3	7.6
	8	9	10	11	12	13	14
	4.8	6.9	10.1	8.4	1.9	5.2	-

Agent purity:- 86%, Corrected mean contamination density 5.2 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.29

DATE 21.10.74

Vehicle type:- Truck without tilt

Paint:- PU

Weathering time:- 0.5 hours

Mean weathering temperature:- 5.8°C

Decontamination:- No

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	134
3 - 6	87
6 - 9	50
9 - 12	35
12 - 15	27
15 - 18	24
18 - 21	21
21 - 24	19
24 - 27	18
27 - 30	16
30 - 33	14
33 - 36	11

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	2.9	3.7	4.0	5.0	6.1	2.3	4.5
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 84%, Corrected mean contamination density 2.7 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.30

DATE 4.11.74

Vehicle type:- Saladin

Paint:- GP

Weathering time:- 0.5 hours

Mean weathering temperature:- 6.0°C

Decontamination:- No

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	315
3 - 6	217
6 - 9	132
9 - 12	89
12 - 15	63
15 - 18	52
18 - 21	47
21 - 24	50
24 - 27	48
27 - 30	39
30 - 33	29
33 - 35	17

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	4.9	2.2	8.6	3.2	1.7	5.7	2.8
	8	9	10	11	12	13	14
	1.3	3.1	0.9	0.2	5.7	3.5	-

Agent purity:- 72%, Corrected mean contamination density 2.2 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.31

DATE 9.12.74

Vehicle type:- Truck with tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 0.5 hours

Mean weathering temperature:- 5.0°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	138
3 - 6	74
6 - 9	50
9 - 12	36
12 - 15	28
15 - 18	23
18 - 21	21
21 - 24	19
24 - 27	17
27 - 30	14
30 - 33	12
33 - 36	11

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	1.9	4.0	1.1	7.1	0.2	3.9	1.2
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 89%, Corrected mean contamination density 2.5 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.32 DATE 17.12.74

Vehicle type:- Saladin

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 0.5 hours

Mean weathering temperature:- 6.0°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	150
3 - 6	91
6 - 9	66
9 - 12	44
12 - 15	32
15 - 18	26
18 - 21	24
21 - 24	30
24 - 27	24
27 - 30	20
30 - 33	19
33 - 36	16

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	6.8	3.1	6.2	3.8	5.2	6.8	3.0
	8	9	10	11	12	13	14
	0.7	1.7	0.08	0.08	0.44	2.0	-

Agent purity:- 93%, Corrected mean contamination density 2.9 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.33

DATE 26.1.76

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 0.7°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 2	28
2 - 4	34
4 - 6	32
6 - 8	27
8 - 10	22
10 - 12	17
12 - 14	14
14 - 16	12
16 - 18	11
18 - 20	10
20 - 22	9
22 - 24	8

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	2.2	2.8	2.9	7.1	1.9	10.0	6.9
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 94%, Corrected mean contamination density 4.4 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.34

DATE 28.1.76

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- PU

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 5.0°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 2	15
2 - 4	22
4 - 6	17
6 - 8	13
8 - 10	9
10 - 12	7
12 - 14	6
14 - 16	5
16 - 18	4
18 - 20	4
20 - 22	3
22 - 24	3

Contamination Density (g m^{-2})	1	2	3	4	5	6	7
	3.0	2.0	0.6	3.6	3.3	3.9	1.5
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 89%, Corrected mean contamination density 2.3 g m^{-2}

Agent:- Unthickened GD

TRIAL NO.35

DATE 3.1.76

Vehicle type:- Truck with tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- -0.4°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 2	190
2 - 4	307
4 - 6	299
6 - 8	260
8 - 10	231
10 - 12	198
12 - 14	173
14 - 16	143
16 - 18	122
18 - 20	108
20 - 22	94
22 - 24	80

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	6.2	3.9	2.8	3.6	4.1	4.9	6.2
	8	9	10	11	12	13	14
	3.6	4.1	8.4	0.6	4.2	1.4	-

Agent purity:- 89%, Corrected mean contamination density 3.5 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.36

DATE 9.2.76

Vehicle type:- Truck without tilt

Paint:- PU

Weathering time:- 6 hours

Mean weathering temperature:- 7.5°C

Decontamination:- No

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 2	15
2 - 4	27
4 - 6	28
6 - 8	25
8 - 10	22
10 - 12	18
12 - 14	14
14 - 16	12
16 - 18	10
18 - 20	8
20 - 22	7
22 - 24	6

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	3.4	2.4	4.3	2.2	0.4	2.9	4.8
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 88%, Corrected mean contamination density 2.6 $g\ m^{-2}$

Agent:- Unthickened GD

TRIAL NO.37

DATE 6.7.76

Vehicle type:- Truck without tilt

Decontamination:- No

Paint:- GP

Washdown:- No

Weathering time:- 3 hours

Mean weathering temperature:- 31.2°C

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	16
3 - 6	26
6 - 9	21
9 - 12	21.6
12 - 15	15
15 - 18	7
18 - 21	5
21 - 24	< 5
24 - 27	< 5
27 - 30	< 5
30 - 33	< 5
33 - 36	< 5

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	9.0	10.8	8.8	5.6	0.1	9.0	0.2
	8	9	10	11	12	13	14
	-	-	-	-	-	-	-

Agent purity:- 81%, Corrected mean contamination density 5.0 $g\ m^{-2}$

Agent:- Thickened GD

TRIAL NO.38

DATE 13.7.76

Vehicle type:- Saladin

Paint:- GP

Weathering time:- 3 hours

Mean weathering temperature:- 22.0°C

Decontamination:- No

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	26
3 - 6	48
6 - 9	40
9 - 12	29
12 - 15	22
15 - 18	17
18 - 21	15
21 - 24	13
24 - 27	14
27 - 30	13
30 - 33	12
33 - 36	9

Contamination Density ($g\ m^{-2}$)							
	1	2	3	4	5	6	7
	9.7	9.5	9.9	6.4	10.3	7.0	7.6
	8	9	10	11	12	13	14
	1.9	4.0	4.4	4.4	0.7	3.1	-

Agent purity:- 76%, Corrected mean contamination density 4.6 $g\ m^{-2}$

Agent:- Thickened GD

TRIAL NO.39

DATE 20.7.76

Vehicle type:- Saladin

Paint:- PU

Weathering time:- 3 hours

Mean weathering temperature:- 21.3°C

Decontamination:- No

Washdown:- No

Sampling Time (hours)	Mean Ct (mg min m^{-3})
0 - 3	64
3 - 6	91
6 - 9	86
9 - 12	64
12 - 15	32
15 - 18	16
18 - 21	9
21 - 24	7
24 - 27	5
27 - 30	5
30 - 33	< 5
33 - 36	< 5

Contamination Density ($g\ m^{-2}$)	1	2	3	4	5	6	7
	3.7	10.1	12.1	7.2	9.9	5.8	11.3
	8	9	10	11	12	13	14
	12.1	7.6	7.4	11.6	0.2	3.9	-

Agent purity:- 76%, Corrected mean contamination density 6.0 $g\ m^{-2}$

Agent:- Thickened GD

APPENDIX E

NORMALISATION OF CONTAMINATION DENSITIES

INTRODUCTION

The contamination of vehicles and equipment in the field is often done by hand spraying and allowing the spray to drift on to the target. The levels of contamination of the targets are therefore variable from experiment to experiment and the contamination density is often not evenly spread over the target. In order to compare the results of one experiment with another, data are often normalised to correspond to an initial contamination density of 10 g m^{-2} spread evenly over the target on the assumption that effects may be linearly correlated with the mean target contamination density. This Appendix reports the results of some experiments carried out to confirm that the vapour hazard from painted surfaces was linearly related to the initial contamination density.

EXPERIMENTAL

Neale (1) has already shown that the uptake of drops of agent by alkyd paint is proportional to the residence time of the drop on the surface. In this work, 1 mg drops of GD were placed on an aged paint surface (5 x 5 cm) on a metal plate, and the excess agent rinsed away with alcohol after 5 min, 30 min and 60 min. The levels of contamination corresponded to 1 g m^{-2} and 10 g m^{-2}.

After the excess agent had been removed, the painted metal plates were allowed to dry stand for 30 min in a fume cupboard. The vapour evolution from the plate was then monitored by a method closely similar to that of Neale (1) and immediately, the paint was dissolved from the plate and analysed for agent by a colorimetric method.

RESULTS AND DISCUSSION

The results of the experiments are recorded in Figure E1. It may be seen that the rate of vapour evolution is independent of contamination density and the period of absorption; it is dependent only on the absolute quantity of GD in the paint film. The rate of vapour evolution was found to be 2.8 μg min^{-1} for each milligram of agent in the paint. For a first order decay this gives a rate constant of 0.17 h^{-1}; this compares with

figures ranging from 0.05 - 0.22 h^{-1} for the military vehicles studied in this paper (see Table 1).

REFERENCE

(1) E. Neale and others. CDE TP 13.

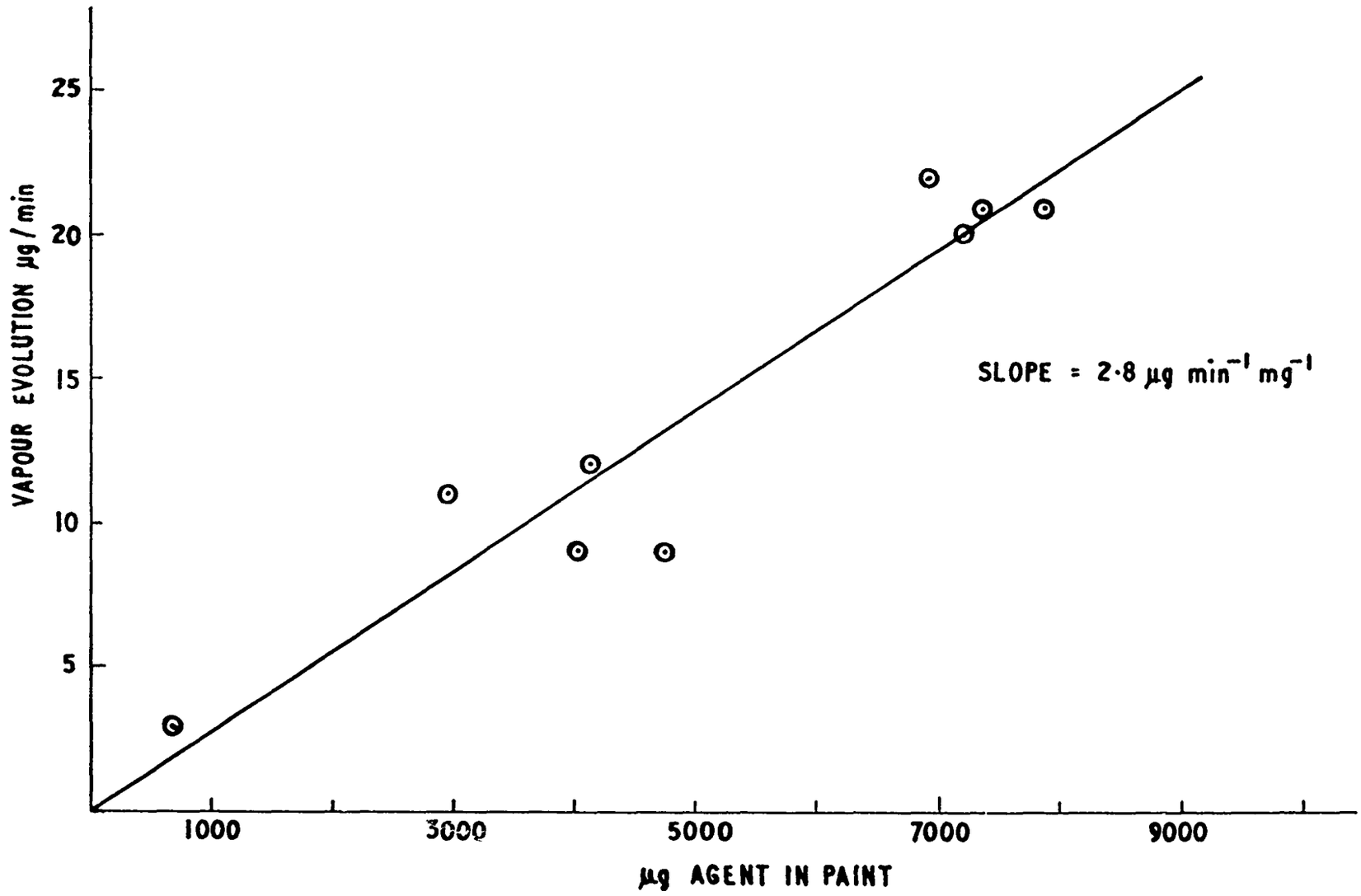


FIG. E1.

DEPENDENCE OF VAPOUR EVOLUTION ON GD CONTENT OF PAINT

APPENDIX F

REDUCTION OF VAPOUR HAZARDS BY WEATHERING - CALCULATION OF THE REQUIRED WEATHERING TIME

It has been shown (1) that the concentration of agent vapour in a confined space due to the presence of a contaminated object will rise to an equilibrium concentration given by the expression

$$C \simeq \frac{R_1}{R_2 . V} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where C is the equilibrium concentration of agent (mg m^{-3})

V is the volume of the confined space (m^3)

$R_1 = \frac{dm}{dt(t_w)}$ and is the rate of vapour evolution from the contaminated object (mg h^{-1})

R_2 is the air changes per hour of the confined space (h^{-1})

The maximum permitted dosage for G agents before masking is 5 mg $min^{-1}m^{-3}$(2), thus the agent concentration in a working area must not exceed 0.01 mg m^{-3} to allow the working of a full shift (500 min) in that area without protection. R_1 must not exceed the value of ($0.01.R_2.V$).

Now $R_1 = K_1 m$

and $m = m_o e^{-K_1 t}$ (see Appendix C)

so that $R_1 = K_1 m_o e^{-K_1 t}$ $\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

Values of K_1 and m_o for various military vehicles are listed in Table 2 of this report. By using these figures, together with Equations 1 and 2, the safe working times (t) for any situation can be calculated. Table 2 lists the weathering times (t_R hours) which must elapse before various contaminated military vehicles can be worked on for a full 500 minute shift in a typical workshop (R_2 = one air change per hour) of 1000 m^{-3} volume, where t_R is given by

$$t_R = -\frac{1}{K_1} \ln \left(\frac{10.4}{K_1 m_o}\right) \text{hours}$$

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REFERENCES

(1) A. Bailey, CDE TN 313.

(2) NATO Document AC/196 (WP7) D.100.

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12	Captain, NBCD
13	Air Eng. 31b (RAF)
14	OR 42c (RAF)
15	GD3 (RAF)
16	DD Av.Med. (RAF)
17 - 27	Members of Chem.Cttee.
28 - 31	MVEE (3 copies attn. Mr. A.W. Glassbrook)
32	IAM
33 - 35	Home Office SAB (1 copy attn. Mr. R. Cotterill)
36 - 37	DRIC
38 - 55	US Army Standardisation Group, UK (2 for FCST)

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