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SUFFIELD MEMORANDUM

NO. 1265

COMPARISON OF THREE SKIN DECONTAMINATION SYSTEMS FOR ACTIVITY AGAINST G AND H AGENTS (U)

by

R.W. Bide, S.J. Armour, T.W. Sawyer,
D. Parker and D. Risk

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ABSTRACT

The Canadian Decontaminating Mitt (Mitt) and the US Personnel/ Casualty Decontamination System: Skin Decontamination Kit (SDK) were compared to the proposed Canadian Reactive Skin Decontaminant Lotion (RSD) by parallel exposure and decontamination of guinea pigs. GD and HD were placed on depilated areas on the back for 55 sec and the skin decontaminated. Mortality, time-to-effect and time-to-death were recorded for GD tests. The burn damage from HD was assessed.

All three decontamination systems effectively decontaminated 10 LD_{50} of GD. At 14 LD_{50} GD, the upper limit of the challenge used, the SDK was fully effective and the RSD and the Mitt appeared to be slightly less effective. However, a true numerical comparison could not be made and the functional comparison shows similar activity for the three systems.

All three decontaminants provided significant protection against the deep, third degree chemical burns resulting from 0.8 -2.0 *u*L drops of HD applied directly to the skin.

The utility of skin decontamination was demonstrated as all three systems counteracted the lethal effects of GD and significantly reduced the vesicant damage from HD. In addition to preventing death from GD, use of a skin decontaminant also provided a longer period within which to apply other therapeutic measures directed against systemic effects.

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INTRODUCTION

For some time, the Canadian Forces (CF) have used Fuller's earth as the main personnel decontaminant. The earth is dispensed from a porous cloth mitt. Two new decontaminants have been under development, one in Canada (2, 9, 10) and the other in the United States (3), which are potential replacements for the Canadian Decontaminating Mitt (Mitt). The Canadian Reactive Skin Decontaminant Lotion (RSD) is to be applied, as a liquid, directly to a contaminated area of the skin. The solvent which decontaminates (2) also contains an active ingredient that reacts chemically with and destroys chemical warfare agents. The US Personnel/Casualty Decontamination System: Prototype Skin Decontamination Kit (SDK) consists of a plastic tear-open pouch containing a fiber pad which acts as a carrier for decontamination resin which removes agents. The pad and its contents are intended to be rubbed onto a contaminated area of the skin.

Previously (1), when the first prototype formulation of the RSD was compared to the SDK, the two decontaminants were found to be roughly similar in effectiveness against chemical agents. In the 12 months since those tests were done, techniques have improved and a second version of the RSD has evolved. The current study was undertaken to provide a comparison of the effectiveness of the Mitt, which is in service, and the two new decontaminants, the SDK and the second prototype formulation of the RSD.

MATERIALS AND METHODS

Animals.

Male albino guinea pigs, *Cavia porcellus*, virus free, Hartley strain CRL(HA)BC, 250-350 g body weight were purchased from Charles River Laboratories, St. Constant, Que. They were housed in plastic cages and provided with food and water *ad libitum* for a minimum of 7 days in the Vivarium at DRES before use. The animals weighed between 500 and 800 g when used in GD tests and between 500 and 1000 g when used for HD testing.

Animals selected for experiments were housed individually in stainless steel cages with mesh floors. A chow diet was supplied *ad libitum* with daily supplements of fresh carrots, cabbage or lettuce.

During chemical exposure and subsequent decontamination, the guinea pigs were immobilized in a stainless steel restrainer that was developed at DRES (4). Felt pens used to mark animals were VWR Lab Markers, permanent alcohol/waterproof, black (VWR Scientific, San Francisco, Calif.).

Materials.

The Reactive Skin Decontaminant Lotion, currently under development as part of a decontamination system for the Canadian Forces (10), is a liquid with physical properties similar to engine oil (1.44 poise at 25°C), containing an active ingredient that destroys G, V and H agents (2, 9). The second prototype, which was used in these studies, consists of a 1.25 molal solution of potassium 2,3-butanedione monoximate (KD) in a mixture (1:9 w:w) of H_2O and polyethyleneglycol monomethylether of nominal molecular weight 550 (MPEG). KD (MW. 139) was prepared by Raylo Chemicals, Edmonton (lot number 1363-A-1). MPEG, lot No. 0608CK, was purchased from Aldrich Chemical Co., Milwaukee, WI. RSD was prepared by dissolving KD (17.4 g) in the H_2O:MPEG (1:9) mixture by gentle heating (60°C max) and stirring. The resulting "lotion" was sealed in amber bottles and stored at room temperature until used. This second prototype RSD has been formulated to produce the physical properties required by the CF (10) and to obtain an optimised biological effect.

Personnel/Casualty Decontamination System: Skin Decontamination Kits (Produced under Contract DAMD 17-85-C-5200) were provided by the United States Department of

the Army, United States Army Medical Materiel Development Activity, Fort Detrick, MD. for independent evaluation. Each DECON PACKET contained 2.8 g AMBERGARD^{R} XE-555 decontaminant (3), which is a dry resin system with both sorbant and reactive characteristics, packaged in a plastic tear-open pouch containing a fiber pad which acts as a carrier and applicator for the decontaminant. The pad and its contents are intended to be rubbed onto a contaminated area of the skin.

The Canadian Decontamination Mitt (NATO Stock No. 4230-21-845-6696) is the current personnel decontaminant used by the CF. Samples were drawn from current stock. It consists of a loosely woven cloth mitt with pockets on both faces containing Fuller's earth. When the mitt is rubbed or patted on a surface, the Fuller's earth, a chemical absorbent, is discharged onto that surface and is then brushed off.

Pinacolyl methylphosphonofluoridate (GD, MW 182) was synthesized and purified by the Chemical Biological Defence Section, DRES. All doses of GD are expressed in multiples of the LD_{50}. The LD_{50} value used for the percutaneous application of GD to guinea pigs was 2.6 mg/kg (5, 7).

Bis (2-chloroethyl) sulfide was purified by distillation (HD, MW 159) by the Chemical Biological Defence Section, DRES. HD was applied to the animals as droplets of the neat chemical.

Experimental procedures

Animal preparation and handling

Forty-two to 46 hr before chemical exposure, the backs of subject guinea pigs were carefully shaved with electric clippers and then depilated by a 30 min application of Neet^{R} depilatory cream. The depilant was liberally applied immediately after shaving and the animals were held in small mouse tubs for the 30 min depilation period. They were then washed in running, tepid water with only hand rubbing to facilitate the washing process. After drying with paper towels using only patting motions to avoid abrasion, they were returned to their individual cages.

On the morning of the day of exposure, day 0, the animals were weighed, placed in individual restrainers shortly before exposure, and distributed into experimental groups of 4 animals. For GD exposure, two spots were marked, 3 cm apart, with a felt marking

pen, in the depilated area along the mid-dorsal line, to define a target line for application of the agent dose. For HD exposure, four dots were placed upon the mid-dorsal line, about 1.5 cm apart to guide the spacing of the HD drops on either side of the dorsal line. Doses of agent were dispensed using Western Model 800 positive displacement micro-volume dispensers (VWR Scientific, San Francisco, CA.).

During the following procedures the animals were held under restraint and kept in a fume hood, facing the door of the hood. The air flow (> 1 m/s) provided an effective barrier to prevent inhalation of any agent or agent-product vapours emanating from the back of the animal itself or from adjacent members of the group.

Agent exposure

At time 0, the prescribed dose of GD was applied as a single drop near the middle of the target line.

HD drops of 0.8, 1.2, 1.6 and 2.0 *u*L were applied in a fixed pattern to each side of the back of each animal and one side only was treated with decontaminant. The order of application was reversed on the two sides so that the 0.8 and 2.0 *u*L drops were opposite in each case (Fig. 1). Each animal had both control and test areas, which were well separated, and a direct, visual comparison of effect and efficacy could be made.

Decontamination

Decontaminants were applied 55 sec after the agent dose.

For decontamination with RSD, 0.7 mL of RSD was applied to the target area from a polyethylene tuberculin syringe taking care to cover the surface contaminated with agent. The RSD covered skin was rubbed gently for 20 sec with the syringe barrel to ensure full contact between the RSD, skin and remaining agent. After 1 hr, the RSD was wiped off using surgical gauze and, after a second volume (about 1 mL) of RSD was applied to both control and test sides, the whole contaminated area was carefully wiped again with fresh gauze to remove the RSD. The animals were then washed as described below.

For decontamination with the SDK, each pouch was opened and the pad cut in half along the centre fold of the pouch. Each half-pad was used to decontaminate one animal. A half-pad was rubbed over the contaminated area for 20 sec, working the pad against the

direction of hair growth to ensure that the decontaminant was in close contact with the skin. After 1 hr, the control areas were treated with 1 mL RSD and the animals were washed as described below.

When decontaminating with the Mitt, the operator donned the Mitt according to standard instructions and rapidly rubbed the face of the mitt on the contaminated area for 20 sec to transfer the Fuller's earth to the surface. The reverse side of the Mitt was used to decontaminate a second animal. After 1 hr, the control areas were decontaminated with 1 mL RSD and the animals were washed as described below.

During decontamination of GD with the SDK and the Mitt, a cardboard mask was held over the head to keep the decontamination resin system or the Fuller's earth away from the face and nose of the animal. When decontaminating HD, a cardboard mask was pressed onto the mid-dorsal line of the back to keep control and test areas separate.

Washing and subsequent observation

Each animal was washed first with tepid, running tap water, then with 0.5% (v:v) Savlon disinfecting solution and then washed again with tap water. After drying with paper towels, the animals were returned to their individual cages.

The animals exposed to nerve agents were closely watched for clinical signs of poisoning throughout exposure, decontamination and the immediate post-treatment periods. They were examined regularly for 5 days and weighed on days 1 and 5. Survivors were sacrificed on day 5. All animals were examined post mortem for gross lesions.

Animals exposed to HD were kept for at least 28 days for observation of the healing process. For each animal, a photographic record was created, a Draize score (6), a scab-type score and a scar score were compiled, measurements were made of burn, scab and scar areas at various intervals and body weight was recorded at regular intervals. The experiment was closed on day 28 although the animals continued under observation until day 38.

Assessment of HD effects

A scab-type score, which was assessed daily, was based upon the nature of the scab formed. HD causes a defined series of events as it acts on the skin and the hair

follicles. Surface damage to the skin first forms an eschar (8). When hair follicles are present, HD enters the follicle and causes damage to the follicle tube (Millard, M. and N.K. Jaax, USAMRICD, Personal communication). Shallow penetration of the follicle tube or the skin surface results in a serum exudate and a light tan serum scab. Deeper penetration to the base of the follicle or to the vascular tissues of the skin produces a blood exudate and a dark red/purple blood scab. A simple score was based upon these concepts. No eschar or scab was scored as 0. Eschar, a clear covering of dead skin, was given a value of 1. A serum scab was scored as 2. A mixed serum and blood scab (10% - 70% blood) was scored as 3. An all blood scab was scored as 4. The scores for the control and test sites on each animal were summed and averaged to obtain the reported score value.

Scar damage was scored on day 28 according to the apparent depth of the scar and the state of healing. The animals were shaved carefully immediately before this assessment was done. No visible scar was scored as 0. A visible lesion with normal hair growth was scored as 1. A visible lesion with affected hair growth was scored as 2. A lesion without hair growth but with normal appearing skin was scored as 3. A scar with no hair and visibly altered skin surface was scored as 4. A scar with a depressed and discoloured centre or one still showing healing in progress was scored as 5. If the scab was still present, the lesion was not scored and the maximum possible score for that animal was reduced accordingly. The scores for the control and test sites on each animal were summed and averaged to obtain the reported number.

Scar and scab areas were estimated from photographs using a known area in each picture for reference. The areas were established by tracing the scar or scab image with a cursor on a graphics tablet connected to a SigmaScan Scientific Measuring System (Jandel Scientific, Sausalito, Calif.).

RESULTS

The Neet^{R} depilatory cream, in combination with careful close shaving with clippers, effectively removed the hair from the back skin of the guinea pigs. When the animals were used about 42 hr later, short hair stubble could be felt when the skin was stroked against the direction of hair growth. On some animals, small areas or islands of longer stubble were present where the depilation was not as effective. In general, these were ignored. The

depilation was not as complete as can be, and was, achieved (1) by more vigorous wash procedures. However, decontamination provided much greater protection from GD for animals depilated with this mild treatment than was observed previously with those depilated by more vigorous action (1).

The hair stubble posed no problem for either the Mitt which is made of substantial cloth or the RSD which, being liquid, readily flowed among the stubble onto the skin surface. However, when using the SDK, the stubble tended to trap and catch the fibers of the application pad and, on many occasions, the pads were destroyed following 20 sec of rubbing on the stubble.

Application of decontaminants

The liquid RSD applied easily and tended to form a layer on the skin that stayed at the application site although some excess did run off (Fig. 2a). After 1 hr, the majority of the RSD was still in place on the back of the animal. The water soluble RSD washed away readily leaving no visible residue.

The SDK, a very fine mesh black powder, spread rapidly over all surfaces in the vicinity of the application site (Fig. 2b). Before the application time was complete, the majority of the decontamination resin had been carried away by the airstream of the hood used to house these experiments. Enough decontamination resin was retained by the hair and skin of the animal to colour the application area black. The black mixture was difficult to remove when dry and repeated efforts with Savlon solution and water failed to remove the black residue from the animals. Most animals retained resin for 10 days and many still showed blackening on day 38.

The Mitt rapidly discharged the Fuller's earth onto the contaminated area. The agent spots were readily identified as wet spots following the first pass with the Mitt (Fig. 2c). The wet areas disappeared by the third pass of the Mitt. A quantity of Fuller's earth was swept away by the air stream of the hood and, at the end of the 20 sec decontamination period, the back of the animal and the restraint were covered with dry Fuller's earth. Most of the Fuller's earth was washed away by the running tap water and by day 3 there were no signs of Fuller's earth on the animals.

The cardboard masks used were effective in keeping the decontaminant powders away from the face and nose of the animals when decontaminating GD and in preventing decontamination of the control side in experiments with HD (Fig. 2b,c). In both procedures, the face and nose usually remained white and it is unlikely that any of the decontaminants were inhaled. No black resin was seen in the respiratory tract upon post mortem examination of animals decontaminated with SDK.

Decontamination of GD.

All non-decontaminated animals died when exposed to more than 2 LD_{50} of GD (Table I). All animals that died and some of those that survived, exhibited the clinical signs typical of GD poisoning ie. excess salivation (chewing), tremors, convulsions, flaccid paralysis and coma before death. The appearance of clinical signs (Table II) and the time-to-death (Table III) were inversely related to the dose of GD applied.

For decontamination of GD, two trials were run. In the first, where the maximum dose was 10 LD_{50}, all decontaminated animals survived. In the second trial, when the maximum dose was increased to 14 LD_{50}, all animals decontaminated with SDK survived. Animals given 10 LD_{50} GD and decontaminated with RSD survived but 1 of 4 and 2 of 4 given, respectively, 12 and 14 LD_{50} died. In each of the 10, 12 and 14 LD_{50} groups decontaminated with the Mitt, 2 of 4 animals died.

The onset of clinical signs of GD poisoning (Table II) generally occurred later in animals that were decontaminated as compared to those that were not decontaminated. The range of responses was large. In some groups, there were one or more animals in which the clinical signs appeared at the same time as in the non-decontaminated controls. However, other animals in the same group showed much delayed effects. In some animals, clinical signs appeared and were followed by remission and recovery. As a result, the numbers of animals surviving (Table I) and the numbers of affected animals (Tables II & III) do not agree. Also, because of the large ranges in times-to-effect within a given group and because the groups contained only 4 animals, the total data and an approximate mean are given in the tables rather than statistical values based upon the Normal assumption which may not be valid.

As with time-to-effect, the time-to-death values (Table III) were generally longer in animals treated with decontaminant. There were also large variations within the groups. Animals that died overnight on day 1 were recorded as >500 min and those that died during the second night were recorded as >1000 min. To estimate the mean time-to death, the 500 or 1000 values were included directly in the calculations. Again, statistical calculations were not done as much of the data is not amenable to analysis.

No significant changes ($P > 0.05$) in body weight were recorded between groups. All animals lost weight on day 1 and survivors regained and increased their weight by day 3.

A number of animals survived for 1 or 2 days, albeit in a much afflicted state. Dehydration and anorexia with concomitant weight losses were observed in individual animals that were severely affected by GD but survived the initial insult. Some of these "survivor" animals also exhibited limb and torso paralysis which seemed to occur randomly and were not consistent either in severity or with regard to the limb or body area affected.

Post mortem examination of control and test animals revealed no gross lesions. Histologic examination of the paralysed animals indicated that the paralysis resulted from a neuronal degeneration and focal necrosis in the brain stem (This condition has been seen regularly during the development of the RSD and may result from extended anoxic periods during the toxic crisis. Bide, R.W., Unpublished observation.).

Decontamination of HD.

No significant changes in body weight were observed that could be attributed to HD exposure. All animals lost weight immediately following the treatment but regained and surpassed the original weight by day 3. The weight loss on day 1 was attributed to trauma and stress caused by handling during the experimental procedure.

On post mortem examination of the animals, no changes caused by HD, other than the burns, were observed. In addition, no changes were observed that could be attributed to the Mitt, the RSD or the SDK (other than the accumulation of decontamination resin on the skin from the SDK).

The Draize scores of all burns were similar. On day 1 all erythema scores were 4 and all edema scores were 3. The Draize method (6) calls for a 1 mm rise in the skin surface due to edema to warrant an edema score of 4. This condition was not observed

because of the slow appearance of the HD lesions and the depressed centre of the HD burn resulting from the formation of an eschar. By day 2, scabs were formed and erythema and edema had subsided. Formation of scabs prevented further scoring of the burns. As no differentiation could be obtained, the Draize scores were not considered in the analysis of the HD effects.

Control burns

HD applied to the control side of each animal caused similar third degree burns (Fig. 3, 4 & 5). On day 0, about 4 hr after treatment, the burn areas were erythematous and edematous. On a few animals, an eschar had formed in the centre of the affected area. On day 1, all control burns had the typical doughnut-like appearance with a white area of dead or keratinized skin (eschar) in the centre surrounded by a ring of erythematous and mildly edematous tissue. Within experimental error, on day 1 the area of both the eschar and the erythematous rim of the control burns were similar on each animal at each dose and the areas of the burns were roughly related to dose.

Scab scores are presented (Table IV) for days 2 and 4 only. Between day 1 and day 3, most of the control burns developed a hard red/brown scab over much of the burn area (scab score 3 or 4). Scab scores were generally constant between days 2 and 4 although some development was recorded. The scabs were not fully developed on control burns on day 1 and sloughing of scabs (*vide infra*) between days 5 and 9 caused changes in the scab scores. Two animals decontaminated with the Mitt had much less severe control burns (average scores 1.0 and 1.25). Examination of the photographs indicated that some decontaminant may have reached the control burns on these animals. On two animals, both decontaminated with RSD, the control burns were larger and shallower than those of the other animals. The scab scores were 2.0 and 2.25 and the areas were 6.4 and 8.5 respectively. Examination of the photos indicated that larger shallow burns were present.

The areas of the lesions were maximum on day 1 and appeared to have some linear relation to dose on some animals. However, on others, there was no relationship and even a negative relation in one instance. For this reason, the areas of the four control burns were summed to provide the data of Table V. The areas on day 1 are given because the lesions reduced rapidly in size on subsequent days until the sizes of lesions and scabs

were similar. The areas of the scabs increased between days 1 and 2 and then were constant until sloughing began on day 5 (*vide infra*). On some of the animals, the scab areas appeared to have a relationship with dose but there was no consistency between animals. Again, the areas were summed to provide the reported figures (Table V).

Between days 5 and 9, some of the animals developed a marked erythema around the scabs of the control burns that became sensitive to tactile stimulus. In some cases, confluence with adjacent burns resulted in a continuous erythemic area surrounding all of the control burns. Where erythema was present, the original blood scabs were sloughed from the control burns between days 5 and 9 and new blood scabs were formed. The second scabs were larger and in some cases confluent with adjacent areas and the tenuous relationship between scab size and dose was greatly reduced. The second scabs were lost between days 18 and 28. A third scab was formed in the centre of some of the larger wounds and the healing and scarification process continued.

Many of the scars left by the control burns were large, hairless scar tissue (scar score 3 and 4) and often had depressed centers with a blood red colour (scar score 5). The overall average scar score for control burns was 4.2. The individual scar areas were measured and, as was the case with lesion and scab sizes, the areas were summed (Table V). A reasonable relationship could be established between scar area and dose of HD. The relationship was usually clear when the animal retained the original scab throughout the healing period. However, when the scabs sloughed and reformed, they were often enlarged, the relationship between dose and scar area was altered and confidence in the scar area as a measure of HD damage was reduced. As noted with the scab areas, the scar areas of control burns on the RSD group were larger than those recorded for the other two groups.

Decontaminated burns

Upon visual examination of the decontaminated burns, all three decontaminants appeared to work well (Fig. 3, 4 & 5). In most cases, the apparent affected area seemed to be reduced, the scabs formed were smaller and eventually the scars were less severe.

On day 0, the decontaminated areas had erythematous, edematous burns. The burns were usually crisply defined and not as diffuse as the control burns. On day 1, most

of the decontaminated burns had formed an eschar and had the characteristic doughnut appearance of HD lesions. At each dose of HD and with each decontaminant, the areas of the decontaminated burns were smaller than the control burns (Table V). Again, no consistent linear relationship between area and dose was obtained although a linear relationship was seen on some animals. The burn areas were summed and upon comparison of the total areas there was a definite reduction in size of the decontaminated lesions.

On the decontaminated burns, scabs formed about one day later than observed with the control burns and the majority of scabs were a light clear cover or, at most, the tan/brown hard cap that is usually indicative of a serum scab (scab score 2; Table IV). The scabs of the decontaminated burns generally remained undisturbed for the healing period. As with the control burns, the lesion size reduced between days 1 and 4 when the lesion and scab sizes became similar. Although a progression of size was evident with dose, the areas were not linear with dose. The total scab areas were consistently smaller than the control values.

The erythematous rings that appeared around the control burns on days 5 to 9 were not observed on the decontaminated burns. No confluence or spreading of the scabs or affected areas was observed. The scabs on the 0.8 *u*L burns were sloughed first around day 12 and those of the 2.0 *u*L some 4 to 6 days later. In many animals, guard hair grew through the scabs on decontaminated burns which affected the apparent timing of the scab release because, when the scab and hair were intimately joined, the scab remained trapped in the hair.

Scab scores (Table IV) for the test areas decontaminated by the RSD, SDK and Mitt were, respectively, 1.0, 0.75 and 1.0 on day 2 and 0.9, 0.8 and 0.5 on day 4. The main factor in the smaller value obtained with the Mitt on day 4 was 0 scores on two animals.

The superficial scars left on the decontaminated sites were generally smaller than those on the control sites. In some cases, the decontaminated burns healed completely and on many sites the hair growth was returning to normal at the end of the observation period. The usual scar score was between 0 and 2. On one or two animals the new hair was imbedded in the scab and a new wound was opened during shaving with the result

that no scar score was obtainable. Scar areas were larger on those animals decontaminated with RSD (Table V).

DISCUSSION

Without decontamination, all of the animals would have died following the GD doses used in this study. All three decontamination systems tested provided excellent protection up to 10 LD_{50} of GD and measurable protection to 14 LD_{50}, the highest dose used in this study. Although no fatalities were recorded at 14 LD_{50} GD with the SDK, the clinical signs that were observed indicated that GD was penetrating the skin and causing toxicity and that higher doses almost certainly would have proven fatal. In the previous study (1), the full protection against GD was limited to 6 LD_{50}. Changes in the depilation process and a shift to larger test animals appear to be responsible for the difference.

Despite the primitive nature of the estimates of HD decontamination, the data from visual observations, scab and scar areas clearly show a beneficial effect of all three decontaminants against vesicant action. Assessments of HD damage based upon lesion and scab area provided a clear separation between control and decontaminated animals but failed to provide any differentiation between the decontamination systems. The RSD lesion, scab and scar areas were greater than those of the other two groups, but so were the areas of the control burns. A simple proportional comparison is untenable as a dose - area relationship was not demonstrated. A similar but more tenuous result was obtained from scar scores and scar area measurements. In this case, the increased size of some of the scars following early sloughing of the scabs also distorted the results.

In several cases, the areas of scabs and scars were similar but the depth of the lesion as indicated by the scab and scar scores was very different. The control lesions observed with 0.8 *u*L HD were often equal or smaller than the lesions from decontaminated 2.0 *u*L spots but the final results, in terms of tissue damage and scarring, were very different because the greater depth of the burns. Comparisons made from any one assessment method did not provide a satisfactory scale for comparison of control and decontaminated lesions. Therefore, numerical comparisons (ie. per cent protection) were not obtained although the data are being carefully reviewed to see if such comparisons are, in fact, meaningful.

All three decontaminant systems worked at about the same degree of efficacy in the conditions of these tests, although the SDK would appear to be more efficacious in counteracting GD than either the Mitt or the RSD, and the apparent efficacy of the three was SDK > RSD > Mitt. However, the data presented must be interpreted with caution. The amount of decontaminant applied with the RSD was 0.7 mL or 0.8 g. The half-pack of SDK would contain a nominal 1.4 g of decontaminant. The amount of Fuller's earth decontaminant applied from the Mitt was probably higher. However, the effective quantities of SDK and Mitt decontaminants used could not be established because of the air-borne dispersal of the SDK and Fuller's earth. Also because of the dispersal of the SDK and Mitt powders, the time of contact with the skin will have been different than that of the RSD which was left on the skin for 1 hr. Thus, it is not possible to provide a meaningful numerical relationship between the number of LD_{50}s of GD controlled and the amount of a given decontaminant applied. The results obtained may be very different when the systems are tested under conditions in which the amounts or capacities of the decontaminants and the time of contact are closely controlled.

This study, similarly, does not and cannot provide an estimate of the proportion of agent destroyed as opposed to adsorbed/solvated by the different systems. For the RSD, the roles of solvent and active ingredient have not been established (2) nor have the relative roles of the adsorbent or catalytic actions of the SDK (3) under the test conditions. From the amounts of RSD agent applied, the RSD should have destroyed all of the agent present (9). Although the reaction of the SDK is reported to be slower (3) than with the RSD, the destructive capacity should have been sufficient to inactivate the agent doses applied assuming that the resin and agent were in reasonable contact in the highly dispersed black powder. The Mitt is considered to be only an adsorbent although some surface destruction may occur.

From the data presented here, there would appear to be no clear choice between the decontaminant systems on the basis of efficacy alone. A similar conclusion was reached in the earlier study which compared the first prototype RSD with the SDK (1). The second prototype RSD and SDK both provide equal decontamination with less material and both would appear to be superior to the Mitt in that there is a destructive capacity as well as a physical removal of agent. However, the ease of application and removal, the effects

upon sensitive tissues and, particularly, the eyes, the acceptability to personnel and the presence of solid materials that will foul mechanisms and optical systems, must all be taken into account and may well dictate the decontaminant to be used in a given situation.

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Table I

Survival (%) following exposure to GD and decontamination

Treatment	Dose of GD applied in LD_{50}					
	2	6	8	10	12	14
Control, no decontamination						
	50	0	0	0	-[a]	
Trial 1						
Mitt	-	100	100	100		
SDK	-	100	100	100		
RSD	-	100	100	100		
Trial 2						
Mitt	-	-	-	50	50	50
SDK	-	-	-	100	100	100
RSD	-	-	-	100	75	50

All groups contain 4 animals.

[a] Value not determined.

Table II

Time (min) for appearance of clinical signs following GD exposure and decontamination

Treatment	Dose of agent applied in LD_{50} (GD)					
	2	6	8	10	12	14
Control, no decontamination						
	6,10,11,13 10	7,8,8,11 9	5,6,6,7 6	-[a]		
Trial 1						
Mitt	-	17,ns,ns,ns[b] >17[c]	ns	ns	-	-
SDK	-	ns	ns	ns	-	-
RSD	-	ns	ns	11,ns,ns,ns >11	-	-
Trial 2						
Mitt	-	-	-	5,9,ns,ns >7	11,14,ns,ns >13	8,21,26,ns >19
SDK	-	-	-	ns	28,ns,ns,ns >28	15,35,35,ns >28
RSD	-	-	-	11,ns,ns,ns >11	14,ns,ns,ns >14	11,24,28,40 26

All groups contained four animals. Data presented are the actual values obtained and, below, the mean value.

[a] Value not determined

[b] No clinical signs observed

[c] Mean of values obtained. However, animals in the group did not show clinical signs so that the average value will be greater than that indicated.

Table III

Time-to-death (min) following GD and decontamination with various lotions

Treatment	Dose of agent applied in LD_{50} (GD)					
	2	6	8	10	12	14
Control, no decontamination						
	18,24,2S[a] >21	9,10,10,17 12	7,8,8,9 8	-[b]		
Trial 1						
Mitt	-	ns[d]	ns	>2000[e],2ns,S >2000	-	-
SDK	-	ns	ns	ns	-	-
RSD	-	ns	ns	3ns,S	-	-
Trial 2						
Mitt	-	-	-	18,25,2ns >22	357,>1000,2ns >678	25,>1000,ns,S >510
SDK	-	-	-	4ns	3ns,S	ns,3S
RSD	-	-	-	3ns,S	>500,3ns	>500,>1000,2ns

All groups contained four animals. Data presented are the actual values obtained and, below, the mean value.

[a] Survivor that showed clinical signs, no value obtained.

[b] Value not determined

[c] Mean of values obtained but with surviving animals in the group so that a value greater than that shown is indicated.

[d] No clinical signs observed, animals unaffected.

[e] >500 = animal died overnight, >1000 = animal survived first nioght and died second day, >2000 = animal died second night.

Table IV
Decontamination of HD on skin
as shown by scab and scar scores.

Decontaminant	Animal No.	Scab scores (4 max) Day 2 Control	Day 2 Test	Day 4 Control	Day 4 Test	Scar score Day 28 Control	Day 28 Test
Mitt	1	2.5	1.0	2.5	0.0	3.8	-[a]
	2	1.0	1.0	1.0	1.0	2.4	1.0
	3	1.3	1.0	1.3	0.0	4.0	0.8
	4	2.5	1.0	2.5	1.0	4.3	1.8
	average	1.8	1.0	1.8	0.5	3.75	1.25
SDK	1	2.0	1.0	1.5	0.5	2.4	0.4
	2	4.0	1.0	4.0	0.0	3.0	0.4
	3	3.0	1.0	3.0	0.8	3.6	0.2
	4	2.8	0.0	3.0	1.3	4.0	1.4
	average	2.9	0.75	3.1	0.8	4.1	0.75
RSD	1	2.0	1.0	2.0	1.5	3.6	1.2
	2	3.5	1.0	3.5	1.0	4.4	0.5
	3	3.3	1.0	3.3	1.0	5.0	0.5
	4	2.3	1.0	2.3	0.0	5.0	0.8
	average	2.8	1.0	2.8	0.9	4.8	1.1
Overall averages		2.5[b] (2.8)		2.5		4.2	

[a] Value not available, open wound from shaving.

[b] Value with all data used. Value in brackets below has had suspect data (Mitt animals 2 & 3) removed.

Table V

Decontamination of HD on skin as shown by lesion, scab and scar areas.

Decontaminant	Animal No.	Lesion, Day 1 Sq. cm Control	Lesion, Day 1 Sq. cm Test	Scab, Day 4 Sq. cm Control	Scab, Day 4 Sq. cm Test	Scar, Day 28 Sq. cm Control	Scar, Day 28 Sq. cm Test
Mitt	1	11.9[a]	7.88	4.03	2.19	2.19	1.48
	2	10.6	5.63	5.41	2.61	3.37	1.50
	3	5.63	5.10	2.44	2.64	2.30	1.21
	4	4.97	4.40	3.48	1.07	1.83	0.91
Average		8.3±1.5	5.7±1.5	3.8±1.2	2.1±0.7	2.4±0.7	1.3±0.3
SDK	1	7.92	4.03	3.89	1.91	2.45	0.45
	2	5.72	4.77	2.55	-[c]	2.65	1.29
	3	9.35	4.78	3.57	2.29	2.43	0.09
	4	8.45	3.31	3.32	1.44	1.71	0.72
Average		7.8±1.5	4.2±0.7	3.3±0.6	1.9±0.4	2.3±0.4	0.6±0.5
RSD	1	10.5	9.5	5.72	3.28	2.76	2.08
	2	14.7	7.96	5.04	1.98	3.49	1.69
	3	19.5	8.56	6.37	2.29	4.71	1.11
	4	18.7	13.4	8.51	4.19	6.94	2.86
Average		25.8±4.1	9.8±2,4	6.4±1.5	2.9±1.0	4.5±1.8	1.9±0.7

[a] Data are total area of four spots for each control or test site.

[b] Significant difference ($P < 0.01$) between test and control.

[c] Data not available.

FIGURE CAPTIONS

Fig. 1. Pattern of application of HD spots. The four black dots on the centre-line were made with a Lab Marker to guide the placement of the HD droplets. In the 8 control target areas (A-D) and decontaminant test areas (E-H) the doses of HD applied were; A. 0.8 *u*L, B. 1.2 *u*L, C. 1.6 *u*L, D. 2.0 *u*L, E. 2.0 *u*L, F. 1.6 *u*L, G. 1.2 *u*L and H. 0.8 *u*L.

Fig. 2. Decontaminants applied to animals; (a) RSD, (b) SDK and (c) Mitt. Some RSD has flowed from the target area. The wholesale coverage of the surrounding area by the SDK and Mitt decontaminants is clearly indicated. The "wet" spots visible in the back of the animal in (c) are liquid HD mixed with a fine layer of Fuller's earth.
The guinea pig restrainer used throughout this study is shown in (a).

Fig. 4. The appearance of HD lesions on a guinea pig decontaminated with the Mitt showing the lesions on (a) day 1, (b) day 2, day 4 and day 28.

Fig. 5. The appearance of HD lesions on a guinea pig decontaminated with SDK showing the lesions on (a) day 1, (b) day 2, day 4 and day 28.

Fig. 6. The appearance of HD lesions on a guinea pig decontaminated with RSD showing the lesions on (a) day 1, (b) day 2, day 4 and day 28.

Figure 1

Pattern of application of HD spots. The four black dots on the centre-line were made with a Lab Marker to guide the placement of the HD droplets. In the 8 control target areas (A – D) and decontaminant test areas (E – H), the doses of HD applied were: A. 0.8 μL; B. 1.2 μL; C. 1.6 μL; D. 2.0 μL; E. 2.0 μL; F. 1.6 μL; G. 1.2 μL and H. 0.8 μL.

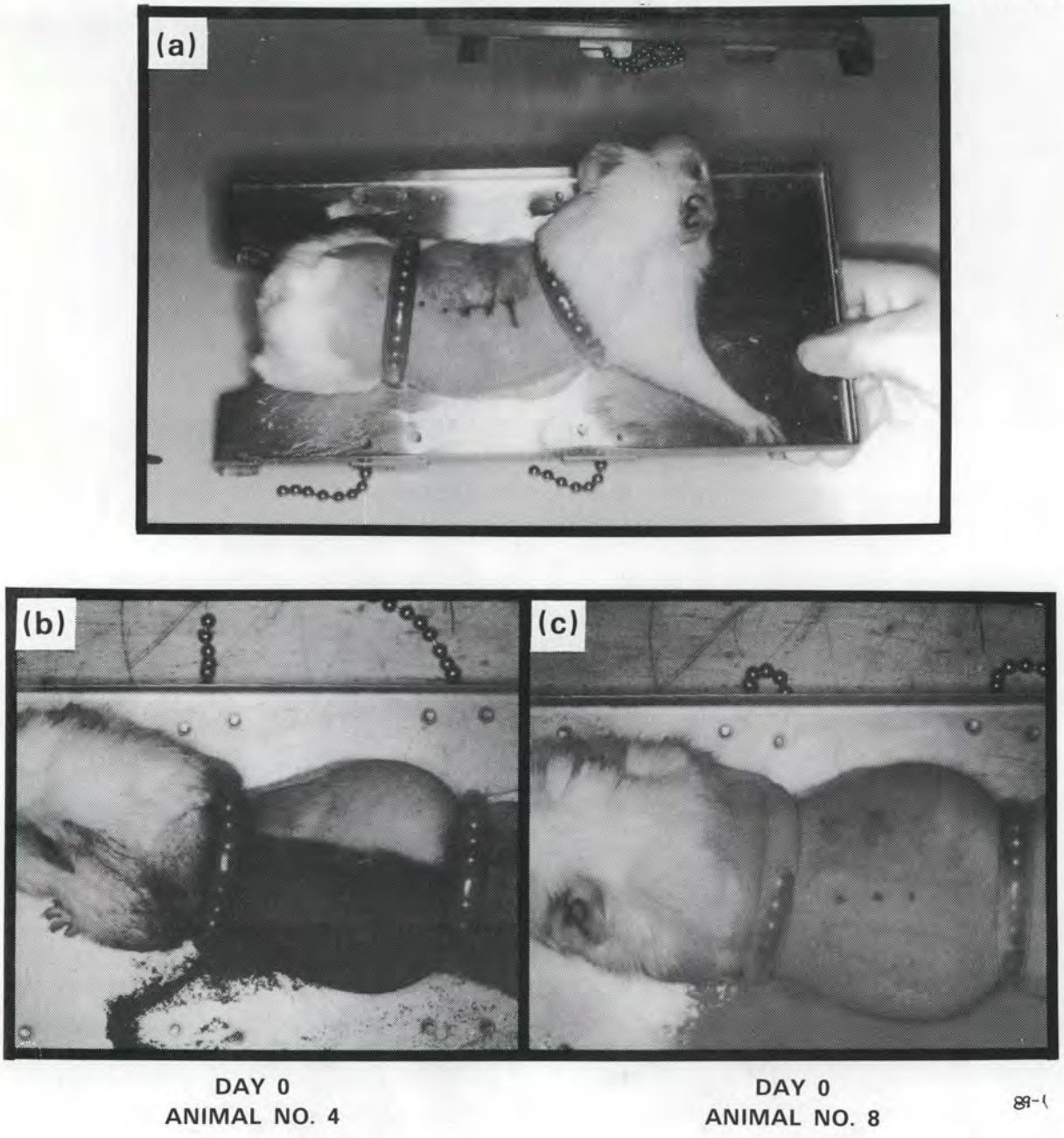

Figure 2

Decontaminants applied to animals; (a) RSD; (b) SDK and (c) Mitt. Some RSD has flowed from the target area. The wholesale coverage of the surrounding area by the SDK and Mitt decontaminants is clearly indicated. The "wet" spot visible in the back of the animal in (c) are liquid HD mixed with a fine layer of Fuller's Earth. The guinea pig restrainer used throughout this study is shown in (a).

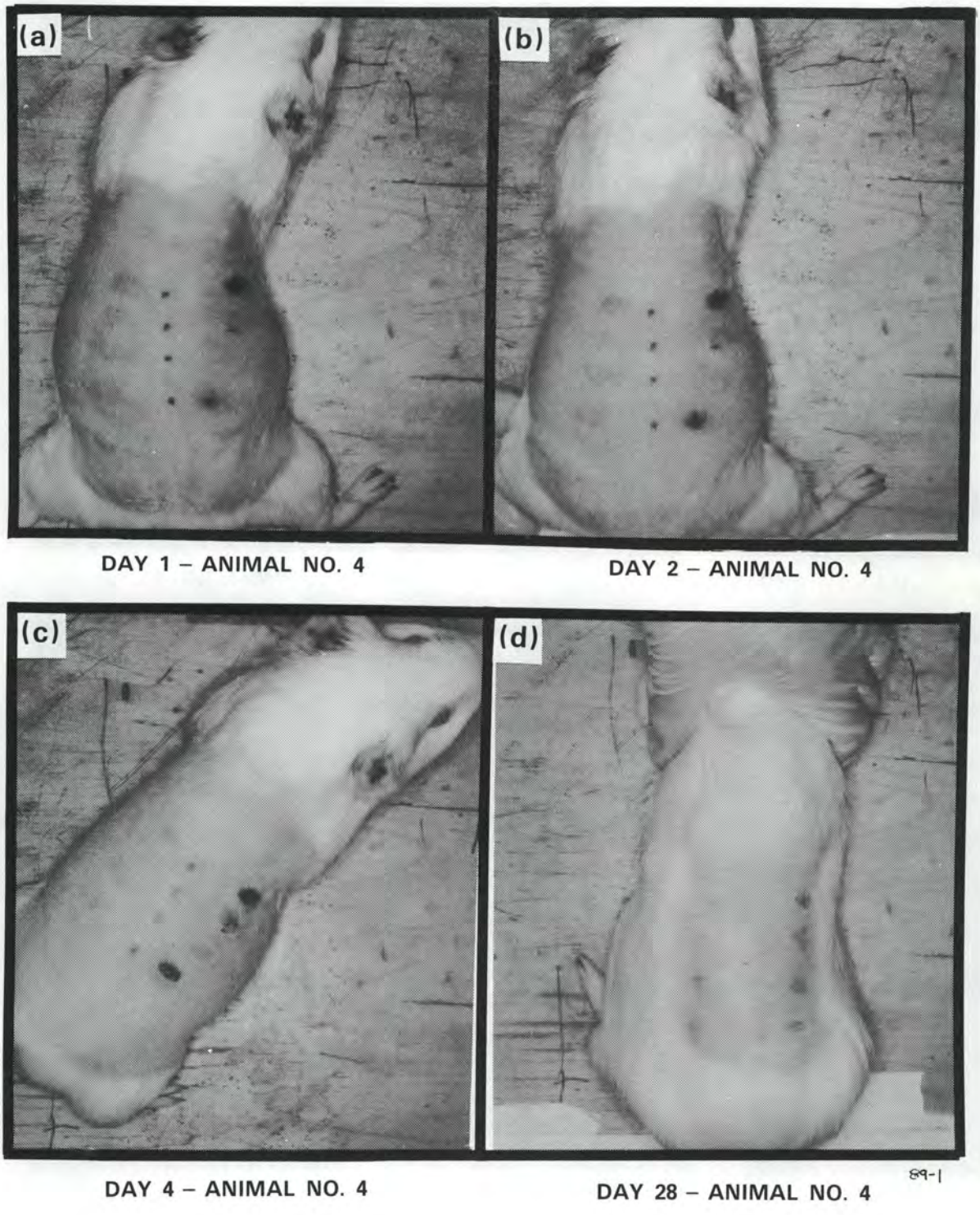

Figure 3

The appearance of HD lesions on a guinea pig decontaminated with the Mitt showing the lesions on (a) day 1; (b) day 2; (c) day 4 and (d) day 28.

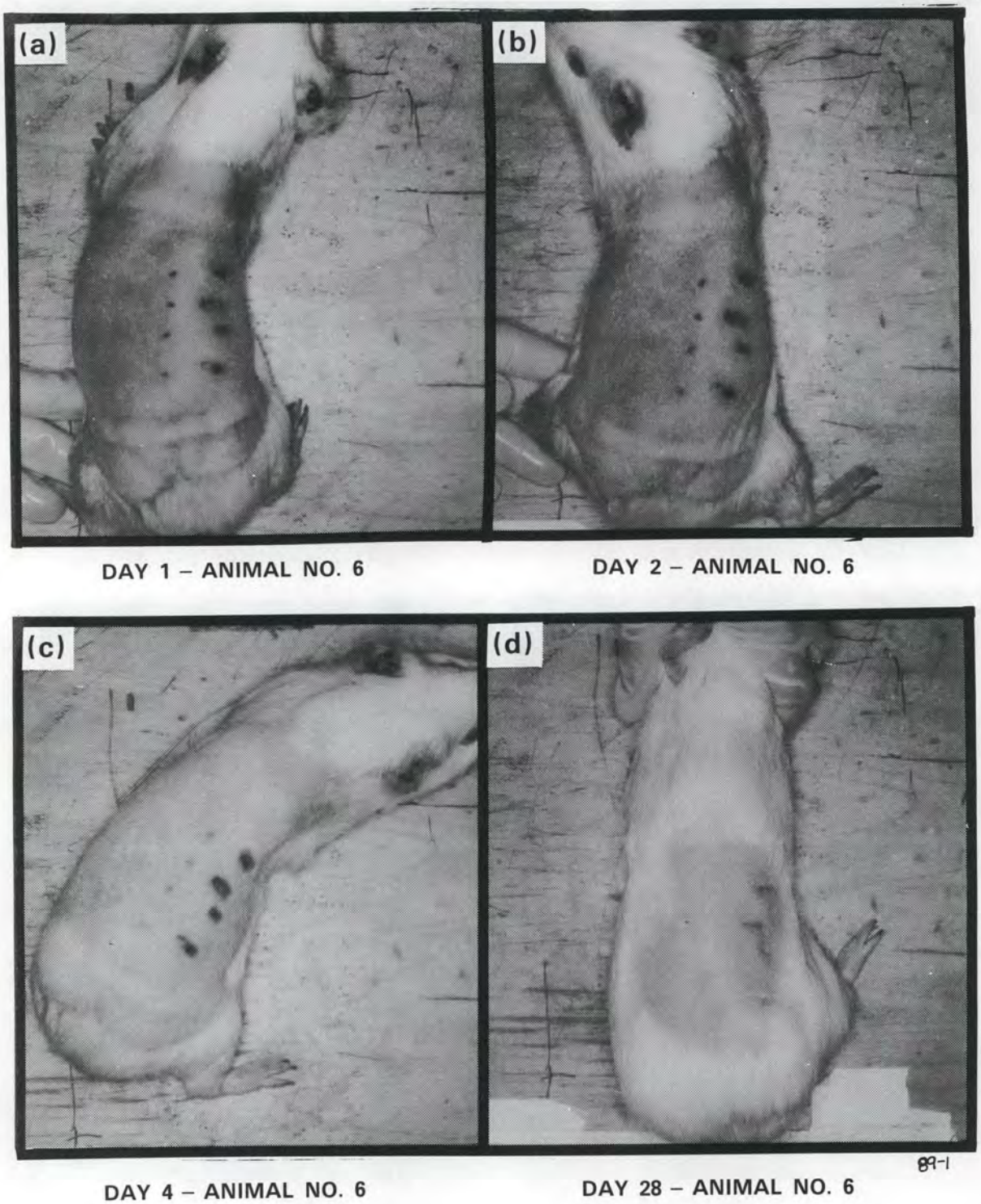

Figure 4

The appearance of HD lesions on a guinea pig decontaminated with SDK showing the lesions on (a) day 1; (b) day 2; (c) day 4 and (d) day 28.

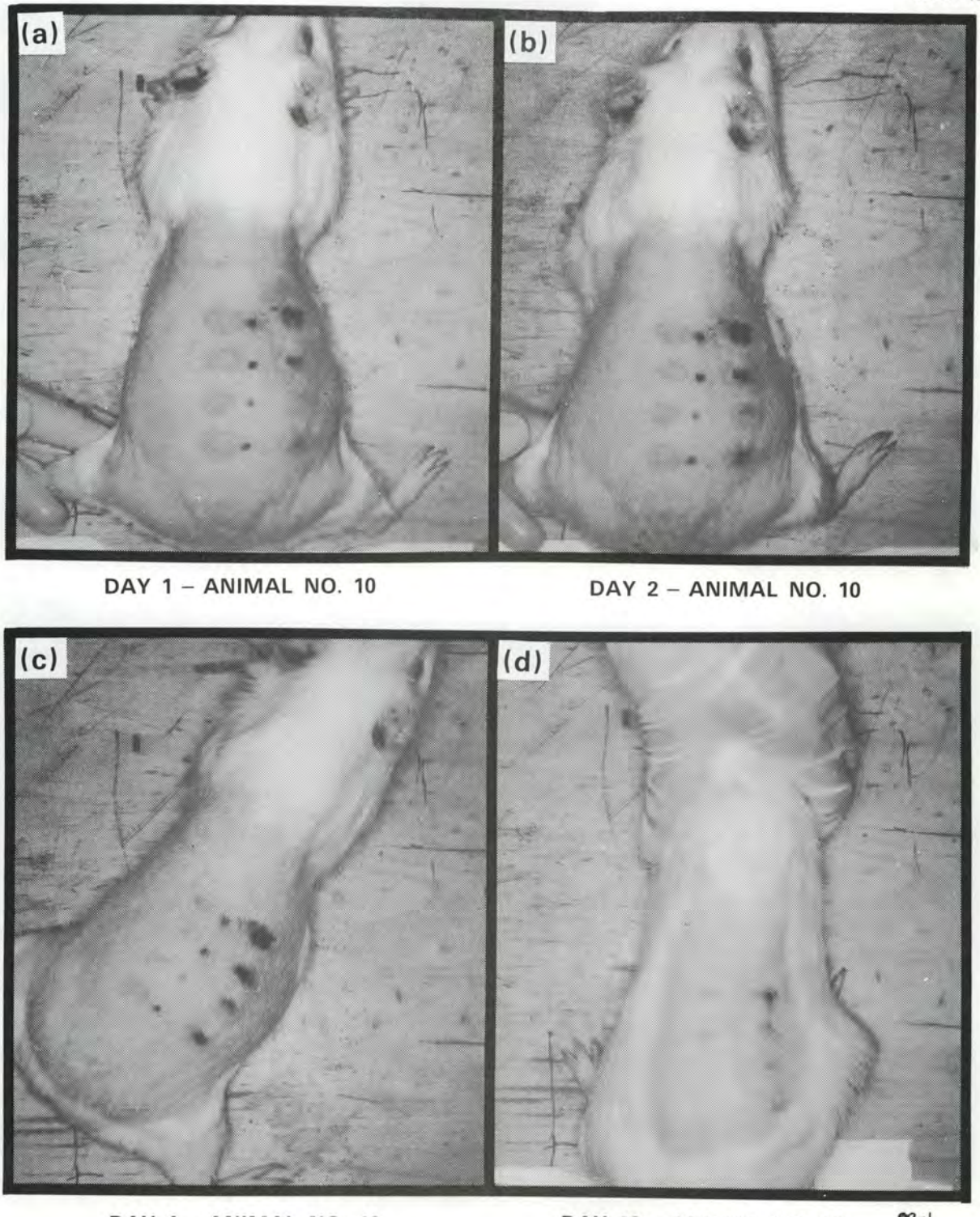

Figure 5

The appearance of HD lesions on a guinea pig decontaminated with RSD showing the lesions on (a) day 1; (b) day 2; (c) day 4 and (d) day 28.

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(U) The Canadian Fuller's Earth Mitt (Mitt) and the US Personnel/Casualty Decontamination System: Skin Decontamination Kit (SDK) were compared to the proposed Canadian Reactive Skin Decontaminant Lotion (RSD) by parallel exposure and decontamination of guinea pigs. GD and HD were placed on depilated areas on the back for 55 sec and the skin decontaminated. Mortality, time-to-effect and time-to-death were recorded for GD tests. The burn damage from HD was assessed.(U)

All three decontamination systems effectively decontaminated 10 LD_{50} of GD. At 14 LD_{50} GD, the upper limit of the challenge used, the SDK was fully effective and the RSD and the Mitt appeared to be slightly less effective. However, a true numerical comparison could not be made and the functional comparison shows similar activity for the three systems.

All three decontaminants provided significant protection against the deep, third degree chemical burns resulting from 0.8-2.0 µL drops of HD applied directly to the skin.

The utility of skin decontamination was demonstrated as all three systems counteracted the lethal effects of GD and significantly reduced the vesicant damage from HD. In addition to preventing death from GD, use of a skin decontaminant also provided a longer period within which to apply other therapeutic measures directed against systemic effects.

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RSD

SDK

Fuller's Earth Mitt

Decontaminate GD, HD