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FINAL REPORT

TO

U. S. ARMY CHEMICAL CORPS

CHEMICAL AND RADIOLOGICAL LABORATORIES

ON

REMOVAL OF RADIOACTIVE CONTAMINANTS FROM SKIN

UNDER

CONTRACT NO. DA 18-108 CML 2597, ORDER NO. 1-13034

30 June 1952

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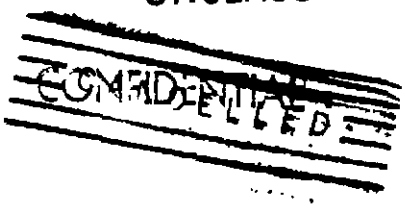

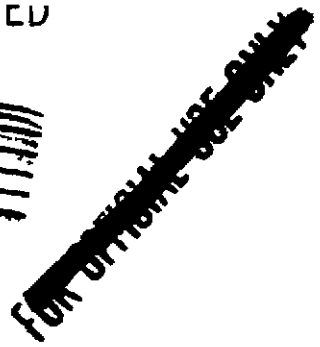

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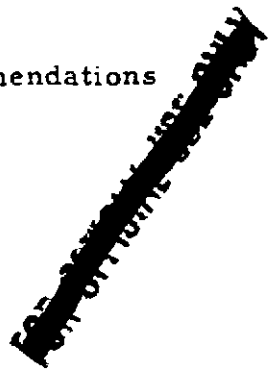

Summary.

A. Entire Project

This is the final report to the Chemical and Radiological Laboratories under Contract No. DA 18-108 CML 2597, Order No. 1-13034, on the removal of radioactive contaminants from skin.

In accordance with the provisions of the contract, the decontaminating efficiency of various soaps and syndets were evaluated. Their effectiveness was determined on three types of surfaces, metallic, animal skin, and human skin.

The culmination of the project, however, was the formulation of several superior decontaminating agents for use on human skin. In the tests with the limited number of paid subjects available, the Contractor's decontaminant formulations compared very favorably with commercially-available products. It is felt, however, that further experimentation with humans would probably permit development of even more effective decontaminants.

[redacted]

B. Fourth Quarter

This report covers the work completed during the final quarter of the contract.

Literature pertaining to the decontamination of human subjects is presented.

The experimental work was devoted to the decontamination of animal and human skin. Representative soaps and syndets were evaluated, and several superior decontaminating compositions were developed and evaluated. A 5 0% solution of the following general formula was found to be most effective on human skin:

30.0% detergent

65.0% sequestrant

5.0% carboxymethyl cellulose.

[redacted]

1. Introduction.

The first phase of the contract was devoted to an intensified co-ordination of all pertinent information. The literature was thoroughly surveyed under the following headings:

A. Decontaminating Agents

(1) Abrasives

(2) Chemical Reactants

(3) Surfactants

a. Soaps

b. Synthetic detergents

1- Cationic

2- Anionic

3- Non-ionic

4- Ampholytic

(4) Sequestering Agents

B. Soils

C. Skin

D. Radioactivity

Various laboratories working on the problem of decontamination were contacted and valuable guidance was secured.

The second quarter saw the development of decontamination technics and the evaluation of some commercial products on copper and stainless steel surfaces and on the skin of the rabbit. A study was also made on the effect of successive washings.

Animal experimentation was emphasized during the third quarter. Decontamination technics were improved and developed, and the determination of the efficiency of soaps and syndets was continued, using both the skin of the rabbit and of the pig.

In anticipation of the use of human subjects, metabolism and absorption studies on the rabbit and pig were conducted. These preliminary animal absorption studies were required by the Atomic Energy Commission prior to their granting of approval for experimentation with humans. The percutaneous absorption of the following contaminants was studied in animals:

A. Synthetic city soil plus fission products

B. Neutron-irradiated soil

C. Carbon-14 labeled soil

D. Radioactive soil from Nevada test site

Finally, following the approval of the Atomic Energy Commission, the ultimate aim of the contract was attained in the fourth quarter. With the granting of permission for the use of human subjects, several superior decontaminating agents were formulated for use on human skin. These and commercially-available products were evaluated and their comparative efficiencies were tabulated.

2. Literature Survey.

Only one recent publication has been found that is of direct relevance to the decontamination of living human skin. Because of its great importance, and because it is feared that it may not have the wide circulation it merits, a literal translation is appended to this report.

[redacted]

3. Experimental Work.

A. Fourth Quarter

Although evaluation of the efficiency of soaps and detergents on human subjects was the most important work of the fourth quarter, some further experiments were carried out on rabbits. Most of the rabbit work was done in connection with another project in this laboratory, but it is included in this report because of its obvious interest.

As in previous work, the rabbits were clipped and contaminated with an aqueous suspension of synthetic soil and fission products. After the contaminated area had dried thoroughly in air, it was counted, swabbed for one minute with cotton applicators of the type known as Q-tips soaked in detergent, and the excess detergent removed with absorbent tissue paper. This was followed by rinsing for half a minute with a Q-tip soaked in water, drying with absorbent tissue paper, and a final count was taken. The following results were obtained:

TABLE I

Live Rabbit Skin

Detergent	Initial count	Final count	% Removed
5% D3V(1)	28300	800	97.2
5% D4V(2)	21500	625	97.1
5% I4V(3)	17500	500	97.1
5% D2V(4)	22300	670	97.0
0.7% Calglo	23700	769	96.8
0.35% Ivory + 0.35% Calgon	30500	1090	96.4
5% Tide	26400	1000	96.2
5% Carolite 1000	32300	1250	96.1
0.2% Tide + 0.5% Calgon	29400	1090	96.1
5% IC(5)	20900	850	95.9
0.2% Ivory + 0.5% Calgon	32800	1470	95.5
0.7% Calgonite	45000	2180	95.2
0.35% Surf + 0.15% Calgon	29200	1400	95.2
5% DC(6)	53200	2800	94.7(7)
10% Flobar	33900	1950	94.2
0.7% Noca	35300	2100	94.1
5% OS(8)	58600	3540	94.0(7)

TABLE I (Cont.)

Detergent	Initial count	Final count	% Removed
0.5% Surf	26400	1630	93.8
0.35% Kirkman Flakes + 0.15% Calgon	34800	2160	93.8
0.7% Tide	26200	1730	93.4
0.35% Oxydol + 0.15% Calgon	23300	1580	93.2
0.35% Kirkman Flakes + 0.35% Calgon	33600	2320	93.1
0.7% Ivory	31200	2170	93.0
1:6 Radiacwash	30400	2270	92.5
0.5% Oxydol	22600	1930	91.5
0.35% Kirkman Flakes + 0.15% Versene-2(9)	29900	3000	90.0
0.7% Kirkman Flakes	33900	3460	89.8
0.35% Kirkman Flakes + 0.15% Sodium Citrate	29000	3120	89.2
0.5% Kirkman Flakes	28900	3280	88.6
0.7% Oxydol	26100	3070	88.2

(1) 30% Duponol ME, 65% trisodium salt of ethylene diamine tetra-acetic acid (monohydrate), 5% carboxymethyl cellulose. D3 V

(2) 30% Duponol ME, 65% tetrasodium salt of ethylene diamine tetra-acetic acid, 5% carboxymethyl cellulose. D 4V

(3) 30% Ivory, 65% tetrasodium salt of ethylene diamine tetra-acetic acid, 5% carboxymethyl cellulose. I 4V

TABLE I (Cont.)

(4) 30% Duponol ME, 65% disodium salt of ethylene diamine tetra-acetic acid (dihydrate), 5% carboxymethyl cellulose. D2V

(5) 30% Ivory, 65% adjusted Calgon, 5% carboxymethyl cellulose. | C

(6) 30% Duponol ME, 65% adjusted Calgon, 5% carboxymethyl cellulose. D C

(7) These tests were performed on a rabbit whose skin was definitely affected by some disease, hence the results may not be strictly comparable to the others.

(8) Disodium salt of ethylene diamine tetra-acetic acid (dihydrate). 0S

Even a hasty perusal of the above table reveals how important to a formulation a good sequestrant may be. This is particularly so in the case of a soap, for the sequestrant will inhibit the formation of sticky precipitates and allow the detergent properties of the soaps full play. Of interest also is the superior performance of the formulations identified as IC, D2V, D3V, D4V, and I4V. They were formulated in this laboratory in the belief that it would be relatively easy to prepare a formulation at least equal to the best commercially-available detergent. It is seen that the results obtained fully substantiate this view.

The effect of adding silica gel to the detergent was tried at two different detergent concentrations. The silica gel used was a product of the Davison Chemical Corporation of Baltimore, Md., 200 mesh, code number 22-08-X-2926. The detergent used was a formulation consisting of 30% Duponol ME, 70% tetrasodium salt of ethylene diamine tetra-acetic acid, and 5% carboxymethyl cellulose, abbreviated to D4V in these tables. These tests were performed on subjects having some sort of skin affection common among rabbits, and hence the results obtained, although comparable among themselves, cannot be compared to those obtained on healthy animals.

TABLE II

Live Rabbit Skin

Detergent: D4V

% Detergent	% Silica Gel	Initial count	Final count	% Removed
1	0	32400	2700	91.7
1	0.1	29300	1100	96.2
1	0.5	34300	2700	92.1
1	1.0	33700	3350	90.0
5	0	24400	1100	95.8
5	0.1	40900	2300	94.4
5	0.5	23800	1050	95.6
5	1.0	17000	800	95.3

It is seen that the addition of silica gel in quantities up to one per cent does not affect the detergent efficiency appreciably. On the other hand, the detergent concentration is a very important factor.

As soon as the necessary authorization had been obtained from the Atomic Energy Commission, work on human subjects was started. Sixteen paid volunteers were used. They were first given physical examinations by a physician, with special attention being given to any possible allergies or dermatological disturbances that might be present. Naturally, only healthy subjects were used.

TABLE III

Characteristics of Human Subjects

Subject	Sex	Age	Skin	Color of Hair
A	male	35	fair	brown
B	male	32	dark	brown
C	male	26	dark	black
D	male	50	fair	blond
E	male	29	fair	black
F	male	45	freckled	blond
G	female	22	freckled	brown
H	male	38	fair	brown
I	female	22	fair	brown
J	male	24	fair	black
K	female	23	dark	black
L	male	30	fair	black
M	male	25	dark	black
N	female	19	fair	black
O	male	24	fair	brown
P	male	33	fair	brown

The hair from an area of several square inches at about the middle of the outer side of each forearm was removed with electrical clippers. Special care was taken during this operation not to damage the skin in any way. Circles of about one inch in diameter were drawn with a soft wax pencil on the skin; one on each forearm and one on each palm. Without any other treatment, the contaminant was added slowly, allowed to dry in air, and the activity determined. The counting was done with an unshielded Geiger tube with a 1.4 mg./cm.^{2} mica end window. The Geiger tube was surrounded by a tightly fitting cardboard cylinder which extended one-half inch beyond the end window. Constant geometry was assured by holding firmly the end of cardboard cylinder on the circles that enclosed the activity. The four contaminants described in previous reports were used. The soil from the Nevada test grounds, the carbon-labeled synthetic soil, and the neutron-irradiated synthetic soil were applied in alcoholic suspensions. About 0.3 ml. of suspension was used each time. The synthetic soil-fission products contaminant was an alcoholic suspension containing about 0.3 mg. of soil and enough fission products to give about 2000 counts per minute in each 0.025 ml. of suspension. Each skin area used was contaminated with 0.025 ml. of the suspension just described. Washing was performed by the procedure already described for the work on rabbits.

TABLE IV

Forearms of Human Subjects

Detergent: 5.0% Ivory

Contaminant	Subject	Initial count	Final count	% Removed
Neutron-irradiated synthetic soil	K	13021	100	99.2
	L	5308	95	98.2
Carbon-14 labeled synthetic soil	J	1717	26	98.5
	K	848	22	97.4
Soil from Nevada Test Site	I	6931	178	97.4
	J	4293	236	94.5
Synthetic soil plus fission products	I	1283	71	94.5
	L	1280	163	87.3

TABLE V

Palms of Human Subjects

Detergent: 5.0% Ivory

Contaminant	Subject	Initial count	Final count	% Remove
Neutron-irradiated synthetic soil	K	6448	190	97.0
	L	4664	199	95.7
Carbon-14 labeled synthetic soil	J	1192	42	96.5
	K	1309	119	90.9
Soil from Nevada Test Site	I	3328	472	85.5
	J	2736	119	84.9
Synthetic soil plus fission products	I	1226	286	76.7
	L	1373	498	63.7

Although Ivory is a rather inefficient decontaminating agent, the synthetic soil plus fission products was the only contaminant that was held tenaciously enough to be of much value in these studies. It must be borne in mind, however, that other contaminating or decontaminating procedures may give quite different results.

The last two tables above also show an interesting aspect of the problem that was further substantiated by later work; viz., that the skin of the forearm is easier to decontaminate than that of the palm. No differences due to skin pigmentation or sex of the subject were detected.

A dozen products were tested on a synthetic soil-fission products mixture with the following results:

TABLE VI

Forearms of Human Subjects

Detergent	Subject	Initial count	Final count	% Removed
5.0% D4V	M	1570	Background	>99.9
	N	2530	Background	>99.9
5.0% I4V	M	2400	Background	>99.9
	P	2200	5	99.8
5.0% D3V	N	1840	Background	>99.9
	O	1950	25	98.7
5.0% Tide	A	1844	Background	>99.9
	C	1620	Background	>99.9
	O	2160	Background	>99.9
	P	2017	28	98.6
5.0% Carolite 1000	D	1486	4	99.7
	E	1311	18	98.6
5.0% DC	I	2406	3	99.9
	L	2599	44	98.3
5.0% Surf	G	1722	3	99.8
	H	2229	35	98.4
1:6 Radiacwash	A	2908	39	98.7
	B	1567	48	96.9
5.0% Oxydol	G	1610	34	97.9
	H	2431	56	97.7
10.0% Flobar	E	1615	Background	> 99.9
	F	1696	97	94.3
5.0% Palmolive	D	2635	118	95.5
	F	2272	154	93.2
5.0% Ivory	B	1283	71	94.5
	C	1280	163	87.3

TABLE VII

Palms of Human Subjects

Detergent	Subject	Initial count	Final count	% Removed
5.0% I4V	M	1240	Background	>99.9
	P	1240	Background	>99.9
5.0% D3V	N	1260	Background	>99.9
	O	1400	15	98.9
5.0% D4V	M	1320	10	99.2
	N	1358	25	98.2
5.0% Tide	A	1080	10	99.1
	C	1253	12	99.0
	O	1870	20	98.9
	P	1525	102	93.3
5.0% Carolite 1000	D	1671	24	98.6
	E	1951	72	96.3
5.0% DC	I	1676	35	97.9
	L	1423	53	96.3
10% Flobar	E	1861	32	98.3
	F	1173	70	94.0
1:6 Radiacwash	A	1499	48	96.8
	B	1379	152	89.0
5% Surf	G	1984	139	93.0
	H	1187	100	91.5
5.0% Oxydol	G	1326	101	92.4
	H	1301	134	89.7
5.0% Palmolive	D	1691	151	97.1
	F	1884	380	79.8
5.0% Ivory	B	1286	286	76.7
	C	1373	498	63.7

For obvious reasons, it was thought prudent to keep the initial activity as low as possible. This, however, resulted in an added measure of uncertainty, for the final counts were then often too low for reliability. As a matter of fact, consideration of experimental conditions throws doubt upon the significance of any counts lower than about ten counts per minute above background. Naturally, this detracts from the validity of some of the results obtained, particularly for the more efficient products. On the other hand, when the products used are listed according to their decontaminating efficiencies, they fall in almost the same order, whether tried on forearm or palm. This consistency also extends to the work done on rabbits, although the concentrations used were not always the same. Consequently, it is felt that the results obtained are probably somewhat more reliable than simple consideration of counting statistics would indicate.

As in the case of the rabbit, the formulations developed in this laboratory compared most favorably with the best commercial products. However, it has not been possible to conduct all the studies that would be essential in order to formulate the very best possible decontaminating agent. Should further work be done along these lines, it will be necessary to use either a higher initial activity or a different, more persistent, contamination procedure, or both. Due to a number of adverse circumstances, it has not been possible to investigate many important phases of the problem. It is to be hoped that this situation may be remedied in the near future.

B. Summary of First Three Quarters

Unless otherwise specified, the contaminant used consisted of a 0.2% aqueous suspension of a synthetic city soil to which a solution of mixed long-lived fission products had been added. Enough radioactive material was added to give 5,000 to 50,000 counts per minute per drop. One or more drops of the contaminant were placed on the surface to be studied, dried thoroughly, with the aid of an infra-red lamp in the case of metallic surfaces, or by natural evaporation in the case of animal skins, and the activity determined with a Geiger counter. This was followed by washing, rinsing, drying, and counting.

Washing steel and copper discs one inch in diameter with an ordinary hand brush actuated by a mechanical scrubber gave the following results:

[redacted]

TABLE VIII

Decontamination Technic: *Mechanical Scrubbing*

Surface	Detergent	No. of Cycles	% Removed
Stainless Steel	Distilled water	3	98.7
		4	99.2
		6	98.0
	0.15% Nacconol NR	1/2	99.4
	+ 0.15% Calgon	1	99.7
		2	99.2
		3	99.6
		4	98.9
		9	99.7
		27	99.7
Copper	Distilled water	3	97.5
		6	98.3
	0.15 % Nacconol NR	3	99.6
	+ 0.15% Calgon	6	99.9
		30	99.7

Covering the metallic discs with the detergent solution and agitating manually for five minutes with a circular motion gave a less vigorous procedure.

TABLE IX

Decontamination Technic: Manual Agitation

Surface: Stainless Steel

Detergent	% Removed
1.0% Tetrasodium Versenate + 0.15% Nacconol NR	99.1
1.0% Tetrasodium Versenate	99.1
5% Carolite 1000	98.4
0.15% Adjusted Calgon + 0.15% Nacconol NR	97.5
0.3% Tide	97.4
0.15% Sodium Tripolyphosphate + 0.15% Nacconol NR	97.1
0.3% Radiacwash #3	96.9
0.3% Radiacwash #4	96.9
0.3% Radiacwash #2	96 3
0.3% Standard Radiacwash	95.0
0.15% Sequestrene NA3 + 0.15% Nacconol NR	94.8
0.3% Radiacwash #1	94.5
0.15% Unadjusted Calgon + 0.15% Nacconol NR	94.0
0.3% Noca	92.0
0.3% Radiacwash #8	90.8

[redacted]

TABLE IX (Cont.)

Detergent	% Removed
1% Carolite VK	90.5
0.15% Calgonite + 0.15% Nacconol NR	90.1
0.15% Sodium Citrate + 0.15% Nacconol NR	89.8
0.15% Trisodium Phosphate + 0.15% Nacconol NR	83.2
0.3% G808(1)	83.2
0.15% Citric Acid + 0.15% Nacconol NR	80.4
0.15% Disodium Versenate + 0.15% Nacconol NR	80.1
1% Flobar	71.5
SBS11(2)	47.3
Distilled Water	49.0

(1) A product of the Geigy Company, Inc., New York

(2) This product is manufactured by the Sugar Beet Byproducts Co., Saginaw, Michigan

TABLE X

Decontamination Technic: Manual Agitation

Surface: Copper

Detergent	% Removed
0.15% Disodium Versenate + 0.15% Nacconol NR	98.5
0.15% Unadjusted Calgon + 0.15% Nacconol NR	95.0
Distilled Water	44.3

Simple immersion in a solution of 0.15% Nacconol NR and 0.15% Calgon for twelve hours caused the removal of 99.1% and 99.4% from steel and copper respectively.

Successive washings with intervening drying gave the following values:

TABLE XI

Effectiveness of Successive Washings

Decontamination Technic: Manual Agitation

Detergent: 0.15% Nacconol NR + 0.15% Calgon

Surface	% Removed After First Washing	Total % Removed After Second Washing	Total % Removed After Third Wash.
Stainless Steel	91.7	95.3	96.6
Copper	95.0	97.6	98.2

Some experiments were performed on dead rabbit skins. Dr. Victor H. Witten, consulting dermatologist for this project, pointed out that death brings immediate and important physiological changes to the skin. Furthermore, no particular experimental advantages were found; as a matter of fact, the living animal was easier to handle than the detached skin. Consequently, work along these lines was abandoned early and only living animals used from then on.

As much of the fur as possible was removed with fine animal clippers, taking care not to damage the skin in any way. Circles about one inch in diameter were drawn and the area in the circles dampened slightly to facilitate penetration of the contaminant. The contaminant, about 0.05 ml. of an aqueous suspension of synthetic soil plus fission products, was then placed within the circles, rubbed in with a glass rod, and allowed to dry in air. The activity was

determined with a mica end-window Geiger tube enclosed in a cardboard cylinder extending about one-half inch beyond the window. Washing by firm but gentle brushing with a Nylon surgical brush gave the following results:

TABLE XII

Live Rabbit Skin

Decontamination Technic: Brushing

Detergent	% Removed
1:6 Radiacwash	98.9
0.5% Noca	98.2
0.35% Tide + 0.15% Calgon	97.3
0.5% Tide	96.4
0.5% Ivory	96.0
1.0% Versene + 0.7% Tide + 0.3% Calgon	95.7
0.35% Ivory + 0.15% Calgon	95.6
5.0% Tide	95.5
Distilled Water	93.2
5.0% Ivory	89.8

A less vigorous procedure consisted of swabbing the contaminated area for one minute with cotton pads soaked in the detergent solution and rinsing for one-half minute with similar pads soaked in water.

TABLE XIII

Live Rabbit Skin

Decontamination Technic: Swabbing

Detergent	% Removed
5% Carolite 1000	98.3
Undiluted Flobar	97.7
1:6 Radiacwash	96.8
0.5% Tide	94.3
0.5% Noca	91.3
0.5% Ivory	69.4
Distilled Water	72.7

Two series of absorption studies were carried out. In one, the contaminant was added in an alcoholic suspension, counted, and counted again after varying lengths of time.

TABLE XIV

Percutaneous Absorption in Animals

Contaminant: Synthetic Soil plus Fission Products

Subject	Time elapsed in minutes		% Change
Rabbit	60		- 2.3
"	80		+ 2.5
"	30		-11.0
"	30		-11.0
"	30		-18.1
"	30		- 1.0
"	30		- 5.4
"	20		- 7.5
"	105		+ 4.0
"	90		+ 4.3
"	30		+ 0.3
		Mean	- 4.1
Pig	60		+ 1.0
"	60		- 2.1
"	60		+ 0.7
"	60		- 4.0
		Mean	- 1.1

[redacted]

In another series, large amounts of various contaminants were placed on the clipped backs of rabbits and allowed to remain for varying lengths of time. The contaminated areas were then washed and the animals sacrificed. Various organs were then taken, dissolved in hot nitric acid, evaporated to dryness, and counted. The organs used varied, but generally included the entire liver, 20 to 40 ml. of blood, the bones of both hind legs, and sometimes kidneys and a urine sample. The results obtained were:

TABLE XV

Percutaneous Absorption in the Rabbit

Contaminant	Activity in counts/minute	Hours elapsed between contamination and sacrifice	% of applied activity recovered in organs
Fission products	10^6	4	0.2
Fission products	10^6	67.5	0.6
Fission products	10^6	124	0.2
Fission products plus synthetic soil	7.6×10^5	2	0.3
Fission products plus synthetic soil	10^6	26.5	0.1
Fission products plus synthetic soil	10^6	95	2.1
Neutron-irradiated synthetic soil	4.4×10^4	18	2.8
Neutron-irradiated synthetic soil	1.1×10^5	19	0.9
Carbon-14 labeled soil	3.1×10^4	18	0.8
Nevada soil	7200	1	8.9

The values for the per cent of applied activity recovered in the organs are not too reliable, for the counts obtained on the aliquots used were barely above background. The conclusion may be drawn, however, that total absorption of the contaminants used is probably less than two per cent. The unexpectedly high value for the Nevada soil was ascribed to accidental contamination and, for various reasons, not worthy of further investigation.

[redacted]

4. Conclusions and Recommendations.

(1) Suitable technics have been developed to determine the efficiency of radiological decontaminants on the human skin.

(2) Live rabbits were found to be excellent for the development of suitable technics and preliminary evaluation studies. Final tests, however, must be carried out on the living human skin.

(3) Percutaneous absorption of the contaminants used is probably less than 2% in the case of the rabbit and pig.

(4) Within very wide limits, the efficiency of a decontamination process is independent of the initial activity present. However, greater precision is possible by using higher levels of activity.

(5) Most of the activity is removed in the first washing. The second removes relatively little of the remaining activity, and further washing is of doubtful value.

(6) The palm of the hand is more difficult to decontaminate than the forearm.

(7) Three superior decontaminating agents were formulated:

(a) 30% Duponol ME, 65% tetrasodium salt of ethylene diamin tetra-acetic acid, 5% carboxymethyl cellulose.

(b) 30% Ivory, 65% tetrasodium salt of ethylene diamine tetra-acetic acid, 5% carboxymethyl cellulose.

[redacted]

(c) 30% Duponol ME, 65% trisodium salt of ethylene diamine tetra-acetic acid (monohydrate), 5% carboxymethyl cellulose.

These products represent only initial attempts at formulating highly efficient decontaminants, and must not be thought of as the final answer to the problem.

(8) Phases of the problem that should be investigated may include:

(a) Contamination and decontamination of hair.

(b) Possible effect of the soil used on decontamination efficiency.

(c) Retentivity of skin areas other than palm and forearm.

(d) Development of other contaminating procedures that may result in greater adhesion of the contaminant to the skin. Some of these have been considered, but lack of time and subjects has not permitted experimentation along these lines.

(e) Testing of a greater variety of products, particularly syndets, in various concentrations and in combination with various sequestrants and other substances that would aid in the removal of the contaminant.

(9) It is possible to use higher levels of activity than those employed so far and still remain well within the limits of safety and the Atomic Energy Commission's requirements.

Respectfully submitted,

FOSTER D. SNELL, INC.

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SKIN CONTAMINATION BY RADIOACTIVE SUBSTANCES

MEANS OF PROTECTION AND DECONTAMINATION

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Translated by G. Segura

Radioactive contamination of skin, especially of the hands, may be observed:(1)

1. In times of peace

2. In times of war.

1. At the present time, a large number of organizations use radioactive products; laboratories, hospitals, various industries, agriculture, etc. Their number can only increase, because the range of isotope uses becomes greater every day.

Workers in the field have been given instructions on how to handle them without danger. In particular, it is recommended to protect the hands by the use of gloves, but it should be realized that, for various reasons, these suggestions are not always followed. Furthermore, accidental contaminations may occur in spite of the precautions taken.

2. However, it is in wartime that this question may take on an exceptional importance. For some time, as a matter of fact, a new method of aggression has been discussed: radiological warfare. This would consist in the spread-

(1) "Contamination" is a French word; "decontamination" is not. However, this neologism is necessary; as a matter of fact, the nearest term, "disinfection", is not proper, since it refers to the destruction of contagious germs.

ing of radioactive products in sufficient quantity to kill the people in the contaminated area.

Radioactive substances offer, from the military point of view, a double interest; they are, first of all, dangerous and cannot be detected except by the use of special, expensive, and complicated apparatus; on the other hand, some of them can kill in even extremely small quantities, making them the most violent poisons known.

Radioactive substances may be dispersed for aggressive purposes in several ways:

a) Explosion of an Atomic Bomb - When an atomic bomb explodes in air, only the immediate radiation (gamma and neutrons) is to be feared, for the radioactive products are carried high into the atmosphere (save, perhaps, in the case of rain), and any dangerous neutron-induced activity cannot be found on the ground or on objects.

In the case of an underwater or ground explosion, a large number of radioactive products remain, and the contamination is, therefore, considerable.

This last method, however, could not neutralize extensive regions. Contamination of the entire surface of the earth would require about one million atomic bombs; one for every 500 km^2.

b) Hydrogen Bomb Explosion - Aerial explosion of an H-bon would hardly liberate any more radioactive substances than those of the atomic bomb which serves as the detonator.

However, it would doubtlessly be possible to produce a large quantity of radioactive substances by using the considerable number of neutrons emitted by the thermo-nuclear bomb. By suitably surrounding a hydroge bomb with some particular element, it would be possible, according to Szilard, to produce a radioisotope, such as cobalt-60, in sufficient quantity to kill the population of the entire earth. According to him, this would require 50 tons of neutron which should be liberated by 10,000 tons of deuterium. This quantity could be produced in ten years by a country having the economic importance of the United States.

c) By-products of Atomic Piles - Radioactive contamination may be accomplished without recourse to an explosion by the dispersion of the radioactive by-products removed from atomic piles.

This idea was first mentioned in the H. D. Smyth report, and has been long studied by H. Thirring of the University of Vienna. He estimate that by 1960 the U. S. would be able to contaminate monthly 4,500 km^2, and the U. S. S. R., 3,000 km^2.

The radioactive products from the piles would be mixed with fine sand and spread by airplanes and guided missiles. An airplane carrying a ton of the finished product, could contaminate an area of 167 km^2.

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* *

In spite of the competence of the authors of these studies, radiological warfare is still in the domain of scientific speculation, and we must hope that it may remain there forever. The immediate problem concerns the personnel who handle radioelements; also, it would be useful to undertake experimental research on protection and decontamination of the skin.

EXPERIMENTAL TECHNIC

The experimental technic was as follows:

1. Hammer handles were first activated by the deposition of thorium. In order to accomplish this, the tool is placed for 15 minutes under a bell jar enclosing a cupel of radiothorium-thorium X.

2. A subject was asked to hammer a sheet of lead with the radioactive tool, with one hand, for 30 to 45 minutes.

3. At the end of this period, the activity on the hand was measured, (initial activity).

4. The chosen decontamination procedure was then performed.

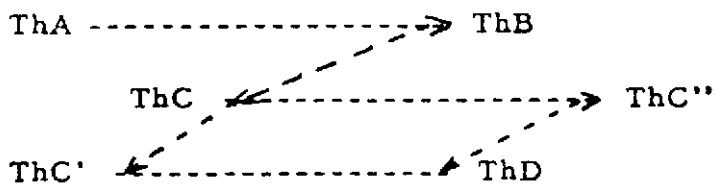
5. Finally, the residual activity was measured and compared with the initial activity.

Activation by thorium was chosen because the short half-lives of its descendants remove all danger. In fact, the activity on the hand was negligible on the following day, and none at all one day later.

Table I gives the characteristics of the contaminating agent.

TABLE I

Contaminating Agent



	Z	A	Isotope	Half-Life	Energy in MeV
ThA	84	216	Po	0.168 s	α : 6.77
ThB	82	212	Pb	10.6 h	(β) β :0.36; (0.59) γ :0.43;0.71;0.238 e-
ThC	83	212	Bi	60.5 m	β : 2.256 γ :0.73;1.80 α :6.05;6.08;5.76;5.60;(5.62) γ :0.15 to 2.20
ThC'	84	212	Po	3×10^{-7} s	α :8.78
ThC''	81	208	Tl	3.1 m	β :1.805 γ :2.62;0.57;0.51;0.277

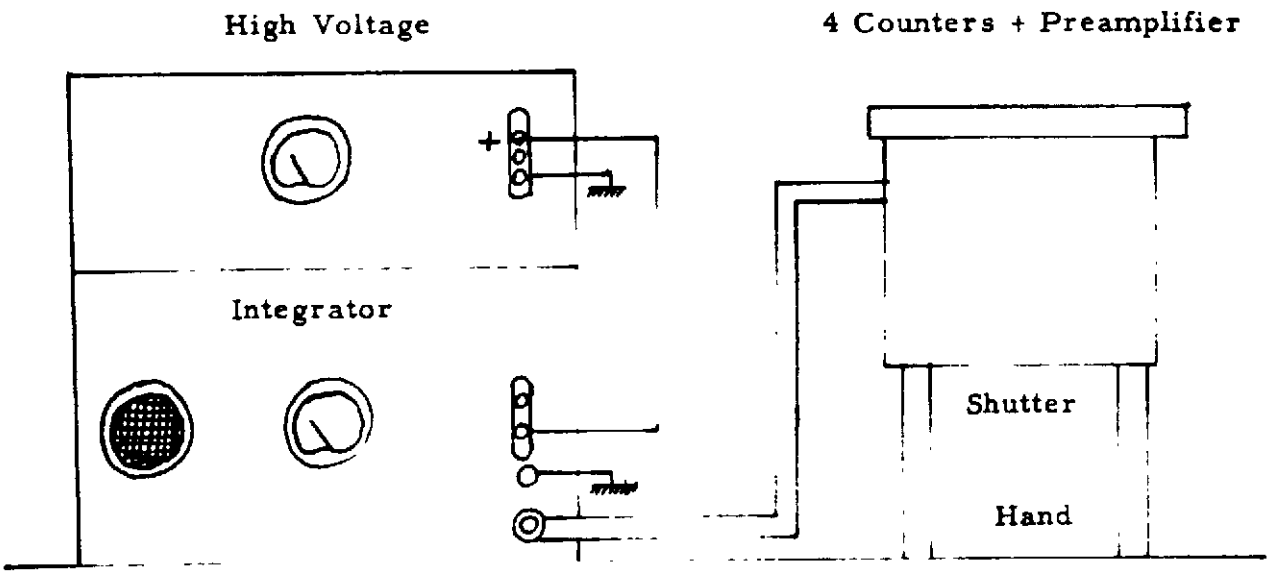
Note: Numbers in parentheses are $<1\%$.

Experimental conditions were chosen so as to give 250 counts per second when the hand was held 10 cm. from the measuring apparatus without intervening absorbers.

The activities were measured with an instrument built by the A.E.C. (figure 1).

FIGURE 1

Diagram of the Counting Apparatus



This instrument consists essentially of four counter tubes in a small box on a stand. The thin walls of the counters rest on the perforated plexiglas bottom of the box. A metallic shutter just beyond may be used as a radiation absorber. To measure the activity, the hand was placed flat, the palm facing the counters at a predetermined distance.

The counters are set in parallel, connected to a preamplifier and fed the required high voltage.

An integrator indicates the average counts given by the counters. It has 3 ranges: 50 cps, 100 cps, and 250 cps.

This instrument has always functioned remarkably well. About one-hundred experiments were performed.

RESULTS

I. - Degree and Distribution of the Contamination

1. Experience has shown that the degree of contamination depends on:

a) Activation period of the hammer handle - This, after some preliminary work, was set at 15 minutes. Less than this, the handle did not becom active enough, at least under the experimental conditions employed.

b) Manipulation period - Suitable degree of contamination required hammering for 30 to 45 minutes under the experimental conditions. It is important to carry out the hammering for at least half an hour and with vigor in order to impregnate the skin with the radioactive particles thoroughly. Beyond

this period, the contamination increases little, as if some equilibrium had been reached. (Figure 2)

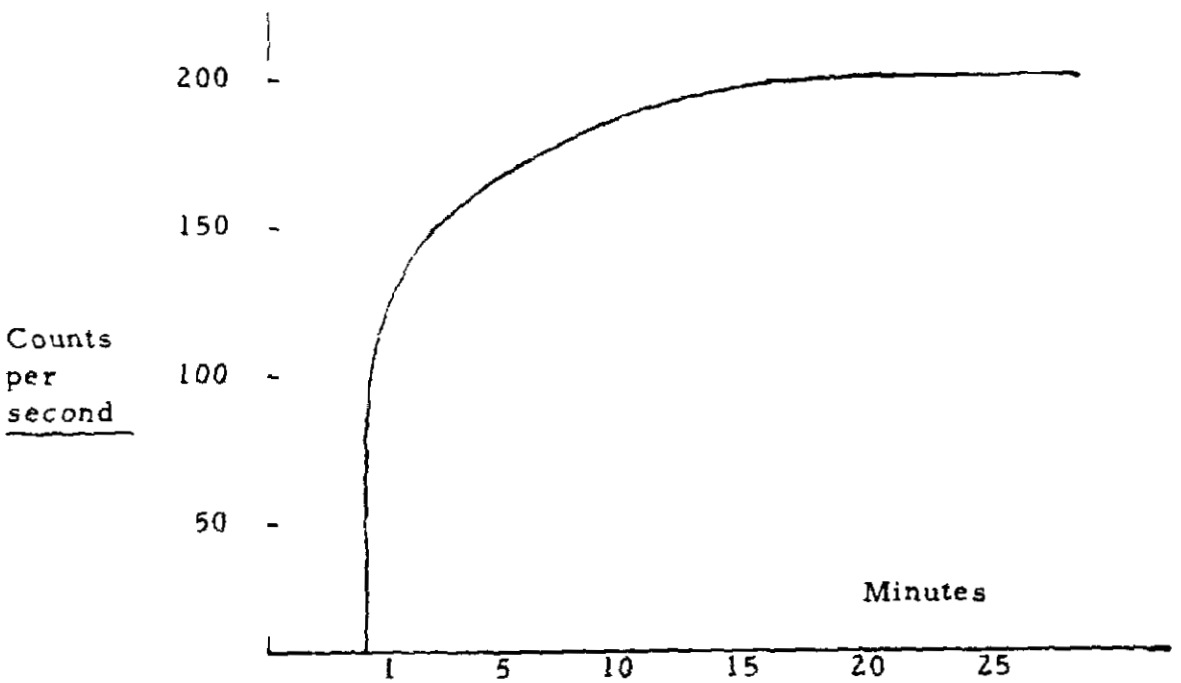


FIGURE 2

Activity of the Hands as a Function of the Manipulation Time

c) Nature of the skin - The contamination is less persistent on delicate than on thick and calloused skins. Perspiration, particularly in hot weather, likewise modifies the degree of contamination.

2. The hand does not contaminate uniformly. The activities, measured with a single counter, are listed in decreasing order in Table II.

TABLE II

Distribution of Skin Activity

Region	Activity (cpm)	%
Median	65,000	36
Proximal	60,000	33
Digital	38,000	21
Distal	17,000	10

This distribution is of some interest, for it indicates the regions that should be decontaminated most carefully.

II. - Decontamination Procedures

Logically, all tests should have been done on the same subject, then repeated on other persons in order to take into account individual variations; the average of the results obtained would thus have offered a well-based classification of the different experimental procedures.

This project was not carried out. As a matter of fact, the length of the tests limited the number of subjects that were not annoyed by the irksome hammering. As a result, it was possible to perform only part of the procedure on each

subject. The simplest method of all, brushing with soap, was tried on all subjects

This was the method used as a comparison standard. The results are listed in Table III. There the index +10 or -10 given to a process, means that the activity left by that process is 10% greater or smaller than the activity left by brushing with soap.

TABLE III

Residual Activity of the Decontamination Procedures

(These values are referred to the residual activity of brushing with soap.)

1N HCl + Mergital	-21
Citric Acid	-10
Citric Acid + Mergital	-7
Soap + Sawdust	-7
0.1N HCl + Mergital	-5
1N HCl	-2
Permanganate	0
Soap + Mergital	0
3-33 Soap	+3
Titanium Dioxide	+5
Organic Solvent	+7
Depilatory	+9
Soap + Starvon	+9
Water + Mergital	+8
Permanganate + Mergital	+11
Brushing alone	+14
Lanolin	+36

1. Brushing with soap - The procedure consisted in brushing with Marseille soap with two or three intervening rinsings with tap water. The operation lasted 5 minutes. It was repeated twice, making a total of 3 operations.

The results are listed below.

Brushing, Soaping, and Rinsing

Residual Activity

	Mean %	Maximum %	Minimum%
After the first operation.	35	86	16
After the second operation. . . .	25	56	10
After the third operation.	23	56	9

2. Brushing alone - In order to determine the relative values of the mechanical and detergent actions of soap brushing, the preceding test was repeated without soap.

The average residual activity was 14% higher than above.

3. Brushing with a mixture of soap and sawdust - In order to increase the detergent action of the soap, sawdust was added to the soap powder. This has been recommended by Cruikshank as most efficient for the removal of petroleum oil stains from the hands.

The same tests as above were repeated. The residual activity was 7% less than that obtained with soap.

4. Brushing with 3-33 soap - This soap is used in garages for the removal of grease stains from the hands. It is a mixture of ordinary soap, fine sawdust, talcum, formaldehyde, and calcium carbonate. The same procedures as those of test No. 1 were carried out with this special soap.

They showed that the remaining activity was 3% above that of ordinary soap.

5. Rubbing with corn meal and lanolin - The A.E.C., in a pamphlet entitled, "Standard Safety Requirements", recommends, in case of contamination of the hands, to rub for 2 to 3 minutes with a teaspoonful of lanolin and corn meal. Rinse with warm water; repeat three times.

Tests using this technic showed a residual activity 36% greater than that left by three brushings with ordinary soap.

6. Application of TiO_2 paste - For contamination with fission products, the above-mentioned paper recommends the use of a paste of TiO_2. This is applied on the skin for at least two minutes; rinsed with hot water; brushed with soap.

With this procedure, the residual activity was 5% greater than with ordinary soap.

7. Application of a solution of $KMnO_4$ - In the manual "Safe Handling of Radioactive Isotopes", the National Bureau of Standards recommends the use of a saturated solution of $KMnO_4$ followed by rinsing with a 5% $NaHSO_3$. The desired result is to cause a superficial tanning of the skin by the $KMnO_4$, and then the removal of the tanned portion with the $NaHSO_3$.

This method has shown that, in general, the residual activity was the same as that left by ordinary soap.

8. Use of a depilatory - Along the same line of thought, a keratolytic agent in the form of a depilatory based on calcium thioglycolate was used.

The depilatory was applied to the skin for 10 minutes, then removed by simply rinsing with water. Residual activity : +9%.

9. Brushing with a solution of citric acid - In a booklet recently published by the American Government, "The Effects of Atomic Weapons", it is mentioned that the Bikini ships were decontaminated fairly satisfactorily with sodium citrate solutions. In this fashion, complex compounds will be formed with the fission products and the unfissioned material.

This process had already been suggested by several authors, notably by Sullivan, for the decontamination of clothing soiled with radioactive products.

Experiments have shown that, compared to soap, the residual activity was diminished by 10%.

Contaminated hands were therefore brushed with a 3% citric acid solution.

10. Brushing with a solution of normal hydrochloric acid - The A.E.C. recommends, after the previous methods have failed, the use of acid solutions. The hands should be brushed with a solution of normal HCl. The operation should continue for 15 minutes. However, it was brough to an end after 5 minutes becaus of the skin irritation produced by this strongly acidic solution.

The residual activity was about the same (diminished by 2%) as after 3 brushings with ordinary soap.

11. Rubbing with organic solvents - Evans suggested the use of organic solvents to carry away the dust fixed on the hands of personnel working in the prep aration of radioactive paints. The hands were rubbed for 5 minutes with 100 cc. of the following mixture: xylene: 1; trichloroethylene: 1; ethyl alcohol: 2.

The residual activity compared to that of brushing with soap, was +7%.

It should be noted that this procedure seems to have been recommended to dissolve the adhesive of the paint.

12. Brushing with a wetting agent - In hopes of facilitating the carrying away of radioactive substances, experiments were performed with several wetting agents. It is logical to think, in fact, that because of the capillarity phenomena, the solutions used did not get to penetrate to the very interior of the skin pores in order to withdraw the radioactive substances that lodged there. Two products were used: Mergital and Starvon, which are alkylaryl sulfonates manufactured by the Societe Sinnova.

At first, the product alone was tried. The hands were brushed with a 2% aqueous solution of Mergital, following the technic of test #1.

The residual activity was 8% greater than with soap.

13. Brushing with a mixture of wetting agents - The same operations were repeated with the following mixture:

Starvon . . . . . 2 Parts
Mergital. . . . . 1 Part

The residual activity was the same as with ordinary soap.

14. Brushing with ordinary soap and a wetting agent - The same operations as those of test #1, but with the addition of Starvon to ordinary soap increased the residual activity by 9%.

15. Application of a solution of permanganate and a wetting agent - Test #7 was repeated adding 2% Mergital to the solutions of permanganate and bisulfite.

The residual activity was +11%.

16. Brushing with a solution of normal hydrochloric acid and a wetting agent - Test #10 was repeated with the addition of 2% Mergital to the normal HCl

A single brushing was made which lasted for 5 minutes.

The residual activity was -21%.

17. Brushing with one-tenth normal HCl and a wetting agent - By using a solution one-tenth as strong, it was possible to brush twice, 5 minutes each time, without irritating the skin too much.

The residual activity was -5%.

18. Brushing with a solution of citric acid and a wetting agent - Test #9 was repeated with the addition of 2% Mergital to the citric acid.

The residual activity was -7%.

COMMENTS

Just as in the case of radioactive contamination of inert surfaces (Tompkins), the radioelement may be retained on the surface of the skin by a triple mechanism:

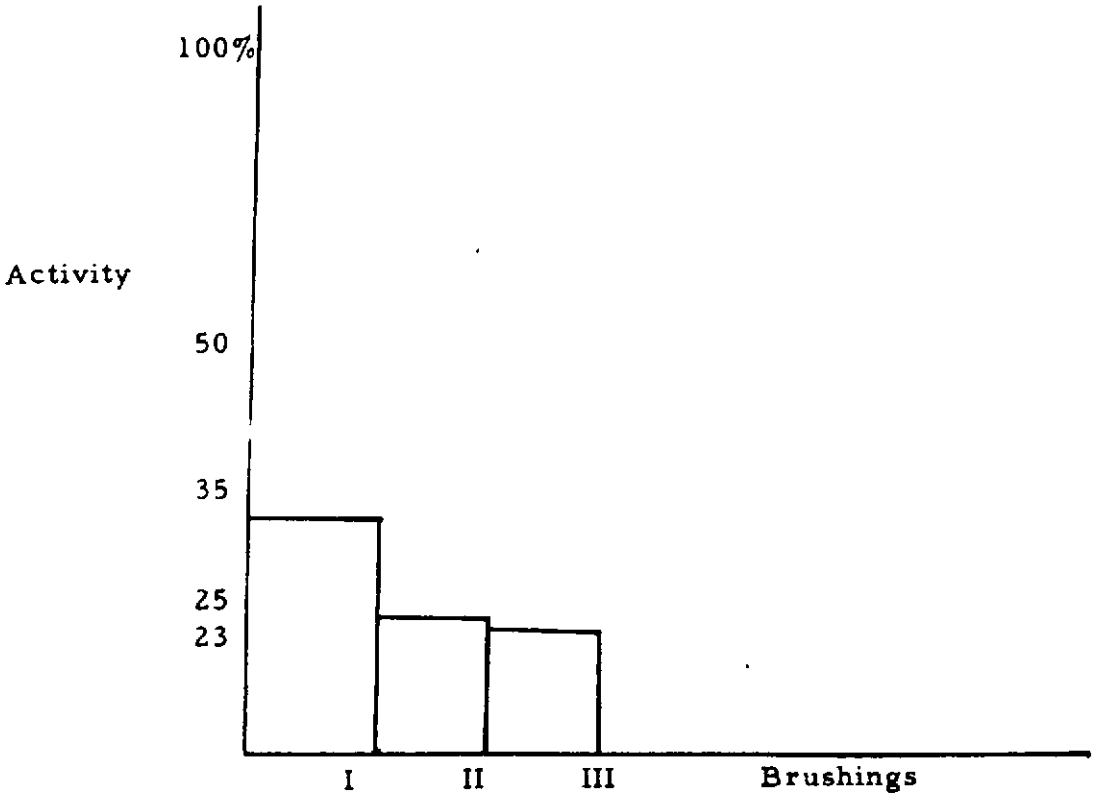
1. Chemical - (i.e. ionic exchange)
2. Physical - (by adsorption)
3. Mechanical - (diffusion into pores of the skin)

The decontamination procedures act upon one or more of these mechanisms.

During decontamination operations, it is seen that the activity decrease very rapidly, and then does not change greatly, as if a state of equilibrium, similar to that of contamination, was reached. As a result, the effect of a decontamination agent is practically fully attained after the first trial. Further work bring only insignificant improvement. Thus, in the case of brushing with soap (test #1) the first brushing removed 65% of the activity, the second 10% more, and the third had no effect. (Figure 3)

FIGURE 3

Residual Activity of the Hands After Each of Three Brushings with Soap



Whichever method is employed, it is not possible to decontaminate completely soiled tissues. It is true that the experimental conditions were unusually severe; the initial activity was high and the radioactive particles were strongly attached to the tissues.

Exploration of the palm of the hand by means of a counter similar to on used for the same purpose by the A.E.C. gave, in one case:

Initial activity . . . . . 45,000 counts/minute
Residual activity . . . . . 6,000 counts/minute

The residual activity, amounting to 13% of the initial activity, is thus close to ten times greater than the tolerance dose, which has been fixed at 700 cpr

These measurements refer only to beta and gamma radiation and not to alpha, the tolerance dose of which is much smaller.

The lowest residual activity that has been obtained was 3% in a test with acid solutions. This corresponded to 1,600 cpm; that is to say, twice tolerance dose.

From Table III it may be seen that the experimental procedure may be classified in three categories by comparison with brushing with soap:

1. Most effective procedure - brushing with normal HCl with the addition of Mergital.

2. Least effective procedure - brushing alone without soap; rubbing with a mixture of lanolin and corn meal.

3. Procedures of comparable efficiencies - all the rest.

For the interpretation of this classification, a very important point should be taken into account. As clearly stated above, it was not possible to try every procedure on every subject. Naturally, because of individual variations, some given method will not give the same results with different subjects. On the other hand, before finally adopting a technic, certain factors should be taken into account. First of all, the price; wetting agents that we have used are rather expensive, something like 300 francs per kilogram, so that each washing of the hands comes to about 3 francs. The expense obviously is not too great for laboratory personnel, but it would become so in case of radiological warfare when a large number of people having large areas of the body contaminated would have to be treated. Certain procedures can be used only under exceptional circumstances; for example, permanganate solutions. This is also true of solutions of normal HCl, which are efficient, but which cause small blisters on the skin. Also organic solvents which destroy the oily protection that covers the skin, produce a disagreeable dry feeling and may facilitate the penetration of fine radioactive particles.

Concerning radioactive contamination of inert surfaces, Tompkins has noted that three variables are involved:

1. Contamination conditions
2. Contaminated surface
3. Decontamination agent

If one of these factors is changed, the solution of the problem is changed

The same may be said concerning radioactive contamination of the skir It has been seen, as a matter of fact, that the decontamination efficiencies vary with the decontamination procedure (third factor), and that for a given procedure it varies with different subjects (second factor). The first factor remains to be studied. That is, these tests should be repeated using different radioelements in different physical and chemical states. As a result of the above, it is difficult to set a general decontamination method, since so many variables are involved.

Some twenty procedures have been studied; these are the most important. There are others. However, the study of the problem is sufficiently advanc to believe, however improbable this may seem, that much better results than those which have been obtained may yet be found.(1)

This is the reason why, from a practical point of view, it seems that the simplest, and most economical, if not always the most efficient, is, in the last analysis, brushing with soap. This may, however, be completed by the use of other substances because of individual variations.

The method that seemingly should be retained is the following:

A soft brush, ordinary soap, and warm water.

The entire surface of the hands should be brushed methodically. One may begin, for example, on the thumb, then the space between the thumb and forefinger, etc.

(1) The addition of stable isotopes to the decontamination agent has not been tried since this method has not given positive results in the decontamination of inert surfaces.

Special attention should be paid to the palm of the hand, the interdigital spaces, and the nails, which should be cut as close as possible.

Strong brushing should be avoided so as not to irritate the skin, since the least scratch could become a port of entry.

The hands should be rinsed three times, with fresh warm water and not with water from previous washings.

This operation should last 5 minutes by the clock. The activity then should be determined with a counter. If the activity is above the tolerance dose (700 cpm), continue brushing for 5 minutes.

If, after two operations, activity remains above tolerance, it is useless to try a third brushing, particularly since there is a risk of irritating the skin. One may then try one of the following procedures:

Brushing with 0.1N HCl, or 3% citric acid, with the addition of a wetting agent, while taking all possible precautions to avoid blistering.

Applying a saturated solution of permanganate, followed by rinsing with a 5% sodium busulfite.

After washing, apply on the skin some lanolin or skin cream.

III. - Protection Means

Several means of protection for the hands have been tried; first of all, rubber gloves, then various skin protectors.

Rubber Gloves - In principle, rubber gloves should confer total protectic However, since some workers have doubted it, we performed one hammering test under the usual conditions while the hand was protected with a rubber glove of the surgical type. Protection was complete. On the other hand, the glove, after being brushed for 15 minutes with soap, showed a residual activity of 14%.

Skin Protectors -

a) Collodion - A collodion solution was applied to the hands. After evaporation, it formed a thin, dry film. After manipulation, the film, which developed several cracks, was removed with ether, although with difficulty.

The protection afforded was 50%; that is to say, the activit on the hands was one-half that of the unprotected hands.

b) Tincture of Benzoin - The hands were covered with the tincture of benzoin which, upon evaporation, left an invisible film. This was removed with alcohol after manipulation.

The protection obtained was about the same as that with collodion.

c) Isolex 10 - This product comes in the form of a greasy paste that is spread on the hands like a cream. It dries in a few minutes, covering the skin with an invisible film which forms something like a glove. The skin remains normal, neither humid nor dry, and retains its suppleness.

After the test, dip the hands in water without rubbing them together nor bending the fingers. When the film is well-detached, rinse the hands in pure water.

The protection afforded by this method is 80%; that is to say, the hands retained an activity one-fifth as strong as that of the bare hands.

It is, therefore, a product that gives considerable protection. Furthermore, as opposed to the two previous portective agents, the remaining activity often approaches the tolerance dose. As a matter of fact, in one case decontamination was nearly total.

SUMMARY

1. Radioactive contamination of skin is a problem of Peace and War.

2. Some twenty procedures have been tried. None is capable of complet decontamination of the skin. Residual activity has been generally one-fifth of the initial activity.

3. The simplest procedure is brushing with soap.

4. Certain skin protectors are highly effective.

Using a mixture of Ultrawet 30 DS and Janusol, a non-ionic dispersant, only slightly better results were obtained.

TABLE XXV.

Surface: Human Hair
Detergent: 5.0% UJC *

Initial Count	Final Count	Per Cent Removed
20300	1820	91.1
15600	1350	91.4
16600	1770	89.3
Mean		90.6
Standard Deviation		±0.9
Standard Error of Mean		±0.7

*15% Ultrawet 30DS, 15% Janusol, 65% Calgon, 5% carboxymethyl cellulose.

Since such excellent results had been obtained with the Nonic 218 formulation, it was decided to try this non-ionic detergent alone.

TABLE XXVI.

Surface: Human Hair
Detergent: 5.0% Nonic 218

Initial Count	Final Count	Per Cent Removed
14400	4400	69.4
17700	6420	63.5
13900	3240	76.6
Mean		69.8
Standard Deviation		±5.3
Standard Error of Mean		±3.8

Comparing these results with those of Table X, which gave a mean per cent removal of 96.4 for the Nonic-Calgon-CMC combination, it is seen that a good sequestrant can make a tremendous difference. This was further confirmed using Triton NF, another non-ionic detergent, alone and in combination with Calgon and CMC.

TABLE XXVII.

Surface: Human Hair
Detergent: 5.0% Triton NF

Initial Count	Final Count	Per Cent Removed
15200	10200	33.0
10500	5310	49.2
13300	7400	44.5
Mean		42.2
Standard Deviation		±6.8
Standard Error of Mean		±4.8

TABLE XXVIII.

Surface: Human Hair
Detergent: 5.0% TC *

Initial Count	Final Count	Per Cent Removed
18800	855	95.5
15800	871	94.5
19600	764	96.1
Mean		95.4
Standard Deviation		±0.7
Standard Error of Mean		±0.5

*30% Triton NF, 65% Calgon, 5% carboxymethyl cellulose.

In view of the results obtained up to this time, it was decided to try several more non-ionic detergents in combination with Calgon and carboxymethyl cellulose.

TABLE XXIX.

Surface: Human Hair
Detergent: 5.0% CeC *

Initial Count	Final Count	Per Cent Removed
9870	1040	89.4
11200	1440	87.2
8850	1160	86.9
Mean		87.9
Standard Deviation		±1.1
Standard Error of Mean		±0.8

*30% Cerfax 1300, 65% Calgon, 5% carboxymethyl cellulose.

TABLE XXX.

Surface: Human Hair
Detergent: 5.0% AlC *

Initial Count	Final Count	Per Cent Removed
16500	1350	92.8
12700	1000	93.1
17500	1250	93.9
Mean		93.2
Standard Deviation		±0.5
Standard Error of Mean		±0.4

*30% Aerosol C, 65% Calgon, 5% carboxymethyl cellulose.

TABLE XXXI.

Surface: Human Hair
Detergent 5.0% AxC *

Initial Count	Final Count	Per Cent Removed
14500	875	94.0
13300	910	93.2
15400	1070	93.1
Mean		93.4
Standard Deviation		±0.4
Standard Error of Mean		±0.3

*30% Antarox A400 (also sold as Igepal CO-630), 65% Calgon, 5% carboxymethyl cellulose.

TABLE XXXII.

Surface: Human Hair
Detergent: 5.0% T20C *

Initial Count	Final Count	Per Cent Removed
18800	2400	87.2
17400	2830	83.8
17700	2240	87.4
Mean		86.1
Standard Deviation		±1.7
Standard Error of Mean		±1.2

*30% Tween 20, 65% Calgon, 5% carboxymethyl cellulose.

TABLE XXXIII.

Surface: Human Hair
Detergent: 5.0% T21C *

Initial Count	Final Count	Per Cent Removed
32500	3030	90.6
21000	2480	88.2
24100	2400	90.0
Mean		89.6
Standard Deviation		±0.7
Standard Error of Mean		±0.5

*30% Tween 21, 65% Calgon, 5% carboxymethyl cellulose.

For convenience, all the results of the work on human hair are summarized in Table XXXIV. The detergent combinations are listed according to the type detergent, in the following sequence: soap, household anionics, household non-ionics, special types, anionics, non-ionics, and anionic plus non-ionics.

TABLE XXXIV

Surface: Human Hair

Versene + 5% CMC				
Triton NF	non-ionic	5	XXVII	42.2
30% Triton NF + 65% Calgon + 5% CMC	non-ionic	5	XXVIII	95.4
30% Cerfax 1300 + 65% Calgon + 5% CMC	non-ionic	5	XXIX	87.9
30% Alrosol C + 65% Calgon + 5% CMC	non-ionic	5	XXX	93.2
30% Antarox A400 + 65% Calgon + 5% CMC	non-ionic	5	XXXI	93.4
30% Tween 20 + 65% Calgon + 5% CMC	non-ionic	5	XXXII	86.1
30% Tween 21 + 65% Calgon + 5% CMC	non-ionic	5	XXXIII	89.6
15% Duponol ME + 15% Nonic 218 + 65% Calgon + 5% CMC	anionic plus non-ionic	5	XII	88.2
15% Ultrawet 30DS + 15% Janusol + 65% Calgon + 5% CMC	anionic plus non-ionic	5	XXV	90.6

[redacted]

B. Human Skin

Provision was made in the contract for the use of one hundred adults for decontamination studies on the human skin in vivo. A great deal of time has been spent planning this phase of the program. It is hoped that this careful approach, while delaying the experimental work, will yield more meaningful results in the end. Only ten subjects have been used to date, and the full significance of these results will not become apparent until the entire series is completed, at which time the final conclusions will be drawn.

The procedure used on the first three subjects was essentially the one described in the Final Report submitted at the end of the first contract. This procedure was as follows: circles about one inch in diameter were drawn on the skin of the subjects; a small quantity of a suspension of synthetic soil and fission products was placed within each circle and allowed to dry; the activity was determined with a Geiger counter with a 1.8 mg/cm^2 mica end window held about 3 mm. above the skin. The contaminated areas were then washed for one minute with small cotton applicators, of the type known as "Q-tips," soaked in detergent solution and the

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excess detergent removed with absorbent tissue paper This was followed by rinsing, drying with absorbent tissue paper, and then a final determination of the remaining activity. Three skin areas were used; the palm, the back of the hand, and the upper inner aspect of the forearm. The following results were obtained.

TABLE XXXV.

Surface: Human Skin

Subject	Area	Detergent	Rinse *	Initial Count	Final Count	Per Cent Removed
1	L. Palm	5.0% NC**	Distilled Water	893	36	96.0
	L. Back of Hand	5.0% NC**	Distilled Water	847	46	94.6

Some obvious conclusions can be drawn from the preliminary work of Table XXXV:

1. The use of Calgon as a rinse did not prove beneficial.

2. The recommended decontaminants, titanium dioxide paste and potassium permanganate solution plus a bisulfite rinse, did not fare as well as detergents.

3. The hands are harder to decontaminate than the arms, with the palm still being the hardest.

Three important modifications were introduced at this time. Evidence obtained in this laboratory and elsewhere indicates that the palm of the hand is more difficult to decontaminate than the arm or back of the hand. It was decided, therefore, to restrict future experiments to the palms of the hands. Another advantage of this restriction is that the entire activity used on an individual may be concentrated on two spots rather than six, thus permitting the use of higher levels per contaminated area. The other important modification consisted of removing the most loosely held activity before treating with detergent. This was accomplished by swabbing with distilled water for one minute, drying with absorbent paper, swabbing once again with distilled water for one-half minute, and drying with absorbent paper.

The remaining activity was then determined and decontamination proceeded as usual. In the following table the last column refers to the per cent activity removed by the decontaminating agent; i.e., it is obtained by dividing the final count by the after rinsing count, multiplying the quotient by 100, and then subtracting the result from 100. The third modification consisted in extending the length of time between the initial contamination and the first water rinse.

Excepting Subject 4, all of the subjects were rinsed with distilled water for one minute. The left palm of Subject 4 was rinsed with distilled water for five minutes and the right palm with 5.0% sodium bisulfite for seven minutes.

TABLE XXXVI.

Surface: Human Skin (Palms)

An analysis of these results requires a consideration of the characteristics of the subjects used.

TABLE XXXVII

Characteristics of Human Subjects

Subject	Sex	Age	Complexion	Skin	Color of Hair	Color and Miscellaneous
1	male	19	fair	normal	blond	W
2	male	23	fair	normal	brown	W
3	male	18	fair	normal	black	W, 17 year old scar on right arm
4	male	21	fair	normal	blond	W
5	male	35	dark	normal	black	W
6	male	29	fair	dry	brown	W
7	male	25	dark	normal	black	N
8	male	42	sallow	normal	brown	W
9	male	40	fair	normal	brown	W, unusually delicate, thin skin
10	female	22	fair	normal	brown	W

These experiments form but a small part of what will be a unified whole, consequently very few conclusions, and these of the most tentative sort, only may be drawn at the present. However,

even these incomplete results are not without interest or value. Subject 9, for example, offered dramatic proof of the variations in retentivity that may be found from one person to another. It is also seen that reproducibility of results is good. Not all of the variables have been isolated and dealt with properly; therefore, their analysis must await further work. Likewise, it is too early to make any recommendations, even tentatively, concerning the most efficient decontaminant or decontaminating procedures.

3. Conclusions.

(1) The character of the skin is a very important factor in the problem of radiological decontamination. In general, it may be said that soft, delicate, smooth skin is less retentive than rough or hardened skin.

(2) Saturated potassium permanganate followed by decolorization with 5.0% sodium bisulfite solution does not remove all of the activity from the skin.

(3) The application of titanium dioxide paste followed by its removal with water is very ineffective.

(4) The length of time elapsed between contamination and washing may be of considerable importance. It is expected that a few more experiments will decide this question definitely.

(5) The more extensive experiments on human hair show that the addition of a good sequestrant and carboxymethyl cellulose will improve the performance of detergents appreciably. This was particularly true in the case of non-ionic syndets, which are extremely poor when used alone, but which gave excellent results when combined with polyphosphates and carboxymethyl cellulose.

(6) Formulations based on five different anionic syndets gave remarkably similar results.

(7) Formulations based on two different syndets or two different sequestrants did not perform well.

(8) Conclusions reached with studies on various inert surfaces have been generally confirmed by the present series of experiments.

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4. Tentative Schedule for Final Phase of Program.

At least ninety more human subjects and scores of runs on human hair will provide the experimental data. The work will be expanded to include RW agents supplied by the client in addition to the fission products used to date. New formulations, some based on new products, others being simply the same products used in different proportions, will be tested. In this fashion it is hoped that much will be learned, in addition to the development of the most efficient decontaminant possible. One or more decontaminants will be formulated which will be highly satisfactory if used without water and excellent if water is available. It is also expected that, through cooperation with the Mound Laboratory, exceedingly valuable data will be obtained regarding the removal of alpha emitters from the skin.

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This phase of the program is of special interest because of the tenacity with which alpha emitters attach themselves to the skin.

Respectfully submitted,

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