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FINAL REPORT

TO

U.S. ARMY CHEMICAL CORPS

CHEMICAL AND RADIOLOGICAL LABORATORIES

ON

REMOVAL OF RADIOACTIVE CONTAMINANTS FROM HUMAN SKIN (U)

UNDER

CONTRACT NO. DA 18-108-CML-4747

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Summary.

This is the final report to the Chemical and Radiological Laboratories under Contract No. DA 18-108-CML-4747 on the removal of radioactive contaminants from the human skin.

In accordance with the provisions of the contract, the decontaminating efficiency of numerous products was evaluated. The effectiveness of these products was determined on human skin in vivo and on human hair in vitro. Over one hundred human subjects were used in these tests.

The decontaminating formulations tested include several extremely effective cleansing creams which do not require water.

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1. Introduction.

One year was spent in preliminary work. This included a thorough literature survey on every pertinent aspect of the problem, consultations with other interested investigators, and extensive experimentation on inert surfaces and animal skins as well as some preliminary work on human skin. Much valuable information was also obtained as a result of another program of study of a similar nature then being undertaken for a private firm.

The second part of the project was devoted to extensive studies on human hair and human skin.

During the course of these studies, several scores of detergents have been used. This has included ordinary household products, commercial syndets, various chemical agents, and sequestrants. These products have been used alone, in combination, and at various concentrations.

The bulk of the work has been done using an aqueous suspension of synthetic soil mixed with fission products, but some experiments were performed with an irradiated soil, a carbon-14 labeled soil, a sample of soil from the Nevada test site, alpha emitters at the Mound Laboratories, and three radiological warfare agents.

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2. Literature Survey.

A careful search of all pertinent literature formed an important part of this project. However, very little was found on the radiological decontamination of the human skin and nothing at all on the removal of fission products from the human skin. The more important books and published papers found are listed in the Quarterly Reports of this project. These references include studies on detergents and detergency in general, radiological decontamination, dermatology, radioactivity, etc.

3. Experimental Work.

A. Summary of First Year.

The contaminant used in the vast majority of the experiments consisted of a 0.2% aqueous suspension of a synthetic soil to which sufficient aged mixed fission products solution had been added to give about 20,000 counts per minute per drop when placed about half a centimeter from a thin mica Geiger tube. The synthetic soil was developed by Sanders and Lambert of General Aniline and had the following composition:

Component	Per Cent
Humus	35
Cement	15
Silica	15
Clay	15
Sodium Chloride	5
Gelatin	3.5
Carbon Black	1.5
Iron Oxide	0.25
Stearic Acid	1.6
Oleic Acid	1.6
Palm Oil Fatty Acids	3.0
Lanolin	1.0
n-Octadecane	1.0
l-Octadecane	1.0
Lauryl Alcohol	0.5

The procedure generally used consisted in placing a drop of the radioactive suspension on the surface being studied, drying, determining the activity with a Geiger counter, washing, drying again,

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The differences appear to be real, but perhaps not very great. It was decided to use the light brown hair in all subsequent experiments, since that had been the type which was used in the earlier experiments.

The washings given in the previous three tables were done within an hour or two of contamination. In order to determine the sensitivity of the method to time elapsed between contamination and washing, two runs were made at intervals of two and three days after contamination. Still using 5% Tide as the detergent, the following results were obtained.

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TABLE II.

Human Hair

Color: Dark Brown

Initial Count	Final Count	Per Cent Removed
14800	1200	91.8
16400	1140	93.0
16100	1130	93.0
Mean		92.6
Standard Deviation		±0.6
Standard Error of Mean		±0.4

TABLE III.

Human Hair

Color: Dark Brownish Red

Initial Count	Final Count	Per Cent Removed
24000	3450	85.6
21900	3760	82.8
25500	4740	81.4
Mean		83.3
Standard Deviation		±1.8
Standard Error of Mean		±1.3

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In order to determine the dependence of decontaminability on hair color, a series of runs were made with three different types of hair. The detergent used was 5% Tide in every case.

TABLE I

Human Hair

Color: Very Light Brown

Initial Count*	Final Count*	Per Cent Removed
19100	2900	84.8
23400	3760	83.9
22400	2650	88.2
32200	6950	78.5
30500	3100	89.9
25300	6010	76.3
Mean		83.6
Standard Deviation		±4.2
Standard Error of Mean		±1.8

*All counts in this and subsequent tables of this report are expressed as counts per minute and are corrected for background.

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B. Final Six Months.

1. Fission products.

a. Human Hair In Vitro.

Work for the final six months of the contract centered on decontamination experiments on human hair in vitro and human skin in vivo. The procedure used for human hair was as follows: small bundles of hair about one inch long were prepared by dipping the ends in paraffin. Each bundle contained approximately 120 to 150 hairs. The hair was obtained from a dealer and was clean but otherwise untreated. A drop of the radioactive soil suspension was placed on each bundle, rubbed with a glass rod to aid wetting, and dried about 15 inches from an infrared lamp. This speeded the drying time while avoiding the melting of the paraffin. The activity on the bundles was then determined with a thin-window Geiger tube, the contaminated hair was then washed, dried again, and the residual activity determined as before. Precautions were taken to insure constant geometry in counting. Washing was accomplished by placing the bundles in separate 150 ml. conical flasks containing 20 ml. of detergent solution and shaking for ten minutes in an electrical shaker having a frequency of five cycles per second and an amplitude of one and one-half inches. This was followed by two shake rinses with distilled water, the first for three minutes and the second for one minute.

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A few experiments were performed using a sample of the synthetic soil which had been irradiated in a nuclear reactor, another synthetic soil sample prepared with carbon-14, and a sample of soil from the Nevada test site. These experiments were discontinued, however, when it was found that these soils failed to adhere sufficiently to either inert or living surfaces.

and determining the residual activity with the counter. Preliminary experiments on metallic surfaces showed that the procedure was fairly reproducible, and that it could be used to evaluate the decontaminating efficiency of detergents.

Work on metallic surfaces was followed by experimentation on rabbits and pigs. In general, the results obtained on these animals confirmed the earlier ones on inert materials. In addition, it was found that, under the experimental conditions employed, percutaneous absorption of the fission products was negligible.

The results from preliminary experimental work on sixteen human subjects agreed fairly well with the results obtained on animals and metallic surfaces.

By this time, certain definite conclusions could be made. It was found, for example, that different detergents varied greatly in their decontaminating efficiency, and that the best decontaminants were not always the most widely advertised. A satisfactory formulation required the use of good sequestrants, although most sequestrants are relatively poor detergents when used alone at room temperature. These conclusions were further strengthened by results obtained for a private firm on tin, plaster, cement, glass, wood, cotton fabric and other inert surfaces.

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TABLE IV.

Human Hair

Color: Very Light Brown

Washed two days after contamination.

Initial Count	Final Count	Per Cent Removed
12800	1520	88.1
22900	2530	89.0
17600	850	95.3
19600	3600	81.6
15900	2060	86.1
16700	1590	90.4
14100	663	95.3
17400	2590	85.1
Mean		88.9
Standard Deviation		± 4.4
Standard Error of Mean		± 1.7

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TABLE V.

Human Hair

Color: Very Light Brown

Washed three days after contamination.

Initial Count	Final Count	Per Cent Removed
11000	2220	79.8
15000	1840	87.7
6080	413	93.2
19200	4180	78.3
11000	1860	83.1
14800	2070	86.0
9810	700	92.9
20100	3110	84.5
Mean		85.7
Standard Deviation		± 5.2
Standard Error of Mean		± 2.0

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There is little difference between hair that has been allowed to remain contaminated for two days and for three days. However, it would appear that allowing the activity to remain that long makes its removal somewhat easier. At any rate, in order to avoid the introduction of an added variable, all future tests were conducted on freshly contaminated hair.

Extensive experimentation had already shown that, of all of the household products and widely advertised radiological decontaminants, the most efficient were the heavy duty syndets, of which Tide is an excellent example. Accordingly, little time was given to these products except for Tide, which was used as a standard with which to compare the efficiency of the various formulations tried.

The series on human hair was started using distilled water as the detergent.

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TABLE VI

Human Hair

Detergent: Distilled Water

Initial Count	Final Count	Per Cent Removed
18100	15100	16.5
15400	12300	19.7
14700	8560	41.7
Mean		25.9
Standard Deviation		±7.1
Standard Error of Mean		±5.0

A number of runs were then made using various detergents at 1.0% concentration.

TABLE VII.

Human Hair

Detergent: 1.0% Tide

Initial Count	Final Count	Per Cent Removed
21500	3750	82.6
18800	3630	80.7
20200	3450	83.0
17300	3350	80.6
12500	2230	82.1
21100	3730	82.4
Mean		81.9
Standard Deviation		±0.9
Standard Error of Mean		±0.4

TABLE VIII.

Human Hair

Detergent: 1.0% solution of 30% Duponol ME, 65% Calgon, 5% Carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
14100	1640	88.4
17700	1440	92.8
18900	1370	93.5
21900	2630	88.1
26600	3840	85.6
18200	1420	92.2
Mean		90.1
Standard Deviation		± 2.9
Standard Error of Mean		± 1.3

TABLE IX.

Human Hair

Detergent: 1.0% solution of 30% Duponol ME, 65% tetrasodium ethylene diamine tetra-acetate, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
16700	4600	72.5
27400	9600	65.1
14500	2910	80.0
28100	5280	82.3
21900	5620	74.3
24100	8630	64.4
Mean		73.1
Standard Deviation		±6.8
Standard Error of Mean	[redacted]	±3.0

[redacted]

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TABLE X.

Human Hair

Detergent: 1.0% solution of 30% Duponol ME, 32.5% Calgon, 32.5% tetrasodium ethylene diamine tetraacetate, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
19400	2880	85.2
20500	2950	88.2
17500	2560	85.4
15100	2700	82.2
9300	1660	82.1
14700	1960	86.7
Mean		84.9
Standard Deviation		±2.2
Standard Error of Mean		±1.0

TABLE XI.

Human Hair

Detergent: 1.0% solution of 30% Nonic 218, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
18700	4880	74.0
17900	5230	70.8
17700	4190	76.4
31500	7900	75.0
22700	5150	77.5
24100	5420	77.4
Mean		75.2
Standard Deviation		±2.3
Standard Error of Mean		±1.0

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TABLE XII

Human Hair

Detergent: 1.0% solution of 30% Nonic 218, 65% tetra-sodium ethylene diamine tetraacetate, 5% carboxy-methyl cellulose.

Initial Count	Final Count	Per Cent Removed
26800	5990	77.6
15300	4370	68.6
26600	5520	79.2
18600	5570	70.0
17300	4480	74.2
24700	6390	74.3
Mean		73.9
Standard Deviation		±3.8
Standard Error of Mean		±1.7

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TABLE XIII

Human Hair

Detergent: 1.0% solution of 30% Nonic 218, 32.5% Calgon, 32.5% tetrasodium ethylene diamine tetraacetate, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
20300	5780	71.6
16400	5060	69.1
14900	4740	68.4
16400	4900	70.1
17800	5540	68.8
17600	5260	70.1
Mean		69.7
Standard Deviation		±1.1
Standard Error of Mean		±0.5

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The last eight tables show that, while Calgon and tetra-sodium ethylene diamine tetraacetate (Versene) are of about equal worth as sequestrants, a combination of both is definitely inferior.

At this time it should be pointed out that all the data accumulated from these studies, as well as from a related program undertaken for a private firm, show that, in most cases, Calgon, Versene, and sodium tripolyphosphate possess about equal value as sequestrants for mixed fission products. There are a few exceptions, but these are few indeed. In the actual formulation of a decontaminant for practical use, it may be possible to choose among these by considering cost, stability, and other factors. For studies of the type discussed in this report, anyone of the three will do. Because a large quantity of Calgon happened to be on hand, most of the formulations tried from this point on were made using Calgon, except when it was thought that significant differences might be found if Versene were used instead.

Because temperature may affect the efficiency of detergency greatly, runs were made at 10°C., 15°C , and 25°C. Six detergent formulations were used at each of these temperatures.

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TABLE XIV

Human Hair

Detergent: 1% solution of 30% Triton NF, 65% Calgon, 5% carboxymethyl cellulose.

Temperature	Initial Count	Final Count	Per Cent Removed
10°C.	15400	4740	69.2
10°C.	19200	6580	65.8
10°C.	22000	7420	66.2
Mean % Removed at 10°C.			67.1
15°C.	29500	6430	78.2
15°C.	28300	11800	58.4
15°C.	39900	13100	67.0
Mean % Removed at 15°C.			67.9
25°C.	19600	4920	75.0
25°C.	20400	6560	72.7
25°C.	14800	3940	73.2
Mean % Removed at 25°C.			73.6

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TABLE XV

Human Hair

Detergent: 1% solution of 30% Nonic 218, 65% Calgon, 5% carboxymethyl cellulose.

Temperature	Initial Count	Final Count	Per Cent Removed
10°C.	17900	6940	61.2
10°C.	52900	9410	82.2
10°C.	39400	13300	66.2
Mean % Removed at 10°C.			69.9
15°C.	18100	4670	74.2
15°C.	23400	7600	67.6
15°C.	25300	7700	69.6
Mean % Removed at 15°C.			70.5
25°C.	21800	6060	72.2
25°C.	28200	7720	72.6
25°C.	13300	2970	77.6
Mean % Removed at 25°C.			74.1

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TABLE XVI

Human Hair

Detergent: 1% solution of 30% Santomerse D, 65% Calgon, 5% carboxymethyl cellulose.

Temperature	Initial Count	Final Count	Per Cent Removed
10°C.	21100	6170	70.8
10°C.	16300	5040	69.2
10 C.	16800	4790	71.5
Mean % Removed at 10°C.			70.5
15°C.	39000	10700	72.6
15°C.	23800	6820	71.4
15°C.	15300	4520	70.5
Mean % Removed at 15°C.			71.5
25°C.	13000	2930	77.5
25°C.	18200	5730	68.6
25°C.	20600	4050	80.4
Mean % Removed at 25°C.			75.5

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TABLE XVII

Human Hair

Detergent: 1.0% CP Cleaner

Temperature	Initial Count	Final Count	Per Cent Removed
10°C.	23500	4770	79.7
10°C.	16100	2980	81.5
10°C.	24900	6140	75.4
Mean % Removed at 10°C.			78.9
15°C.	40000	10800	73.0
15°C.	21400	3820	82.2
15°C.	38700	6080	84.3
Mean % Removed at 15°C.			79.8
25°C.	20500	4270	79.2
25°C.	17600	2550	85.5
25°C.	13400	1800	86.5
Mean % Removed at 25°C.			83.7

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TABLE XVIII

Human Hair

Detergent: 1.0% All

Temperature	Initial Count	Final Count	Per Cent Removed
10°C.	34900	5740	83.6
10°C.	42500	12600	70.4
10°C.	17300	4610	73.3
Mean % Removed at 10°C.			75.8
15°C.	18700	4790	74.4
15°C.	20200	4620	77.1
15°C.	19300	5470	78.6
Mean % Removed at 15°C.			76.7
25°C.	16000	3660	77.2
25°C.	18500	3330	82.0
25°C.	16100	3190	80.2
Mean % Removed at 25°C.			79.8

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TABLE XIX

Human Hair

Detergent: 1.0% Tide

Temperature	Initial Count	Final Count	Per Cent Removed
10°C.	16200	4440	72.6
10°C.	21700	4300	80.8
10°C.	16500	3650	77.9
Mean % Removed at 10°C.			77.1
15°C.	19400	4710	75.5
15°C.	21700	5200	76.0
15°C.	16900	3170	81.3
Mean % Removed at 15°C.			77.6
25°C.	18200	2970	84.2
25°C.	17300	2940	84.2
25°C.	16000	2870	82.1
Mean % Removed at 25°C.			83.5

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Tables XIV through XIX show an average increase in removal of 0.7% between the temperatures of 10°C., and 15°C., and an increase of 5% between 10°C., and 25°C. Although 5% is not an inconsiderable amount, the temperature of the distilled water in the laboratory does not vary greatly from 15°C. from day to day, so it was decided to continue using it without considering its temperature variations.

For these experiments on hair it was decided to try one of the popular shampoos; Halo was chosen for this purpose. Two concentrations were used, viz., 5% and 10%.

TABLE XX

Human Hair

Detergent: 5% Halo

Initial Count	Final Count	Per Cent Removed
7910	2270	71.3
8170	3150	61.4
9800	3340	65.9
Mean		66.2
Standard Deviation		±4.1
Standard Error of Mean		±2.9

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TABLE XXI

Human Hair

Detergent: 10% Halo

Initial Count	Final Count	Per Cent Removed
9670	3480	64.0
12800	4420	65.4
6400	1410	78.0
15800	5560	65.0
14800	5420	63.5
14700	4260	71.0
Mean		67.8
Standard Deviation		±5.1
Standard Error of Mean		±2.3

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The results were not very promising, but a run was made using the Halo in combination with Calgon.

TABLE XXII

Human Hair

Detergent: 5% solution of 30% Halo, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
16600	2080	84.9
13800	1800	86.9
17500	2240	87.2
Mean		86.3
Standard Deviation		±1.0
Standard Error of Mean		±0.7

These results merely confirmed what has been found repeatedly; viz., that optimum detergency requires the use of a good sequestrant. Since Calgon was being used repeatedly as the sequestrant in these various formulations, it was thought desirable to determine its decontaminating efficiency when used without a detergent.

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TABLE XXIII

Human Hair

Detergent: 3.25% Calgon + 0.25% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
19900	2840	85.7
25300	5210	79.4
16400	3440	79.1
Mean		81.4
Standard Deviation		±3.1
Standard Error of Mean		±2.1

TABLE XXIV

Human Hair

Detergent: 6% Calgon + 0.25% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
25300	4930	80.5
19500	3040	84.4
14300	2790	80.5
Mean		81.5
Standard Deviation		±1.9
Standard Error of Mean		±1.3

Work done on a related problem for a private firm had indicated that Calgon whose pH has been adjusted to 8.4 is a more effective sequestrant than the unadjusted type. Two sets of experiments were then carried out to determine if this held for human hair as well as for other surfaces. Three detergents were used; Triton NF, Nonic 218, and Santomerse D.

TABLE XXV

Human Hair

Detergent: 5% solution of 30% Triton NF, 65% adjusted Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
41100	38800	90.6
38100	5720	85.0
46300	6560	85.8
Mean		87.1
Standard Deviation		±3.3
Standard Error of Mean		±2.4

TABLE XXVI

Human Hair

Detergent: 5% solution of 30% Triton NF, 65% unadjusted Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
19100	2930	84.6
19600	2520	88.1
11400	2800	75.5
Mean		82.7
Standard Deviation		±5.3
Standard Error of Mean		±3.7

TABLE XXVII

Human Hair

Detergent: 5% solution of 30% Nonic 218, 65% adjusted Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
27100	3230	89.1
31200	3030	90.3
14600	2050	86.0
Mean		88.5
Standard Deviation		±1.1
Standard Error of Mean		±0.8

TABLE XXVIII

Human Hair

Detergent: 5% solution of 30% Nonic 218, 65% unadjusted Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
22900	5080	77.8
19400	3050	84.3
17000	2500	85.3
Mean		82.5
Standard Deviation		±3.3
Standard Error of Mean		±2.3

TABLE XXIX

Human Hair

Detergent: 5% solution of Santomerse D, 65% adjusted Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
19100	3430	82.0
16700	2360	85.8
16400	2110	87.1
Mean		85.0
Standard Deviation		±2.2
Standard Error of Mean		±1.6

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TABLE XXX

Human Hair

Detergent: 5% solution of Santomerse D, 65% unadjusted Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
16300	2720	83.3
14500	2370	83.6
14100	2550	81.9
Mean		82.9
Standard Deviation		±0.7
Standard Error of Mean		±0.5

Three runs were also made using Hy-Phos, another brand of glassy sodium hexametaphosphate, similar to Calgon. Whether the sample that was received was in bad condition is not known, but the results were quite disappointing.

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TABLE XXXI

Human Hair

Detergent: 5% solution of 30% Nonic 218, 65% Hy-phos, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
19530	8380	57.1
23340	7840	66.5
19700	7660	61.1
Mean		61.6
Standard Deviation		±3.8
Standard Error of Mean		±2.7

TABLE XXXII

Human Hair

Detergent: 5% solution of 30% Santomerse D, 65% Hy-phos, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
21750	7560	65.2
30000	9200	69.4
19040	7050	63.0
Mean		65.9
Standard Deviation		±2.6
Standard Error of Mean		±1.8

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TABLE XXXIII

Human Hair

Detergent: 5% solution of 30% Ivory, 65% Hy-phos, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
21350	6350	70.3
22720	7430	67.3
25250	6600	73.9
Mean		70.5
Standard Deviation		±2.7
Standard Error of Mean		±1.9

Tests were also run on pHisoderm, a hypoallergenic skin cleanser.

TABLE XXXIV

Human Hair

Detergent: pHisoderm - 5%

Initial Count	Final Count	Per Cent Removed
34150	15400	55.2
29880	10600	64.4
31950	11800	69.0
Mean		62.9
Standard Deviation		±5.9
Standard Error of Mean		±4.1

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TABLE XXXV

Human Hair

Detergent: 5% solution of 30% pHisoderm, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
37500	13600	63.6
31600	9000	71.6
21800	7000	67.9
Mean		67.7
Standard Deviation		±3.3
Standard Error of Mean		±2.3

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Another special skin cleanser, Deconsol, was also used. This consists of 1.51 g. NaCl, 0.90 g. Triton, 1.80 g. Hyamine, and 0.12 ml. concentrated HCl in 177 ml. of water, and is used in some laboratories as a radiological decontaminant. The results were again disappointing, as may be seen from the following table.

TABLE XXXVI

Human Hair

Detergent: 100% Deconsol

Initial Count	Final Count	Per Cent Removed
10100	3190	68.2
14800	4090	72.4
10100	3150	68.6
Mean		69.7
Standard Deviation		±1.7
Standard Error of Mean		±1.2

A long series of formulations were next tried out. The basic formula was the same as in previous cases; viz., 30% active detergent, 65% sequestrant, and 5% carboxymethyl cellulose. The actual weights of detergent used, however, would depend on the "active" content of the commercial product. For example, a detergent which is available at 50% strength would require twice as much weight in order to provide the same detergent activity as one that comes in 100% strength. Every type of detergent was used - anionic, cationic, and amphoteric. Generally, only one detergent was used in each formulation, but a few formulations were tried using two different detergents together.

Several anionic detergents were first used.

TABLE XXXVII

Human Hair

Detergent: 5% solution of 30% Santomerse D, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
11400	1580	86.1
16100	1760	89.1
13600	1180	91.3
Mean		88.8
Standard Deviation		±2.1
Standard Error of Mean		±1.5

TABLE XXXVIII

Human Hair

Detergent: 5% solution of 30% Sulframin LW (6 g./100 ml), 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
16600	3030	81.8
6120	770	87.3
12800	2070	83.8
Mean		84.3
Standard Deviation		±2.3
Standard Error of Mean		±1.6

TABLE XXXIX

Human Hair

Detergent: 5% solution of 30% Sulframin DT, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
14900	3050	79.4
20300	4550	77.6
20400	3530	82.4
20400	4730	76.9
21400	4830	77.5
16900	3250	80.6
Mean		79.1
Standard Deviation		±2.0
Standard Error of Mean		±0.9

TABLE XL

Human Hair

Detergent: 5% solution of 30% Sulframin E, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
13200	2290	82.5
19500	4970	74.5
19700	4030	79.6
18900	3710	80.4
16700	3930	77.6
19700	3780	80.6
Mean		79.2
Standard Deviation		±2.5
Standard Error of Mean		±1.1

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TABLE XLI

Human Hair

Detergent: 5% Acidolate

Initial Count	Final Count	Per Cent Removed
23100	7330	68.3
18100	6080	66.3
23700	521	78.1
Mean		70.9
Standard Deviation		±5.2
Standard Error of Mean		±3.7

TABLE XLII

Human Hair

Detergent: 5% solution of 30% Acidolate, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
16860	2730	83.8
19830	2170	89.1
30920	5550	82.1
Mean		85.0
Standard Deviation		±3.0
Standard Error of Mean		±2.1

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TABLE XLIII

Human Hair

Detergent: 6.5% solution of 46% Acidolate, 50% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
17800	3020	83.0
27600	5640	79.5
23000	3810	83.5
Mean		82.3
Standard Deviation		±1.7
Standard Error of Mean		±1.0

TABLE XLIV

Human Hair

Detergent: 5% solution of 30% CRL #34452, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
24900	3580	85.6
17400	2400	86.2
17100	1870	89.0
Mean		86.9
Standard Deviation		±1.6
Standard Error of Mean		±1.1

TABLE XLV

Human Hair

Detergent: 5% solution of 30% Sorapon SF, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
22700	3570	84.3
18800	1880	90.0
21000	2210	89.5
Mean		87.9
Standard Deviation		±2.6
Standard Error of Mean		±1.8

TABLE XLVI

Human Hair

Detergent: 5% solution of 30% Nacconol NR, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
16600	2050	87.7
22300	2970	86.7
18400	2060	88.8
Mean		87.7
Standard Deviation		±0.9
Standard Error of Mean		±0.6

TABLE XLVII

Human Hair

Detergent: 5% solution of 30% Nacconol NR, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
19900	2230	88.8
21300	2290	89.3
15700	1550	90.1
Mean		89.4
Standard Deviation		±0.5
Standard Error of Mean		±0.4

TABLE XLVIII

Human Hair

Detergent: 5% Alconox

Initial Count	Final Count	Per Cent Removed
25800	5780	77.6
15400	2800	81.8
21100	3300	84.3
Mean		81.2
Standard Deviation		±2.8
Standard Error of Mean		±1.9

Nopcogen 14-L, an excellent nonionic dispersant, although not a very good detergent, was then used in combination with Santomerse D, Ivory, and Nonic 218, but with quite indifferent results.

TABLE XLIX

Human Hair

Detergent: 6.5% solution of 23% Nopcogen 14-L, 23% Santomerse D, 50% Calgon, 4% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
7490	1720	77.0
10500	2050	80.8
6280	1380	78.0
Mean		78.6
Standard Deviation		±1.6
Standard Error of Mean		±1.1

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TABLE L

Human Hair

Detergent: 6.5% solution of 23% Nopcogen 14-L, 23% Ivory, 50% Calgon, 4% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
10600	1840	82.7
8800	1400	81.9
14200	2760	80.5
Mean		81.7
Standard Deviation		±0.9
Standard Error of Mean		±0.7

TABLE LI

Human Hair

Detergent: 6.5% solution of 23% Nopcogen 14-L, 23% Nonic 218, 50% Calgon, 4% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
10300	2090	79.7
7100	1530	79.4
9080	1370	84.9
Mean		81.3
Standard Deviation		±2.5
Standard Error of Mean		±1.8

Similar results were obtained using Lipal 450 instead of Nopcogen 14-L.

TABLE LII

Human Hair

Detergent: 6.5% solution of 23% Lipal 450, 23% Ivory, 50% Calgon, 4% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
16100	4190	74.0
14400	2580	82.0
16400	4690	71.5
Mean		75.8
Standard Deviation		±4.5
Standard Error of Mean		±3.2

TABLE LIII

Human Hair

Detergent: 6.5% solution of 23% Lipal 450, 23% Santomerse D, 50% Calgon, 4% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
21100	4450	78.9
20400	4510	77.8
17000	3410	80.0
Mean		78.9
Standard Deviation		±0.9
Standard Error of Mean		±0.6

No better results were obtained by using the Lipal 450 with the nonionic Nonic 218.

TABLE LIV

Human Hair

Detergent: 6.5% solution of 23% Lipal 450, 23% Nonic 218, 50% Calgon, 4% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
19700	4770	75.8
18800	5000	74.5
19600	4980	74.7
Mean		75.0
Standard Deviation		±0.6
Standard Error of Mean		±0.4

Lipal 450 itself with Calgon and carboxymethyl cellulose was an indifferent detergent.

TABLE LV

Human Hair

Detergent: 5% solution of 30% Lipal 450, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
20400	4400	78.4
13200	2460	81.3
20100	3640	81.9
Mean		80.5
Standard Deviation		±1.5
Standard Error of Mean		±1.1

Quite different results were obtained with Dispersant NIW, another nonionic product. Alone, the following results were obtained.

TABLE LVI

Human Hair

Detergent: 5% solution of 30% Dispersant NIW, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
13300	1310	90.2
7610	900	88.2
8140	943	88.4
9100	841	90.7
7990	622	92.2
8600	1030	89.3
Mean		89.8
Standard Deviation		±1.4
Standard Error of Mean		±0.6

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Combined with Santomerse D, it gave quite impressive results.

TABLE LVII

Human Hair

Detergent: 6.5% solution of 23% Dispersant NIW, 23% Santomerse D, 50% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
7150	224	96.9
10600	474	95.5
12200	426	96.5
Mean		96.3
Standard Deviation		$^{+}_{-}0.6$
Standard Error of Mean		$^{+}_{-}0.4$

Dispersant NIW was later used in combination with many detergents, and quite often it improved their performance notably.

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One cationic detergent, Ethomeen C/15, gave the following results:

TABLE LVIII

Human Hair

Detergent: 5% solution of Ethomeen C/15, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
16700	2690	83.9
13900	2540	81.7
15300	3030	80.2
Mean		81.9
Standard Deviation		±1.5
Standard Error of Mean		±1.1

A few nonionic detergents were then tried, alone and in combination with other detergents.

TABLE LIX

Human Hair

Detergent: 5% solution of 30% Permalene A-100, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
17400	2690	84.5
15900	3920	75.4
16800	2620	84.4
Mean		81.4
Standard Deviation		±4.4
Standard Error of Mean		±3.1

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TABLE LX

Human Hair

Detergent: 5% solution of 30% Repcol A-100, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
16500	3480	79.0
15000	2820	81.2
18700	3970	78.8
Mean		79.7
Standard Deviation		±1.1
Standard Error of Mean		±0.8

TABLE LXI

Human Hair

Detergent: 5% solution of 30% Advawet NA-6, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
18410	2370	87.1
22280	2850	87.2
13690	1850	86.5
Mean		86.9
Standard Deviation		±0.3
Standard Error of Mean		±0.2

TABLE LXII

Human Hair

Detergent: 5% solution of 30% RN-600, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
16000	1890	88.2
22600	2930	87.0
17600	2200	87.5
Mean		87.6
Standard Deviation		±0.5
Standard Error of Mean		±0.3

TABLE LXIII

Human Hair

Detergent: 5% solution of 30% Detergent 77 (7.5 g./100 ml.), 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
18900	3310	82.5
26900	3950	85.3
30800	4540	85.3
Mean		84.4
Standard Deviation		±1.3
Standard Error of Mean		±0.9

TABLE LXIV

Human Hair

Detergent: 5% solution of 30% Detergent 80 (7.5 g./100 ml.), 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
12800	1750	86.3
25700	3580	86.1
26300	3750	85.8
Mean		86.1
Standard Deviation		±0.2
Standard Error of Mean		±0.1

TABLE LXV

Human Hair

Detergent: 5% of Detergent T-12

Initial Count	Final Count	Per Cent Removed
10800	1630	85.9
16900	2720	83.9
14400	1750	87.8
Mean		85.9
Standard Deviation		±1.6
Standard Error of Mean		±1.1

TABLE LXVI

Human Hair

Detergent: 5% Detergent T-12 + 0.25% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
15600	1700	89.1
10200	1490	85.4
14600	1740	88.1
Mean		87.5
Standard Deviation		±1.6
Standard Error of Mean		±1.1

TABLE LXVII

Human Hair

Detergent: 4% Detergent T-12, 1% Calgon, 0.25% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
11100	1380	87.6
21000	2880	86.3
15800	1940	87.7
Mean		87.2
Standard Deviation		±0.6
Standard Error of Mean		±0.5

TABLE LXVIII

Human Hair

Detergent: 5% solution of 30% Sterox SK, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
17000	2450	85.6
11300	1880	83.3
11000	1580	85.6
17700	2580	85.4
16600	2110	87.3
Mean		85.4
Standard Deviation		±1.3
Standard Error of Mean		±0.6

As in the case of the anionic detergents, the addition of Dispersant NIW improved the efficiency of Sterox SK, as may be seen by comparing Table LXVIII above with Table LXIX below.

TABLE LXIX

Human Hair

Detergent: 5% solution of 23% Dispersant NIW, 23% Sterox SK, 50% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
7700	429	94.4
7700	335	95.6
8890	626	93.0
Mean		94.3
Standard Deviation		±1.1
Standard Error of Mean		±0.8

Tween 21, another nonionic detergent, was tried also in combination with Sterox SK, but the results were no better than Sterox SK alone.

TABLE LXX

Human Hair

Detergent: 5% solution of 23% Tween 21, 23% Sterox SK, 50% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
29200	3810	86.9
18100	2040	88.7
26800	3430	87.2
Mean		87.6
Standard Deviation		±1.0
Standard Error of Mean		±0.8

Triton NF gave the following results:

TABLE LXXI

Human Hair

Detergent: 5% solution of 30% Triton NF, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
23200	2590	88.8
15600	2150	86.2
27200	3960	85.5
Mean		86.8
Standard Deviation		±1.4
Standard Error of Mean		±1.0

Nonic 218, which had been tried before, was used again.

TABLE LXXII

Human Hair

Detergent: 5% solution of 30% Nonic 218, 65% Calgon, 5% carboxymethyl cellulose.

Initial Count	Final Count	Per Cent Removed
12300	1010	91.6
4600	690	85.0
13700	2150	84.3
12000	1200	90.0
9110	780	91.4
13800	2220	83.9
13900	1730	87.6
16700	1130	93.2
13100	1780	86.4
18400	1300	92.9
15200	1710	88.8
Mean		88.7
Standard Deviation		±3.1
Standard Error of Mean		±1.0

These results are entirely at variance with those obtained earlier. It appeared that once more the program was plagued with the curse of most detergency studies: occasional inconsistent results. In order to minimize or at least recognize these, it was decided to run five different formulations simultaneously with 5% Tide from this point on. In this fashion Tide would serve as a standard against which all other formulations would be tested every time. At the same time, this would provide a very large number of runs over a long period of time, all using the same detergent and the data thus obtained would doubtlessly provide fairly reliable figures on the reproducibility of the procedure.

All of the results obtained using 5% Tide on human hair are now given in Table LXXIII.

TABLE LXXIII

Human Hair

Detergent: 5% Tide

Initial Count	Final Count	Per Cent Removed
23500	3 010	87.2
20300	2 400	88.2
25100	2420	88.1
19100	2 900	84.8
23400	3 760	83.9
22400	2 650	88.2
33200	6 950	78.5
30500	3 100	89.9
25200	6 010	76.3
12800	1 520	88.1
22900	2 530	89.0
17600	850	95.3
19600	3 600	81.6
15900	2 060	86.1
16700	1 590	90.4
14100	663	95.3

Table LXXIII (cont)

Initial Count	Final Count	Per Cent Removed
17400	2590	85.1
11000	2220	79.8
15000	1840	87.7
6080	413	93.2
19200	4180	78.3
11000	1860	83.1
14800	2070	86.0
9810	700	92.9
20100	3110	84.5
20200	560	97.2
26900	790	97.1
22000	600	97.3
21100	1800	91.6
20100	1500	92.5
13500	1000	92.6
16300	1600	90.2
14500	1410	90.3
14900	1590	89.3

Table LXXIII (cont)

Initial Count	Final Count	Per Cent Removed
14800	2230	84.9
18300	2860	84.4
22400	3060	85.9
11100	1970	82.2
21100	4720	77.6
10000	1560	84.6
24000	1280	94.7
19500	1120	95.2
23600	1270	94.4
21100	2000	90.5
16900	1690	90.0
20200	1670	91.7
19500	2160	88.9
18300	1910	89.6
18900	2600	86.3
18100	3140	82.7
17400	3370	80.6
22300	3820	82.9

Table LXXIII (cont)

Initial Count	Final Count	Per Cent Removed
9280	995	89.7
18500	1640	91.1
19800	1610	91.5
22700	1370	94.0
24100	1870	92.3
20900	1370	93.4
17578	1045	94.2
17139	1121	93.7
23616	1404	94.1
18200	1030	94.3
9670	880	90.9
18200	920	94.9
23000	1530	93.3
20600	1500	92.2
23700	1680	92.9
Mean		88.9
Range		76.3 - 97.3
Standard Deviation		±5.1
Standard Error of Mean		± 0.6

From this point on, then every formulation was compared directly with 5% Tide. The differences between the per cent removed by each formulation and its Tide run are given in the fourth column under the heading "difference with Tide". A + or - indicates that the formulation was more effective or less effective than Tide.

A few more anionic detergents were tested in this fashion.

TABLE LXXIV

Human Hair

Detergent: 5% solution of 30% Santomerse D, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
22900	3010	86.9	- 3.3
19300	2230	88.5	- 1.8
17800	2180	87.8	- 1.5
11200	1910	82.9	- 2.0
15400	2870	81.4	- 3.0
16700	2930	82.5	- 3.4
9850	1650	83.2	- 1.0
18200	3330	81.7	+ 4.1
12600	1700	86.5	+ 2.1
Mean		84.6	- 1.1
Standard Deviation		±2.6	
Standard Error of Mean		±0.9	

TABLE LXXV

Human Hair

Detergent: 5% solution of 30% Maypon SK (3.7 g. /100 ml), 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
23100	3230	86.0	- 2.9
19100	1780	90.7	+ 1.1
20700	2300	88.9	+ 2.6
Mean		88.5	+ 0.4
Standard Deviation		±1.9	
Standard Error of Mean		±1.4	

TABLE LXXVI

Human Hair

Detergent: 5% solution of 30% Maypon 4C (4.5 g. /100 ml), 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
17000	2920	82.8	- 6.1
26100	3110	88.1	- 1.5
19200	2560	86.7	+ 0.4
Mean		85.9	- 2.4
Standard Deviation		±2.2	
Standard Error of Mean		±1.6	

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TABLE LXXVII

Human Hair

Detergent: 5% G-808

Initial Count	Final Count	Per Cent Removed	Difference with Tide
13600	2350	82.7	0
15100	2740	81.9	+ 1.3
17300	2520	85.4	+ 2.5
Mean		83.3	+ 1.3
Standard Deviation		±1.5	+ 1.7
Standard Error of Mean		±1.1	

TABLE LXXVII

Human Hair

Detergent: 5% G-809

Initial Count	Final Count	Per Cent Removed	Difference with Tide
22000	1570	92.9	- 1.8
18900	1530	91.9	- 3.3
12500	564	95.5	+ 1.1
Mean		93.4	- 1.3
Standard Deviation		±1.5	
Standard Error of Mean		±1.1	

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TABLE LXXIX

Human Hair

Detergent: 5% CP Cleaner

Initial Count	Final Count	Per Cent Removed	Difference with Tide
10700	1440	86.5	+ 1.6
15600	2060	86.8	+ 2.4
20700	2890	86.0	+ 0.1
13800	2050	85.2	+ 3.0
15300	1800	88.3	+ 10.7
12400	837	93.3	+ 8.9
16500	1130	93.1	+ 1.9
17700	1580	91.1	+ 0.8
21700	1600	92.6	+ 3.3
Mean		88.1	+ 3.6
Standard Deviation		±2.3	
Standard Error of Mean		±1.2	

Several detergents were then tried in combination with several powerful wetting and dispersing agents.

TABLE LXXX

Human Hair

Detergent: 6.5% solution of 23% Santomerse D, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
14200	830	93.8	- 0.9
19600	1160	94.1	- 1.1
12400	790	93.6	- 0.8
Mean		93.8	- 0.9
Standard Deviation		±0.2	
Standard Error of Mean		±0.1	

TABLE LXXXI

Human Hair

Detergent: 6.5% solution of 23% Duponol ME, 23% Alkanol WXN, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
25300	1680	93.4	+ 2.7
21300	1480	93.1	+ 2.0
20600	1200	94.1	+ 2.7
Mean		93.5	+ 2.5
Standard Deviation		±0.4	
Standard Error of Mean		±0.3	

TABLE LXXXII

Human Hair

Detergent: 6.5% solution of 23% Nacconol NR, (3.75 g./100 ml) 23% Alkanol WXN, 50% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
17400	1300	92.5	+ 0.9
14900	1300	91.3	- 1.2
15500	1900	87.7	- 4.9
Mean		90.5	- 1.7
Standard Deviation		±2.0	
Standard Error of Mean		±1.4	

TABLE LXXXIII

Human Hair

Detergent: 6.5% solution of 23% Ultrawet 30-DS, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
15600	1150	92.6	+ 1.0
20300	1600	92.1	- 0.4
11000	860	92.2	+ 0.4
Mean		92.3	+ 0.3
Standard Deviation		±0.2	
Standard Error of Mean		±0.1	

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TABLE LXXXIV

Human Hair

Detergent: 6.5% solution of 23% Sorapon SF, 23% Alkanol WXN, 50% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
23600	1730	92.7	+ 1.1
18900	1380	92.7	+ 0.2
15500	1190	92.3	- 0.3
Mean		92.6	+ 0.3
Standard Deviation		±0.2	
Standard Error of Mean		±0.1	

TABLE LXXXV

Human Hair

Detergent: 6.5% solution of 23% Santomerse D, 23% Dispersant NIW, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
19900	1650	91.7	+ 2.0
20700	1320	95.6	+ 4.5
18500	1640	91.1	+ 0.4
19200	1970	89.8	- 0.7
21800	1970	91.0	+ 1.0
23700	2180	92.0	+ 0.3
Mean		91.9	+ 1.2
Standard Deviation		±1.8	
Standard Error of Mean		±0.8	

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TABLE LXXXVI

Human Hair

Detergent: 6.5% solution of 23% Oronite D-60, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
14800	925	94.8	+ 4.3
21100	1675	92.1	+ 2.1
14200	835	94.1	+ 2.4
Mean		93.7	+ 2.9
Standard Deviation		±1.1	
Standard Error of Mean		±0.8	

TABLE LXXXVII

Human Hair

Detergent: 6.5% solution of 23% Oronite D-60, 23% Dispersant NIW, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
22500	1675	92.5	+ 2.0
20100	1330	93.4	+ 3.4
17700	940	94.7	+ 3.0
Mean		93.5	+ 2.8
Standard Deviation		±0.9	
Standard Error of Mean		±0.6	

TABLE LXXXVIII

Human Hair

Detergent: 6.5% solution of 23% Oronite D-60, 23% Dispersant NIW, 50% Calgonite, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
13900	1250	91.0	+ 0.5
26200	3100	88.2	- 1.8
25400	2960	88.4	- 2.7
Mean		89.2	- 1.3
Standard Deviation		±1.3	
Standard Error of Mean		±0.9	

TABLE LXXXIX

Human Hair

Detergent: 6.5% solution of 23% Santomerse D, 23% Ahcowet RS, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
15800	3360	78.7	- 5.0
17100	2850	83.3	+ 3.3
16200	2850	82.4	- 0.5
Mean		81.5	- 0.7
Standard Deviation		±2.0	
Standard Error of Mean		±1.4	

TABLE XC

Human Hair

Detergent: 6.5% solution of 23% Sulframin LW (8.0g./100 ml), 23% Alkanol WXN, 5 0% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
23100	1710	93.6	- 0.6
15300	1100	92.8	- 0.9
14900	1010	93.2	- 0.9
Mean		93.2	- 0.8
Standard Deviation		±0.3	
Standard Error of Mean		±0.2	

TABLE XCI

Human Hair

Detergent: 6.5% solution of 23% Maypon SK (3.5 g./100 ml), 2 3% Alkanol WXN, 50% Calgon, 4% carboxymethyl c ellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
15900	1010	93.6	- 0.6
13500	942	93.1	- 0.6
18100	1200	93.3	- 0.7
Mean		93.3	- 0.6
Standard Deviation		±0.4	
Standard Error of Mean		±0.3	

The detergents in Tables LXXX through XCI above were all anionic. Several nonionics were now tested, alone and in combination with wetting and dispersing agents like Alkanol WXN, Janusol, etc.

Table XCII

Human Hair

Detergent: 5% All

Initial Count	Final Count	Per Cent Removed	Difference with Tide
24800	5110	79.4	- 5.5
23900	5810	75.7	- 8.7
24100	5390	77.7	- 8.2
9640	1370	85.9	+ 3.7
11700	2040	82.6	+ 5.0
19500	3570	81.7	- 2.7
14000	1200	91.4	+ 1.2
14500	1280	91.1	+ 0.8
24800	2320	90.2	+ 0.9
Mean		84.0	- 1.5
Standard Deviation		±5.6	
Standard Error of Mean		±2.0	

TABLE XCIII

Human Hair

Detergent: 6% Glim

Initial Count	Final Count	Per Cent Removed	Difference with Tide
23300	3180	86.3	- 3.4
23400	3620	84.5	- 6.6
21100	3580	84.1	- 7.4
Mean		85.0	- 5.8
Standard Deviation		±1.0	
Standard Error of Mean		±0.7	

TABLE XCIV

Human Hair

Detergent: 5% solution of 30% Nonic 218, 65% Calgon
5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
18900	2990	84.2	+ 4.8
19100	3530	81.5	+ 5.8
19200	3090	83.9	+ 6.2
15100	2500	83.5	+ 1.3
8520	1140	86.6	+ 9.0
16300	2560	84.6	+ 0.2
21300	2450	88.3	- 0.9
23700	2340	90.1	- 0.2
13000	1420	89.1	- 0.2
Mean		85.8	+ 2.9
Standard Deviation		±2.7	
Standard Error of Mean		±1.0	

TABLE XCV

Human Hair

Detergent: 6.5% solution of 23% Nonic 218, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
19100	1200	93.7	- 0.5
16400	1150	93.0	- 0.7
14000	825	94.1	0
Mean		93.6	- 0.4
Standard Deviation		±0.5	
Standard Error of Mean		±0.3	

TABLE XCVI

Human Hair

Detergent: 6.5% solution of 23% Nonic 218, 23% Dispersant NIW, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
18000	3350	81.4	- 1.3
12600	2970	76.5	- 4.1
19700	4250	78.4	- 4.5
Mean		78.8	- 3.3
Standard Deviation		±0.2	
Standard Error of Mean		±0.1	

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TABLE XCVII

Human Hair

Detergent: 6.5% solution of 23% Nonic 218, 23% Janusol, 65% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
19900	1750	91.2	- 2.1
24100	2050	91.5	- 0.8
24700	2270	90.8	- 2.1
Mean		91.2	- 1.7
Standard Deviation		±0.3	
Standard Error of Mean		±0.2	

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TABLE XCVIII

Human Hair

Detergent: 5% solution of 30% Triton NF, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
16400	2510	84.7	- 0.2
14300	3070	78.5	- 8.9
14700	2740	81.4	- 4.5
11500	1790	84.5	+ 2.3
9580	1450	84.8	+ 7.2
19600	3520	82.0	- 2.4
19700	2790	85.8	- 4.4
21400	2590	87.9	- 2.4
20000	2530	87.4	- 1.9
16400	950	94.2	- 0.5
20000	1160	94.2	- 1.0
21200	1580	92.6	- 1.8
Mean		86.5	- 1.5
Standard Deviation		±4.8	
Standard Error of Mean		±1.4	

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TABLE XCIX

Human Hair

Detergent: 6.5% solution of 23% Triton NF, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
19700	1150	94.2	+ 4.5
15300	870	94.3	+ 3.2
21800	1470	93.3	+ 1.8
Mean		93.9	+ 3.2
Standard Deviation		±0.4	
Standard Error of Mean		±0.3	

TABLE C

Human Hair

Detergent: 6.5% solution of 23% Triton NF, 23% Janusol, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
16400	970	94.1	+ 4.4
24700	1146	95.4	+ 4.3
15800	900	94.3	+ 2.8
Mean		94.6	+ 3.8
Standard Deviation		±0.6	
Standard Error of Mean		±0.4	

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TABLE CI

Human Hair

Detergent: 6.5% solution of 23% Triton NF, 23% Neoprene R, 5 0% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
27600	1390	95.0	+ 0.3
18400	1060	94.2	- 0.9
Mean		94.6	- 0.3

TABLE CII

Human Hair

Detergent: 5% solution of 30% Dergon MF, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
19100	2860	85.0	- 3.9
18700	2800	85.0	- 4.6
24000	3790	84.2	- 2.1
Mean		84.7	- 3.5
Standard Deviation		±0.4	
Standard Error of Mean		±0.3	

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TABLE CIII

Human Hair

Detergent: 5% solution of 30% Ethofat, 65% Calgon, 5 % carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
17900	2370	86.8	- 2.1
24700	2970	88.0	- 1.6
16100	2050	87.3	+ 1.0
Mean		87.3	- 0.9
Standard Deviation		±0.5	
Standard Error of Mean		±0.3	

TABLE CIV

Human Hair

Detergent: 5% solution of 30% Renex, 65% Calgon 5 % carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
25200	4230	83.2	- 5.7
16100	2040	87.2	- 2.4
20100	2870	85.3	- 1.0
Mean		85.2	- 3.0
Standard Deviation		±1.6	
Standard Error of Mean		±1.2	

TABLE CV

Human Hair

Detergent: 5% solution of 30% Onyxol 336, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
17300	880	94.9	+ 0.6
14100	1080	92.3	+ 1.4
16000	1000	93.8	- 1.1
Mean		93.7	+ 0.3
Standard Deviation		±1.1	
Standard Error of Mean		±0.8	

TABLE CVI

Human Hair

Detergent: 5% solution of 30% Energetic, 65% Calgon 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
16300	1370	91.6	+ 0.7
24900	1620	93.5	- 0.8
19600	1300	93.4	- 1.5
Mean		92.8	- 0.7
Standard Deviation		±0.9	
Standard Error of Mean		±0.6	

TABLE CVII

Human Hair

Detergent: 5% solution of 30% Detergent 80 (7.5 g./100 ml), 65% tetrasodium ethylene diamine tetraacetate, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
15900	400	97.5	+ 2.5
17800	1200	93.8	- 1.4
23300	1140	95.1	+ 0.7
Mean		95.5	+ 0.6
Standard Deviation		±1.5	
Standard Error of Mean		±1.1	

TABLE CVIII

Human Hair

Detergent: 5% solution of 30% Dianol G, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
28100	2390	91.5	- 2.5
19900	1510	92.4	+ 0.1
23600	1590	93.2	- 0.2
Mean		92.4	- 0.9
Standard Deviation		±0.7	
Standard Error of Mean		±0.5	

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TABLE CIX

Human Hair

Detergent: 5% solution of 30% Ethomid HT-15, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
18000	1370	92.4	- 1.6
21700	1440	93.4	+ 1.1
18600	1220	93.4	0
Mean		93.1	- 0.2
Standard Deviation		±0.5	
Standard Error of Mean		±0.3	

TABLE CX

Human Hair

Detergent: 5% solution of 30% Ethomid HT-25, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
26000	2120	91.8	- 2.2
22200	1470	93.4	+ 1.1
13900	857	93.8	+ 0.4
Mean		93.0	- 0.2
Standard Deviation		±0.9	
Standard Error of Mean		±0.6	

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TABLE CXI

Human Hair

Detergent: 5% solution of 30% Ethomid HT-60, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
24000	2370	90.1	- 3.9
27500	2110	92.2	- 0.1
Mean		91.1	- 2.0

TABLE CXII

Human Hair

Detergent: 6.5% solution of 23% Ethomid HT-15, 23% Dispersant NIW, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
14800	800	94.5	+ 4.0
17300	725	95.8	+ 5.8
21700	1080	95.0	+ 3.3
Mean		95.1	+ 4.4
Standard Deviation		±0.5	
Standard Error of Mean		±0.4	

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TABLE CXIII

Human Hair

Detergent: 6.5% solution of 23% Sterox SK, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
22000	440	98.0	+ 0.8
22200	390	98.2	+ 1.1
24300	640	97.4	+ 0.4
Mean		97.8	+ 0.7
Standard Deviation		±0.3	
Standard Error of Mean		±0.2	

TABLE CXIV

Human Hair

Detergent: 6.5% solution of 23% Sterox SK, 23% Alaknol WXN, 50% sodium tripolyphosphate, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
24500	680	97.2	0
19500	480	97.5	+ 0.4
15100	620	95.9	- 1.4
Mean		96.9	- 0.3
Standard Deviation		±0.7	
Standard Error of Mean		±0.5	

TABLE CXV

Human Hair

Detergent: 6.5% solution of 23% Sterox SK, 23% Dispersant NIW, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
22000	1760	92.0	- 0.7
15500	1225	92.1	+ 1.5
22300	1580	92.9	0
Mean		92.3	+ 0.3
Standard Deviation		±0.4	
Standard Error of Mean		±0.3	

TABLE CXVI

Human Hair

Detergent: 6.5% solution of 23% Sterox AJ, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Percent Removed	Difference with Tide
18800	1045	94.4	+ 0.2
16000	880	94.2	+ 0.5
15900	1225	92.4	- 1.7
Mean		93.7	- 0.3
Standard Deviation		±0.9	
Standard Error of Mean		±0.6	

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TABLE CXVII

Human Hair

Detergent: 6.5% solution of 23% Alrosol C, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
16700	1170	93.0	+ 1.4
13500	1180	91.3	- 1.2
18600	1310	93.0	+ 0.4
Mean		92.4	+ 0.2
Standard Deviation		±0.8	
Standard Error of Mean		±0.6	

TABLE CXVIII

Human Hair

Detergent: 6.5% solution of 23% Antarox A-400, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
20200	1840	90.1	- 1.5
17600	1400	92.1	- 0.4
21500	1770	91.8	- 0.8
Mean		91.3	- 0.9
Standard Deviation		±0.9	
Standard Error of Mean		±0.6	

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TABLE CXIX

Human Hair

Detergent: 6.5% solution of 23% Antarox A-400, 23% Dispersant NIW, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
15200	2430	84.0	+ 1.3
14600	2760	81.9	+ 1.3
17800	3420	80.8	- 2.1
Mean		82.2	+ 0.2
Standard Deviation		±1.3	
Standard Error of Mean		±0.9	

TABLE CXX

Human Hair

Detergent: 6.5% solution of 23% Advawet NA-6, 23% Dergon MF, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
20200	1580	92.2	- 1.8
16700	1750	89.5	- 2.8
24400	2920	88.0	- 5.4
Mean		89.9	- 3.0
Standard Deviation		±1.7	
Standard Error of Mean		±1.2	

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Katapol VP-532 and Alro Amines O, C and S are among the most efficient detergents in the cationic group. Accordingly, they were selected to represent this class of detergents.

TABLE CXXI

Human Hair

Detergent: 5% solution of 30% Katapol VP-532, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
24700	1200	95.1	+ 0.8
17300	1080	93.8	+ 2.9
18000	1240	93.1	- 1.8
Mean		94.0	+ 0.6
Standard Deviation		±0.8	
Standard Error of Mean		±0.6	

TABLE CXXII

Human Hair

Detergent: 6.5% solution of 23% Katapol VP-532, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
18100	1310	92.7	- 1.5
16900	1230	92.7	- 1.0
18700	1300	93.1	- 0.1
Mean		92.8	- 1.2
Standard Deviation		±0.2	
Standard Error of Mean		±0.1	

TABLE CXXIII

Human Hair

Detergent: 5% solution of 30% Alro Amine C, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
23800	2630	88.9	- 4.4
23700	8 080	66.0	-26.3
19600	3820	80.5	-12.4
Mean		78.5	-11.0
Standard Deviation		±9.5	
Standard Error of Mean		±6.7	

TABLE CXXIV

Human Hair

Detergent: 5% solution of 30% Alro Amine O, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
16300	1630	90.0	- 3.3
14700	920	93.7	+ 1.4
22700	2340	89.7	- 3.2
Mean		91.1	- 1.7
Standard Deviation		±1.8	
Standard Error of Mean		±1.3	

TABLE CXXV

Human Hair

Detergent: 5% solution of 30% Alro Amine S, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
18400	1640	91.1	- 2.2
25200	2420	90.4	- 1.9
20100	2260	88.8	- 4.1
Mean		90.1	- 2.7
Standard Deviation		±1.0	
Standard Error of Mean		±0.7	

Several of the Miranols were chosen as representative of the amphoteric group.

TABLE CXXVI

Human Hair

Detergent: 5% solution of 30% Miranol CM, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
17700	720	95.9	+ 1.6
16500	600	96.4	+ 5.5
16300	820	95.0	+ 0.1
Mean		95.8	+ 2.4
Standard Deviation		±0.6	
Standard Error of Mean		±0.4	

TABLE CXXVII

Human Hair

Detergent: 5% solution of 30% Miranol SM, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
13800	760	94.5	+ 0.2
10800	690	93.6	+ 2.7
14600	600	95.9	+ 1.0
Mean		94.7	+ 1.3
Standard Deviation		±0.9	
Standard Error of Mean		±0.7	

TABLE CXXVIII

Human Hair

Detergent: 5% solution of 30% Miranol DM, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
24300	620	97.4	+ 0.2
23100	590	97.4	+ 0.3
25100	650	97.4	+ 0.1
Mean		97.4	+ 0.2
Standard Deviation		0.0	
Standard Error of Mean		0.0	

TABLE CXXIX

Human Hair

Detergent: 5% solution of 30% Miranol MM, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
26100	720	97.2	0
25400	520	98.0	+ 0.5
28300	720	97.4	+ 1.5
Mean		97.5	+ 0.7
Standard Deviation		±0.4	
Standard Error of Mean		±0.2	

TABLE CXXX

Human Hair

Detergent: 5% solution of 30% Miranol HM, 65% Calgon, 5% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed	Difference with Tide
25200	550	97.8	+ 0.6
28600	680	97.6	+ 0.1
27500	810	97.1	+ 1.2
Mean		97.5	+ 0.6
Standard Deviation		±0.3	
Standard Error of Mean		±0.2	

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A heavy duty hand cleaner, Pax-Lano-Sav, was also tried under the same conditions.

TABLE CXXXI

Human Hair

Detergent: 5% Pax-Lano-Sav

Initial Count	Final Count	Per Cent Removed	Difference with Tide
28500	2880	89.9	- 3.4
17100	2260	86.8	- 5.5
22300	2100	90.4	- 2.5
Mean		89.0	- 3.8
Standard Deviation		±1.6	
Standard Error of Mean		±1.1	

For convenience, the results given in Table VI and Tables XX through CXXXI are summarized in Table CXXXII below. In order to simplify this table and avoid excessive repetition, the first column usually lists only the detergent component of each formulation. As a rule, the formulations also include adjusted Calgon and carboxymethyl cellulose, unless a different sequestrant is mentioned. Reference should be made to the original tables which are given in the third column, for the exact composition and concentration of the various formulations. Figures are given under the "Difference with Tide" column only when runs were made with Tide and with the formulation simultaneously.

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TABLE CXXXII

Summary of Work on Human Hair

Detergent	Type	Table No.	No. of Runs	Per Cent Removed	Standard Error of Mean (±)	Difference with Tide
Water	---	VI	3	25.9	5.0	---
5% Tide	anionic	LXXIII	67	87.6	0.6	---
5% Pax-Lano-Sav	soap	CXXXI	3	89.0	1.1	-3.8
6% Glim	nonionic	XCIII	3	85.0	0.7	-5.8
5% Halo	anionic	XX	3	66.2	2.9	---
10% Halo	anionic	XXI	6	67.8	2.3	---
Halo, Calgon	anionic	XXII	3	86.3	0.7	---
5% All	nonionic	XCII	9	84.0	2.0	-1.5
5% CP Cleaner	unknown	LXXIX	3	88.1	1.2	+3.6
5% pHisoderm	anionic	XXXIV	3	62.9	4.1	---
pHisoderm, Calgon	anionic	XXXV	3	67.7	2.3	---
Deconsol	nonionic	XXXVI	3	69.7	1.2	---
5% G-808	anionic	LXXVII	3	83.3	1.1	+1.7
5% G-809	anionic	LXXVIII	3	93.4	1.1	-1.3
3.25% Calgon + 0.25% CMC	---	XXIII	3	81.4	2.1	---
6% Calgon + 0.25% CMC	---	XXIV	3	81.5	1.3	---
Ivory + Hy-Phos	soap	XXXII	3	70.5	1.9	---
Ivory, Nopcogen 14-L	soap nonionic	L	3	81.7	0.7	---

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Table CXXXII (cont)

Detergent	Type	Table No.	No. of Runs	Per Cent Removed	Standard Error of Mean (±)	Difference with Tide
Ivory, Lipal 450	soap, nonionic	LII	3	75.8	3.2	---
Santomerse D	anionic	XXIX, XXXVII	6	86.9	1.4	---
Santomerse D	anionic	LXXIV	9	84.6	0.9	-1.1
Santomerse D + unadjusted Calgon	anionic	XXX	3	82.9	0.5	---
Santomerse D + Hy-Phos	anionic	XXXII	3	65.9	1.8	---
Santomerse D, Lipal 450	anionic, nonionic	LIII	3	78.9	0.6	---
Santomerse D, Nopcogen 14-L	anionic, nonionic	XLIX	3	78.6	1.1	---
Santomerse D, Ahcowet RS	anionic anionic	LXXXIX	3	81.5	1.4	-0.7
Santomerse D, Alkanol WXN	anionic, anionic	LXXX	3	93.8	0.1	-0.9
Santomerse D, Dispersant NIW	anionic, nonionic	LXXXV	6	91.9	0.8	+1.2
Sulframin LW	anionic	XXXVIII	3	84.3	1.6	---
Sulframin LW, Alkanol WXN	anionic anionic	XC	3	93.2	0.2	-0.8
Sulframin DT	anionic	XXXIX	6	79.1	0.9	---
Sulframin E	anionic	XL	6	80.6	1.1	---
5% Acidolate	anionic	XLI	3	70.9	3.7	---

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Table CXXXII (cont)

Detergent	Type	Table No.	No. of Runs	Per Cent Removed	Standard Error of Mean (±)	Differenc with Tide
Acidolate, Calgon	anionic	XLII	3	85.0	2.1	---
6.5% Acidolate	anionic	XLIII	3	82.3	1.0	---
CRL # 34452	anionic	XLIV	3	86.9	1.1	---
Sorapon SF	anionic	XLV	3	87.9	1.8	---
Sorapon SF, Alkanol WXN	anionic, anionic	LXXXIV	3	92.6	0.1	+0.5
Nacconol NR	anionic	XLVII	3	89.4	0.4	---
Nacconol NR, Alkanol WXN	anionic, anionic	LXXXII	3	90.5	1.4	-1.7
5% Alconox	unknown	XLVIII	3	81.2	1.9	---
Maypon SK	anionic	LXXV	3	88.5	1.4	+0.4
Maypon SK, Alkanol WXN	anionic, anionic	XCI	3	93.3	0.3	-0.6
Maypon 4C	anionic	LXXVI	3	85.9	1.6	-2.4
Duponel ME, Alkanol WXN	anionic, anionic	LXXXI	3	93.5	0.3	+2.5
Ultrawet 30 DS, Alkanol WXN	anionic, anionic	LXXXIII	3	92.3	0.1	+0.3
Oronite D60, Alkanol WXN	anionic, anionic	LXXXVI	3	93.7	0.8	+2.9
Oronite D60, Dispersant NIW	anionic, nonionic	LXXXVII	3	93.5	0.6	+2.8

Table CXXXII (cont)

Detergent	Type	Table No.	No. of Runs	Per Cent Removed	Standard Error of Mean (±)	Difference with Tide
Oronite D60, Dispersant NIW, Calgonite	anionic, nonionic	LXXXVIII	3	89.2	0.9	-1.3
Nonic 218	nonionic	XCIV	9	85.8	1.0	+2.9
Nonic 218	nonionic	XXVII, LXXII	14	88.6	0.9	---
Nonic 218 + unadjusted Calgon	nonionic	XXVIII	3	82.5	2.3	---
Nonic 218 + Hy-Phos	nonionic	XXXI	3	61.6	2.7	---
Nonic 218, Alkanol WXN	nonionic, anionic	XCV	3	93.6	0.3	-0.4
Nonic 218, Dispersant NIW	nonionic, nonionic	XCVI	3	78.8	0.1	-3.3
Nonic 218, Janusol	nonionic, nonionic	XCVII	3	91.2	0.2	-1.7
Nonic 218, Lipal 450	nonionic, nonionic	LIV	3	75.0	0.4	---
Nonic 218, Nopcogen 14-L	nonionic, nonionic	LI	3	81.3	1.8	---
Triton NF	nonionic	XXV, LXXI	6	87.0	1.0	---
Triton NF	nonionic	XCVIII	12	86.5	1.4	-1.5
Triton NF + unadjusted Calgon	nonionic	XXVI	3	82.5	3.7	---

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Table CXXXII (cont)

Detergent	Type	Table No.	No. of Runs	Per Cent Removed	Standard Error of Mean (±)	Difference with Tide
Triton NF, Alkanol WXN	nonionic, anionic	XCIX	3	93.9	0.3	+3.2
Triton NF, Janusol	nonionic, nonionic	C	3	94.6	0.4	+3.8
Triton NF, Neopone R	nonionic, nonionic	CI	2	94.6	---	-0.3
Dergon MF	nonionic	CII	3	84.7	0.3	-0.9
Ethofat	nonionic	CIII	3	87.3	0.3	-3.0
Renex	nonionic	CIV	3	85.2	1.2	-3.0
Onyxol 336	nonionic	CV	3	93.7	0.8	+0.3
Energetic	nonionic	CVI	3	92.8	0.6	-0.7
Dianol G	nonionic	CVIII	3	92.4	0.5	-0.9
Ethomid HT-15	nonionic	CIX	3	93.1	0.3	-0.2
Ethomid HT-15, Dispersant NIW	nonionic, nonionic	CXII	3	95.5	0.4	+4.4
Ethomid HT-25	nonionic	CX	3	93.0	0.6	-0.2
Ethomid HT-60	nonionic	CXI	2	91.1	---	-2.0
Sterox SK	nonionic	LXVIII	6	85.4	0.6	---
Sterox SK, Dispersant NIW	nonionic, nonionic	LXIX	3	94.3	0.8	---
Sterox SK, Dispersant NIW	nonionic, nonionic	CXV	3	92.3	0.3	+0.3

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Table CXXXII (cont)

Detergent	Type	Table No.	No. of Runs	Per Cent Removed	Standard Error of Mean (±)	Difference with Tide
Sterox SK, Alkanol WXN	nonionic, anionic	CXIII	3	97.8	0.2	+0.7
Sterox SK, Alkanol WXN, STPP	nonionic, anionic	CXIV	3	96.9	0.5	-0.3
Sterox SK, Tween 21	nonionic, anionic	LXX	3	87.6	0.8	---
Sterox AJ, Alkanol WXN	nonionic, anionic	CXVI	3	93.7	0.6	-0.3
Alrosol C, Alkanol WXN	nonionic, anionic	CXVII	3	92.4	0.6	+0.2
Antarox A-400, Alkanol WXN	nonionic, anionic	CXVIII	3	91.3	0.6	-0.9
Antarox A-400, Dispersant NIW	nonionic, nonionic	CXIX	3	82.2	0.9	+0.2
Advawet NA-6	nonionic	LXI	3	86.9	0.2	---
Advawet NA-6, Dergon MF	nonionic, nonionic	CXX	3	89.9	1.2	-3.0
Permalene A-100	nonionic	LIX	3	81.4	3.1	---
Repcol A-100	nonionic	LX	3	79.7	0.8	---
RN-600	nonionic	LXII	3	87.6	0.3	---
Detergent 77	nonionic	LXIII	3	84.4	0.9	---
Detergent 80	nonionic	LXIV	3	86.1	0.1	---
Detergent 80 + EDTA	nonionic	CVII	3	95.5	1.1	+0.6

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Table CXXXII (cont)

Detergent	Type	Table No.	No. of Runs	Per Cent Removed	Standard Error of Mean (±)	Difference with Tide
5% Detergent T-12	nonionic	LXV	3	85.9	1.1	---
5% Detergent T-12, 0.25% CMC	nonionic	LXVI	3	87.5	1.1	---
4% Detergent T-12, 1% Calgon, 0.25% CMC	nonionic	LXVIII	3	87.2	0.5	---
Lipal 450	nonionic	LV	3	80.5	1.1	---
Dispersant NIW	nonionic	LVI	6	89.8	0.6	---
Ethomeen C/15	cationic	LVIII	3	81.9	1.1	---
Katapol VP-532	cationic	CXXI	3	94.0	0.6	+0.6
Katapol VP-532, Alkanol WXN	cationic, anionic	CXXII	3	92.8	0.1	-1.2
Alro Amine C	cationic	CXXIII	3	78.5	6.7	-11.0
Alro Amine O	cationic	CXXIV	3	91.1	1.3	-1.7
Alro Amine S	cationic	CXXV	3	90.1	0.7	-2.7
Miranol CM	amphoteric	CXXVI	3	95.8	0.4	+2.4
Miranol SM	amphoteric	CXXVII	3	94.7	0.7	+1.3
Miranol DM	amphoteric	CXXVIII	3	97.4	0	+0.2
Miranol MM	amphoteric	CXXIX	3	97.5	0.2	+0.7
Miranol HM	amphoteric	CXXX	3	89.0	1.1	-3.8

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b. Human Skin In Vivo

Sixteen human subjects were used during the first year of the project. Since no work had been done on humans before, extremely low levels of activity were used, and the reliability of the results suffered accordingly. However, the tentative results obtained at that time were later confirmed in full. The procedure used was as follows:

The hair from an area of several square inches at about the middle of the outer aspect of the forearm was removed with electrical clippers. Circles of about one inch in diameter were then drawn on each forearm and on each palm. The contaminant was added slowly, allowed to dry in the air, and the activity determined. The counting was done with an unshielded Geiger tube having a 1.8 mg/cm^2 mica end window. The Geiger tube was tightly encased in a cardboard or metal cylinder that extended just beyond the end window. Constant geometry was assured by holding the cylinder lightly but firmly on the circles enclosing the activity.

This procedure was used with soil from the Nevada test grounds, a carbon-labeled synthetic soil, and a neutron-irradiated synthetic soil in addition to the fission products-synthetic soil suspension that has already been described. It was found that only this last type of contaminant was held with sufficient strength by the human skin to make the experiments worthwhile. Accordingly, no further work was done during the

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last six months with Nevada soil, carbon-labeled soil, or neutron-irradiated soil.

Washing was accomplished by soaking cotton swabs of the type known as Q-Tips in the detergent solution for one minute. The excess detergent was removed with absorbent tissue paper, and a final rinse was followed by thorough drying with tissue papers. The remaining activity was then determined as before. The results obtained using the fission products - synthetic soil suspension during both the first year of the contract and the last six months are given in the next two tables.

Once more, in order to avoid lengthy repetitions, certain abbreviations are used in the detergent column. Household products, Radiacwash, Flobar and CP Cleaner were used in the concentrations indicated. The formulations of Ivory, Duponol ME and Nonic 218 with EDTA or Calgon were all 5% solutions of formulations containing 30% detergent, 65% sequestrant and 5% carboxymethyl cellulose.

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TABLE CXXXIII

Forearms of Human Subjects

Subject	Arm	Detergent	Rinse	Initial Count	Final Count	Per Cent Removed
A	l	5% Tide	water	1844	background	>99.9
C	l	5% Tide	water	1620	background	>99.9
O	r	5% Tide	water	2160	background	>99.9
P	r	5% Tide	water	2017	28	98.6
G	l	5% Surf	water	1722	3	99.8
H	l	5% Surf	water	2229	35	98.4
G	r	5% Oxydol	water	1610	34	97.9
H	r	5% Oxydol	water	2431	56	97.7
I	l	5% Ivory	water	1283	71	94.5
L	r	5% Ivory	water	1280	163	87.3
D	r	5% Palmolive	water	2635	118	95.5
F	r	5% Palmolive	water	2272	154	93.2
D	l	30% Carolite 1000	water	1486	4	99.7
E	l	30% Carolite 1000	water	1311	18	98.6
A	r	1:6 Radiacwash	water	2908	39	98.7
B	l	1:6 Radiacwash	water	1567	48	96.9
E	r	10% Flobar	water	1615	background	>99.9
F	l	10% Flobar	water	1696	97	94.3
M	l	5% Duponol ME + EDTA	water	1570	background	>99.9

Table CXXXIII (cont)

Subject	Arm	Detergent	Rinse	Initial Count	Final Count	Per Cent Removed
N	l	5% Duponol ME + EDTA	water	2530	background	>99.9
N	r	5% Duponol ME + EDTA (Na_3 salt)	water	1840	background	>99.9
O	l	5% Duponol ME + EDTA (Na_3 salt)	water	1950	25	99.8
M	r	5% Ivory + EDTA (Na_4 salt)	water	2400	background	>99.9
P	l	5% Ivory + EDTA (Na_4 salt)	water	2200	5	99.8
I	r	5% Duponol ME + Calgon	water	2406	3	99.9
L	l	5% Duponol ME + Calgon	water	2600	44	98.3
1	l	5% Nonic 218 + Calgon	water	1140	4	99.7
1	r	Nonic 218 + Calgon	1% Calgon	665	background	>99.9
2	l	5% CP Cleaner	water	2220	62	97.2
2	r	2% CP Cleaner + 5% Calgon	water	2050	10	99.6
3	l	TiO_2 paste	water	2530	135	94.7
3	r	Sat. $KMnO_4$ sol.	5% $NaHSO_3$	1820	31	98.3

TABLE CXXXIV

Palms of Human Subjects

Subject	Arm	Detergent	Rinse	Initial Count	Final Count	Per Cent Removed
A	l	5% Tide	water	1080	10	99.1
C	l	5% Tide	water	1250	12	99.0
O	r	5% Tide	water	1870	20	98.9
P	r	5% Tide	water	1520	102	93.3
G	l	5% Surf	water	1980	139	93.0
H	l	5% Surf	water	1190	100	91.5
G	r	5% Oxydol	water	1330	101	92.4
H	r	5% Oxydol	water	1300	134	98.7
B	r	5% Ivory	water	1290	286	76.7
C	r	5% Ivory	water	1370	498	63.7
D	r	5% Palmolive	water	1690	151	91.1
F	r	5% Palmolive	water	1880	380	79.8
D	l	30% Carolite 1000	water	1670	24	98.6
E	l	30% Carolite 1000	water	1950	72	96.3
A	r	1:6 Radiacwash	water	1500	48	96.8
B	l	1:6 Radiacwash	water	1380	152	89.0
E	r	10% f lobar	water	1860	32	98.3
F	l	10% Flobar	water	1170	70	94.0
M	r	5% Duponol ME + EDTA	water	1320	10	99.2

Table CXXXIV (cont)

Subject	Arm	Detergent	Rinse	Initial Count	Final Count	Per Cent Removed
N	r	5% Duponol ME + water	water	1360	25	98.2
N	l	5% Duponol ME + EDTA (Na_3 salt)	water	1260	background	>99.9
O	l	5% Duponol ME + EDTA (Na_3 salt)	water	1400	15	98.9
M	l	5% Ivory + EDTA	water	1240	background	>99.9
P	l	5% Ivory + EDTA	water	1240	background	>99.9
I	l	5% Duponol ME + Calgon	water	1680	35	98.6
L	l	5% Duponol ME + Calgon	water	1420	53	96.3
1	l	5% Nonic 218 + Calgon	water	893	36	96.0
1	r	Nonic 218 + Calgon	1% Calgon	950	58	93.9
2	l	5% CP Cleaner	water	1615	75	95.4
2	r	2% CP Cleaner + 5% Calgon	water	1895	66	96.5
3	l	TiO_2 paste	water	1800	402	77.6
3	r	Sat. $KMnO_4$ sol.	5% $NaHSO_3$	1980	306	84.5

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Three important modifications were introduced at this time. Evidence obtained in this laboratory and elsewhere indicates that the palm is more difficult to decontaminate than the arm or the 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 is then concentrated on two spots rather than six, thus permitting the use of higher levels per contaminated area. A second modification consisted in removing the most loosely held activity before washing with the detergent. This was accomplished by gently swabbing with a Q-Tip soaked in water for one minute, drying with absorbent tissue paper, swabbing again with water for one-half minute, and drying once more with absorbent tissue paper. The remaining activity was then determined and the decontamination was performed in the usual fashion. The third modification consisted in extending the length of time between the initial contamination and the first water rinse.

With the exception of Subject 4, all of the subjects were given a one minute water rinse after washing with the detergent. The left hand of Subject 4 was rinsed with distilled water for five minutes and the right hand with 5.0% sodium bisulfite for seven minutes.

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In this and all subsequent tables in which a water rinse preceded the detergent treatment, the column marked "Per Cent Removed by Detergent" is obtained by dividing the final count by the after rinsing count, multiplying the quotient by 100, and then subtracting the result from 100.

Again in order to avoid needless repetition, the column marked "Detergent" has been simplified as follows: the name of a single detergent indicates a 5% solution of a formulation containing a 30% detergent, 65% Calgon, and 5% carboxymethyl cellulose. A detergent plus EDTA indicates a similar formulation, except that tetrasodium ethylene diamine tetraacetone was used instead of Calgon. When the two detergents are listed together, it indicates a 6.5% solution of a formulation containing 23% of each detergent, 50% Calgon, and 4% carboxymethyl cellulose. The word "alone" after a detergent indicates that no sequestrant or carboxymethyl cellulose was added.

Because of the very nature of the radioactive disintegration process, the lower the activity of a sample, the greater the error in measuring it, and for very weak samples the error may be considerable. For this reason values obtained from less than 50 counts per minute are indicated by asterisks to indicate that their accuracy may be doubtful.

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TABLE CXXXV

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
5% Ivory alone	29	l	30	1785	239	86.6	8	96.7*
	32	r	30	3525	790	77.6	150	80.9
	51	l	30	9850	910	90.8	139	84.7
	56	r	30	20300	6000	70.5	585	90.2
	Mean:							88.1
	Mean excluding starred value:							85.3
Ivory	52	l	30	11300	6670	41.0	451	93.2
	55	r	30	20000	8840	58.8	465	94.7
	Mean:							94.0
Ivory, Alkanol WXN	53	l	30	13400	5060	62.1	320	93.7
	54	r	30	14700	8400	43.0	575	93.2
	Mean:							93.4
Pax-Lano-Sav alone with a little water	60	l	30	13800	(no rinse)		400	97.9
	60	r	30	17400	8430	51.7	950	89.5

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
5% G-808 alone	33	l	45	1620	180	88.9	29	83.9*
	28	r	30	2400	485	79.8	125	74.3
	Mean:							79.1
5% G-809 alone	30	l	30	1850	465	74.8	75	83.9
	31	r	30	3650	1000	72.6	270	73.0
	Mean:							78.4
5% Tide alone	49	r	30	15300	2810	81.6	279	92.2
	50	l	30	19000	5940	68.5	454	92.1
	57	l	30	16600	4870	60.6	306	93.7
	58	r	45	11600	5840	49.8	503	91.0
	61	l	30	12300	1940	84.3	65	95.6
	61	r	30	9420	1640	82.5	93	93.2
	28	l	60	1820	218	88.1	35	83.9*
	14	r	30	24000	1600	93.8	140	91.2

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
5% Tide alone (cont)	Mean:							91.6
	Standard Deviation:							±3.2
	Standard Error of Mean:							±1.2
5% Carolite 1000 alone	32	l	45	1840	218	88.1	8	96.3*
	29	r	45	2780	810	68.7	175	78.4
	Mean:							87.8
30% Carolite 1000 alone	72	r	30	16700	2360	85.8	351	85.4
Decon Sol alone	71	l	45	16500	3040	81.5	534	82.1
Saturated $KMnO_4$ + 0.2N H_2SO_4; decolorize with 5% $NaHSO_3$	72	l	45	21600	3800	82.5	1150	69.8
5% CP Cleaner alone	17	l	30	9110	5340	40.4	630	88.2
	18	r	30	19900	2500	87.5	850	66.0
	Mean:							77.1

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
5% Detergent T-12 alone	41	r	30	17800	2900	83.8	330	88.6
	42	l	30	9390	966	89.7	73	92.2
	Mean:							89.4
5% Santomerse D alone	31	l	30	1840	230	87.5	8	96.5*
	30	r	40	1750	620	64.6	60	90.7
	71	r	30	18700	2140	88.5	284	86.1
	73	l	75	20500	2180	89.2	285	85.7
	Mean:							89.8
	Mean excluding starred value:							87.5
Santomerse D, Dispersant NIW	22	l	30	8450	1850	78.2	200	89.2
	25	r	30	9880	2820	71.5	347	87.7
	19	l	30	8470	3890	54.1	310	92.0
	17	r	30	20200	8100	59.5	1200	85.2
	Mean:							88.5

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
Santomerse D, Alkanol WXN	20	l	30	10600	2380	77.6	220	90.6
	24	r	30	9125	4680	48.7	745	85.1
	Mean:							87.9
Oronite D-60, Alkanol WXN	12	l	30	21700	11300	47.8	1430	87.4
	13	r	20	20600	4720	77.2	540	88.6
	25	l	20	13900	4200	61.0	540	87.0
	20	r	20	16900	4800	71.6	556	89.2
	Mean:							88.0
Oronite D-60, Dispersant NIW	13	l	30	20200	3940	81.2	535	86.4
	11	r	30	8400	1890	77.5	365	80.7
	Mean:							83.6
Nacconol NR, Alkanol WXN	44	l	30	8650	2020	76.7	146	92.8
	45	r	30	21300	13400	37.4	600	95.6
	Mean:							94.2

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
Duponol ME, Alkanol WXN	24	l	30	9450	3740	60.4	752	80.0
	21	r	30	22800	7640	66.7	900	88.3
	Mean:							84.2
Ultrawet 30 DS, Alkanol WXN	45	l	30	15200	4340	71.4	314	92.8
	46	r	30	19100	4240	77.8	249	94.1
	64	l	30	16000	6580	59.4	404	92.5
	65	r	30	16800	6210	63.0	757	87.8
	Mean:							91.8
Sorapon SF, Alkanol WXN	70	l	30	16000	6400	60.0	295	95.4
	69	r	30	24200	9400	61.2	430	95.4
	63	l	30	10700	4990	53.6	181	96.4
	64	r	30	12700	7080	44.0	411	94.2
	Mean:							95.4

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
Alrosol C, Alkanol WXN	47	l	30	14000	2460	82.5	136	94.5
	48	r	30	19100	7400	61.3	416	94.4
	65	l	30	15200	7600	49.9	1010	86.8
	63	r	30	17400	6950	60.0	344	95.1
	Mean:							92.7
Antarox A-400, Alkanol WXN	48	l	30	8050	3190	60.4	217	93.2
	47	r	30	15910	5860	63.2	487	91.7
	MeN							92.4
Detergent 80 + EDTA	11	l	30	17700	780	95.6	89	88.6
	16	r	30	16100	2920	81.7	585	80.0
	Mean:							84.3
Dianol G	62	l	30	11100	2530	77.3	106	95.8
Dianol G, Alkanol WXN	62	r	30	17200	8990	53.0	200	97.5

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
Ethomid HT-15, Alkanol WXN	46	l	30	17000	2620	84.6	293	88.9
	44	r	30	22600	4700	79.3	286	93.9
	Mean:							91.4
Ethomid HT-15 Dispersant NIW	21	l	30	7940	3140	60.6	175	94.4
	23	r	45	15900	3500	77.0	260	92.6
	18	l	30	11600	5610	51.9	412	92.7
	19	r	30	14200	5910	76.0	945	84.0
	Mean:							90.9
Energetic	35	l	30	8660	1860	78.6	275	85.2
	40	r	30	12800	2500	80.5	275	89.0
	41	l	30	14900	2510	83.2	140	94.3
	Mean:							89.5
Nonic 218	14	l	30	17700	780	95.6	89	88.6
	16	r	30	16100	2930	81.7	585	80.0
	Mean:							84.3

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
Onyxol 336	37	l	30	11900	1290	89.2	132	89.8
	34	r	30	12800	1990	84.5	160	91.9
	42	r	30	20700	5340	74.2	740	90.0
	Mean:							90.6
RN-600	36	r	30	22200	3280	79.7	204	94.1
	35	r	30	1090	180	83.5	25	86.1*
	43	l	30	15200	3520	76.8	429	88.1
	Mean:							89.4
	Mean exclusive of starred value:							91.1
Sterox AJ, Alkanol WXN	49	l	30	10800	3140	70.8	245	92.2
	50	r	30	15600	5940	61.8	388	93.5
	69	l	30	9480	2300	75.7	76	96.7
	68	r	30	11400	5320	53.4	430	91.9
	Mean:							93.6

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
Sterox SK, Alkanol WXN	27	l	15	14200	4620	67.4	250	94.6
	26	r	15	20500	4400	78.5	250	94.3
	Mean:							94.4
Sterox SK, Dispersant NIW	26	l	15	8830	1480	83.2	74	95.0
	27	r	15	12800	3630	71.5	200	94.5
	Mean:							94.8
Triton NF, Alkanol WXN	23	l	30	11200	1670	85.2	316	81.0
	22	r	30	17100	7485	56.2	1037	86.1
	Mean:							83.6
Triton NF, Janusol	16	l	30	10900	1650	84.8	407	75.3
	15	r	30	14800	5640	62.0	1440	74.4
	Mean:							74.8

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
Triton X-100	58	l	30	16500	6000	63.4	400	93.4
	59	r	45	17000	7520	55.9	455	94.0
	53	r	30	16000	4220	73.7	128	96.0
	54	l	30	6650	2390	64.0	117	95.1
	Mean:							94.6
Triton X-100, Alkanol WXN	59	l	30	16400	5530	66.4	320	94.2
	57	r	45	15100	4580	69.6	185	96.0
	55	l	30	10700	4000	62.8	220	94.3
	52	r	30	19300	8320	56.9	516	93.8
	Mean:							94.6
Tween 20	38	l	30	1890	190	90.0	10	94.7*
	43	r	30	27700	8470	68.6	2000	77.1
	Mean:							85.9

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Table CXXXV (cont)

Detergent	Subject	Hand	Waiting Time (Min)	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Count After Wash	Per Cent Removed By Detergent
Katapol VP-532	34	l	30	8080	2120	73.8	285	86.6
	39	r	30	13600	6040	55.7	155	97.5
	40	l	30	16100	2120	86.9	265	87.6
	Mean:							90.6
Miranol CM, Alkanol WXN	67	l	30	19500	1180	93.6	50	95.8
	70	r	30	13400	2760	79.5	127	95.4
	Mean:							95.6
Miranol SM, Alkanol WXN	68	l	30	20900	11800	43.7	438	96.3
	67	r	30	16900	3000	82.3	198	93.4
	Mean:							94.8

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In order to determine the extent to which contamination may spread during washing, the left palm of a subject was contaminated as usual. After a half-hour wait, the subject was directed to wash the contaminated area with a 6.5% solution of 23% Alrosol C, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose by scrubbing vigorously for one minute with the heel of his right hand. The hands were then rinsed, lightly wiped dry and counted. The heel of his right hand gave only about 30 counts per minute above background, indicating that the spread of contamination is probably not a serious problem in washing, at least with detergents of this type.

A number of hand cleansing creams were then prepared on the basis of the results obtained so far. Although water enters into their composition, they require no additional water at all for their use. Three general formulations were used; one based on Bentonite, another on Vee-Gum, and the third on carboxymethyl cellulose. First of all, detergent concentrations were prepared containing 15% detergent by weight. To 300 g. of these detergent concentrates, 45 g. of 34% tetrasodium ethylene diamine tetraacetate was added to form the detergent-sequestrant concentrate. The cleansing cream was then prepared by homogenizing 23 g. of the

detergent-sequestrant concentrate and 77 g. of a 10% solution of Bentonite, Vee-Gum, or carboxymethyl cellulose.

It may not be out of place to repeat here a statement made earlier in this report. Very extensive experimentation on the removal of fission products from many different types of surfaces have shown that, in general, the best sequestrants, such as EDTA and Calgon, are about equally effective weight for weight, at least under the experimental conditions used. Accordingly, the choice will depend on factors other than mere efficiency. For most of the work already mentioned in this report, Calgon was used because a large quantity happended to be available. The hand creams, however, were all formulated with EDTA because of the greater stability of this compound in solution. It will be considerations of this type that will finally decide the exact composition of any formulations adopted.

The procedure employed was the following: the hands were contaminated and given the preliminary rinse in the usual fashion. A generous quantity of the cream then placed on the contaminated area and worked lightly with a cotton swab (Q-Tip) for one minute. The remaining cream was then removed as completely as possible with absorbent tissue paper and the remaining activity was determined. This treatment with the cream was then repeated in some cases as many as four times. The results obtained

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are given in Table CXXXVI. In this table the various columns marked "Per Cent Removed" are always in reference to the activity left after the water rinse. Thus, they refer to the total activity removed by the cleansing cream after one to five consecutive separate one-minute treatments. The column marked "Cream" lists only the detergent and the base. It is understood that the actual formulation is the one given two paragraphs above; i.e., 3% detergent, 3% EDTA, and 10% base (Bentonite, Vee-Gum or carboxymethyl cellulose. In order to reduce this table to a manageable size that would make the results easy to see and at the same time avoid awkward folding of the pages, the only counts given are the initial counts and the counts after the water rinse. If it is desired to known the activity at any given moment, it may be readily calculated from the figures given by simple arithmetic.

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TABLE CXXXVI

Cleansing Creams

Cream	Subject	Hand	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Per Cent Removed 1 Min	Per Cent Removed 2 Min	Per Cent Removed 3 Min	Per Cent Removed 4 Min	Per Cent Removed 5 Min
Santomerse D, Vee-Gum	93	r	20600	3400	83.5	91.0	96.2	---	---	---
Stepanol WAT, Vee-Gum	93	l	16000	2540	84.1	92.7	96.8	---	---	---
Antarox A-400, Vee-Gum	90	l	18300	3980	79.8	87.7	92.2	93.2	95.0	---
Antarox A-400, Bentonite	89	r	20400	2330	88.6	78.9	88.9	91.9	95.1	---
	85	l	8770	1200	86.4	92.7	97.8	---	---	---
Dianol G, Bentonite	91	l	21300	2500	89.2	92.7	97.0	---	---	---
	77	l	12000	2020	83.2	90.9	94.9	---	---	---
	75	r	13800	3430	75.2	89.0	94.3	---	---	---
DianolG, Dispersant NIW, Bentonite	75	l	15200	3870	74.5	93.7	96.1	---	---	---
	76	r	20800	4020	80.6	84.7	93.0	---	---	---
Dianol G, Alkanol WXN, Bentonite	76	l	14300	1260	91.2	86.2	91.7	---	---	---
	77	r	15200	3800	75.2	85.9	93.0	---	---	---

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Table CXXXVI (cont)

Cream	Subject	Hand	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Per Cent Removed 1 Min	Per Cent Removed 2 Min	Per Cent Removed 3 Min	Per Cent Removed 4 Min	Per Cent Removed 5 Min
Triton X-100, Vee-Gum	84	r	16600	1280	92.3	88.7	93.3	---	---	---
	85	r	14900	1240	91.7	95.6	99.2	---	---	---
	79	l	15300	1810	88.1	87.2	96.7	---	---	---
	88	r	17200	4430	74.2	73.0	89.0	94.3	96.6	97.8
Triton X-100, CMC	82	r	18700	3900	81.4	82.5	89.3	94.9	94.9	---
Glucaterge, Vee-Gum	86	r	13700	1600	88.3	85.5	90.3	91.7	---	---
Glucaterge, Bentonite	86	l	15800	3630	79.6	90.9	93.6	96.2	---	---
	91	r	21800	2740	87.4	89.8	96.4	97.9	---	---
Ethomid HT-15, Vee-Gum	84	l	16900	1690	90.0	84.2	90.9	95.2	---	---
Ethomid HT-15, Bentonite	79	r	10600	899	91.6	86.1	90.8	---	---	---
	92	l	19300	6040	68.7	88.5	95.4	96.7	---	---

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Table CXXXVI (cont)

Cream	Subject	Hand	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Per Cent Removed 1 Min	Per Cent Removed 2 Min	Per Cent Removed 3 Min	Per Cent Removed 4 Min	Per Cent Removed 5 Min
Ethomid HT-15, Alkanol WXN, Bentonite	83	l	15800	2620	83.4	93.4	95.3	---	---	---
Miranol LF, Vee-Gum	87	r	22200	1550	93.0	75.5	83.3	87.5	90.9	91.0
Miranol LF, Bentonite	87	l	20800	1450	93.0	82.3	88.7	91.1	91.9	94.0
SBS-310	73	r	23800	2420	89.8	76.4	---	---	---	---
	74	r	22800	4080	82.8	60.4	---	---	---	---
23% Ethomid HT-15, 23% Alkanol WXN, 50% Calgon, 4% CMC, + sufficient water to form thin paste.	56	l	8680	2520	70.9	94.5	---	---	---	---
	51	r	23100	3160	86.3	92.1	---	---	---	---

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A few runs were also made using some of the creams with sufficient water to form a very fluid mixture.

TABLE CXXXVII

Cleansing Creams With Water

Cream	Subject	Hand	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Per Cent Removed 1 Min	Per Cent Removed 2 Min	Per Cent Removed 3 Min	Per Cent Removed 4 Min
Antarox A-100, Vee-Gum	90	r	22400	5460	75.1	84.5	90.5	92.0	95.3
Ethomid HT-15, Bentonite	82	l	18300	2270	87.5	86.6	92.4	---	---
	92	r	20300	5770	71.5	87.2	94.0	96.1	---
Miranol LF, Bentonite	81	r	18200	2110	88.4	58.1	79.1	89.0	90.5

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Another variant tried consisted in skipping the initial water rinse, and using only the cream from the very beginning. Two runs were made using the cream alone and a third adding sufficient water to make a very thin slurry.

TABLE CXXXVIII

Cleansing Cream Without Initial Rinse

Cream	Subject	Hand	Initial Count	Per Cent Removed 1 Min	Per Cent Removed 2 Min	Per Cent Removed 3 Min	Per Cent Removed 4 Min
Stepanol WAT, Bentonite	80	1	10800	92.9	99.6	---	---
Ethomid HT-15, Bentonite	78	1	15800	93.3	97.0	98.1	98.4
Ethomid HT-15, Bentonite + Water	78	r	18600	97.4	98.7	99.1	99.3

Three runs were then made in which the subjects were directed to wash one hand against the other in more or less normal washing fashion. In the case in which water was added to the cream, the hands were rinsed thoroughly in running water and dried after each washing. No initial water rinses were used in these runs.

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TABLE CXXXIX

Cream	Subject	Hand	Initial Count	Per Cent Removed 1 Min	Per Cent Removed 2 Min	Per Cent Removed 3 Min	Per Cent Removed 4 Min	Per Cent Removed 5 Min	Per Cent Removed 7 Min
Dianol G, Vee-Gum	94	l	18000	98.0	98.9	99.0	---	---	---
	94	r	16900	98.2	98.8	99.0	---	---	---
Ethomid HT-15, Bentonite	95	l	19600	98.3	98.9	99.4	---	---	---
	95	r	19100	97.9	98.6	98.9	---	---	---
Ethomid HT-15, Bentonite + Water	102	l	21900	94.0	96.6	97.5	97.9	98.4	99.7
	102	r	22600	92.6	96.6	96.8	97.2	98.1	99.3

A careful survey of the entire hands of these three subjects did not reveal any spread of the contaminant.

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With the few subject available for the experiments with the creams, it has not been possible to determine with certainty which are the most efficient. This is not too surprising for the detergents used were all known to be extremely efficient as may be seen by referring to the experiments on hair and on skin with the 5% solutions formulations. Two detergents previously unused in these experiments were tried out; Stepanol WAT and Glucaterge, but there was every reason to believe that they would perform as well as the others.

On the basis of the work done, it then becomes impossible to recommend one and only one formulation for the removal of fission products from the human skin. It is felt instead that any one of these creams will do an excellent job, and a final choice will depend on other factors. These factors may include price, availability, stability, behavior at low or high temperatures, and possible skin reactions.

A curious property of these creams is that repeated cleanings seem to continue removing contaminant from the skin, while the usual type of detergent solution seems to cease being useful after about two washes.

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2. Radiological Warfare Agents

a. Human Hair In Vitro

Samples of three radiological warfare agents were supplied by the client. Their compositions and particle sizes were:

PbO

PbO	93%
Ta_2O_5	3%
MoS_2	2%
Ca_3N_2	2%
Particle size:	15 - 20 μ

Ta

Ta	96%
CaH_2	2%
MoS_2	2%
Particle size:	10 μ

$ZnBr_2$

$ZnBr_2$	95%
Ta_2O_5	3%
MoS_2	2%
Particle size	3.5 μ

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Tantalum was the radioactive component in every case.

Preliminary experiments were conducted to determine the extent to which sequestrants would solublilize the tantalum. For this purpose, a single pellet was placed in 10 ml of distilled water, shaken thoroughly and allowed to settle. A 0.050 ml sample of the supernatant liquid was carefully withdrawn, placed in a planchet and counted. Next, one gram of sequestrant, either Calgon or EDTA, dissolved in 2 ml of water was added. The mixture was then shaken thoroughly for one minute and allowed to settle. Another 0.050 m; sample of the supernatant liquid was then withdrawn and counted. The results obtained are given in Table CXL. As in previous cases, values below about 50 counts per minute may be quite unreliable and are indicated by asterisks.

TABLE CXL

Solubility of Radiological Warfare Agents

PbO

Pellet weight: ca. 0.2g.

Solvent	Activity Counts/min/0.05 ml
Water	88
Calgon	298
EDTA	344

$ZnBr_2$

Pellet weight: ca. 0.1g.

Solvent	Activity Counts/min/0.05 ml
Water	232
Calgon	714
EDTA	365

Ta

Pellet weight: ca. 0.07g.

Solvent	Activity Counts/min/0.05 ml
Water	35 *
Calgon	230
Versene	27 *

It is seen that neither sequestrant is particularly effective for the purpose of solubilizing these agents.

Some semi-quantitative experiments also showed that surfactants had little dispersing power on them. Both of these phenomena are probably due to the fact that the particles are too large and heavy, and hence difficult to solubilize or float away. Since the $ZnBr_2$ agent had the smallest particle size, it was decided to use it for a few runs on human hair and later

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on human skin. Eighteen formulations were tried on hair using essentially the same technics that have been employed in the fission products experiments. An aqueous suspension was prepared by dropping a pellet in water and shaking thoroughly. Contamination was effected by quickly withdrawing a small amount of the suspension before it had time to settle and placing a drop on a bundle of hair. This was then allowed to dry, counted, washed and counted again in the usual fashion. With a few exceptions, all runs made on a certain day were markedly below those obtained on the other two days that these runs were made. It was not thought worthwhile to try to determine the source of this discrepancy for the moment. However, these values are indicated by asterisks in the following table, and mean values are calculated both using and omitting these apparently anomalous values.

TABLE CXLI

Human Hair

$ZnBr_2$ Agent

Detergent: 5% Tide

Initial Count	Final Count	Per Cent Removed
7500	704	90.6
12900	583	95.4
12300	4580	62.7 *
Mean:		82.6
Mean excluding starred value:		93.0

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TABLE CXLII

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Duponol ME, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
7860	1050	86.6
9890	1340	86.5
13200	2260	82.9
Mean:		85.3

TABLE CXLIII

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Oronite D-60, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
11000	1310	88.1
7460	526	92.9
11700	3130	73.1 *
Mean:		84.7
Mean excluding starred value:		90.5

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TABLE CXLIV

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Santomerse D, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
7530	580	92.3
6970	720	89.7
11700	5800	50.5 *
Mean:		77.5
Mean excluding starred value:		91.0

TABLE CXLV

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Alrosol C, 23% Alkanol WXN, 50% Cagon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
6840	495	92.5
7410	1030	86.1
12100	4770	60.8 *
Mean:		79.8
Mean excluding starred value:		89.3

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TABLE CXLVI

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Antarox A-400, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
8770	1280	85.4
5350	617	88.5
12500	2500	80.0 *
Mean:		84.6
Mean excluding starred value:		86.9

TABLE CXLVII

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Detergent 80, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
15500	1850	88.0
6120	400	93.4
1580	4230	63.2 *
Mean:		81.5
Mean excluding starred value:		90.7

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TABLE CXLVIII

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Dianol G, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
13500	1070	92.1
9440	1070	88.7
14200	4360	69.2 *
Mean:		83.3
Mean excluding starred value:		90.4

TABLE CXLIX

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Energetic, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
7220	910	87.6
15300	1230	91.9
14400	5200	64.0 *
Mean:		81.2
Mean excluding starred value:		89.8

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TABLE CL

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Ethomid HT-15, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
10100	550	94.5
9440	1070	88.7
11400	2390	69.1 *
Mean:		84.1
Mean excluding starred value:		91.6

TABLE CLI

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Nonic 218, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
16400	863	94.5
15800	1960	87.6
26300	5560	78.8 *
Mean:		87.0
Mean excluding starred value:		91.0

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TABLE CLII

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Onyxol 336, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
10600	1100	89.5
11800	1400	88.1
21300	7110	66.6 *
Mean:		81.4
Mean excluding starred value:		88.8

TABLE CLIII

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Sterox SK, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
11900	1340	88.7
5366	430	92.0
12500	5470	56.4 *
Mean:		79.0
Mean excluding starred value:		90.4

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TABLE CLIV

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Triton NF, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
9460	930	90.2
7790	1130	83.3
17400	3930	77.4 *
Mean:		83.6
Mean excluding starred value:		86.8

TABLE CLV

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Miranol MM, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
14300	1200	91.6
4960	303	93.9
8400	1200	85.7*
Mean:		90.4
Mean excluding starred value:		92.8

TABLE CLVI

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5 % solution of 23% Miranol HM, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
12200	1060	91.3
13100	1480	88.7
6490	647	90.0
Mean:		90.0

TABLE CLVII

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Miranol CM, 23% Alkanol WXN, 50% Calgon, 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
10700	1280	88.0
10700	1100	89.7
13800	6810	50.6 *
Mean:		76.1
Mean excluding starred value:		88.8

TABLE CLVIII

Human Hair

$ZnBr_2$ Agent

Detergent: 6.5% solution of 23% Katapol VP-532, 23% Alaknol WXN, 50% Calgon 4% carboxymethyl cellulose

Initial Count	Final Count	Per Cent Removed
8000	391	95.1
6630	770	88.4
12700	1040	91.8
Mean:		91.8

Except for the anomalous values already mentioned, the results were quite good. This was hardly surprising, however, since the formulations tried were already known to be highly effective.

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b. Human Skin In Vivo:

The procedure used for the $ZnBr_2$ agent was essentially the one previously employed with fission products. A pellet of the agent was dropped in water, a drop of the suspension placed on the palm of the hand and allowed to remain there for 30 minutes. The more loosely held activity was removed with a cotton swab soaked in water and a count was taken. This was followed by a one-minute wash with detergent, a final rinse, and a final count.

When it was found that the activity was very readily removed, the subjects were given much higher initial counts than heretofore. This did not change the picture, however, and every subject was brought to background by a relatively light second wash. Six formulations were used. All were 6.5 % solutions of 23% of a detergent, 23% Alkanol WXN, 50% Calgon, and 4% carboxymethyl cellulose. To avoid useless repetition, only the variable detergent is listed under the "Detergent" column. As in other cases, values obtained from less than 50 counts per minute are indicated by asterisks.

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TABLE CLIX

Human Skin

$ZnBr_2$ Agent

Detergent	Subject	Hand	Initial Count	Count After Rinse	Per Cent Removed By Rinse	Final Count	Per Cent Removed By Detergent
Nonic 218	98	l	49100	1850	96.2	8	99.6 *
	96	r	23900	2070	91.3	87	95.8
	Mean:						97.7
Miranol HM	98	r	21800	700	96.8	20	97.1 *
	96	l	13800	1140	91.7	13	98.9 *
	Mean:						98.0
Ethomid HT-15	97	l	28700	1420	95.0	88	93.8
	100	r	24800	1900	92.3	162	91.5
	Mean:						92.6
Oronite D-60	97	r	19500	840	95.7	128	84.8
	100	l	42300	1980	95.3	51	97.4
	Mean:						91.1
Dianol G	99	l	32400	995	96.9	2	99.8 *
	101	r	38100	1230	96.8	65	94.7
	Mean:						97.2
Katapol VP-532	99	r	17900	946	94.7	32	96.6 *
	101	l	27800	728	97.4	13	98.2 *
	Mean:						97.4

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In only one case did the detergent fail to remove less than 90% of the activity remaining after the initial rinse, while the mean for all the detergent runs was 95.7. More important still was the fact that gentle treatment with water alone removed an average of 95% of the initial activity.

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3. Alpha Emitters.

The work described here was performed at Mound Laboratory *, Miamisburg, Ohio with the cooperation of Dr. John E. Bradley, Chief, Health Physics Section and the assistance of Mr. J. Garner. The object was to investigate the effectiveness of general detergent combinations in removing alpha contamination from human hands. The actual composition of the contaminant was not revealed except that it contained alpha emitters.

The following detergent mixtures were used:

TABLE CLX

Symbol	Composition
NC	30% Nonic 218, 65% Calgon, 5% carboxymethyl cellulose
TC	30% Triton NF, 65% Calgon, 5% carboxymethyl cellulose
SC	30% Santomerse D, 65% Calgon, 5% carboxymethyl cellulose
DC-1	30% Duponol ME, 65% Calgon, 5% carboxymethyl cellulose
OC-1	30% Oronite D-60, 65% Calgon, 5% carboxymethyl cellulose

* Operated by Monsanto Chemical Company under contract with the U. S. Atomic Energy Commission.

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For this work an alpha scintillation counter with a count rate monitor was used. In all, seven human subjects were used; all were employees of Mound Laboratory. Four were freshly contaminated with the alpha contaminant and the remaining four had been contaminated during the normal course of their work at Mound Laboratory. The latter subjects had already been decontaminated by the usual procedures and their wipe count was down to minimum.

The following table summarizes the work done on the four subjects which were freshly contaminated by placing several drops of an aqueous solution of the alpha emmiter on the palms of the subjects' hands. The contaminant was allowed to dry, then counted, decontaminated, the area patted dry for one minute and counted again. All counts in this and subsequent tables are expressed as counts per minute and are corrected for background.

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TABLE CLXI

Freshly Contaminated Subjects (Palms)

Subject	Palm	Detergent	Technic	Initial Count	Final Count	Per Cent Removed
I	left	10% SC	Brushing vigorously for one minute	2480	25	99.0
	right	10% SC	Massaging small quantity of detergent for one minute	2480	Background	>99.9
II	left	10% DC-1	Massaging small quantity of detergent for one minute	975	10	>99.9
	right	5% DC-1	Massaging small quantity of detergent for one minute	975	Background	>99.9

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Table CLXI (cont)

Subject	Palm	Detergent	Technic	Initial Count	Final Count	Per Cent Removed
III	left	10% TC	Massaging small quantity of detergent for one minute	2485	75	97.0
	right	10% TC	Brushing vigorously for one minute	2480	Background	>99.9
IV	left	OC-1	Massaging small quantity of detergent for one minute	2980	75	97.5
	right	OC-1	Massaging small quantity of detergent for one minute	4980	25	99.5

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The results as shown in Table CLXI indicate that the removal of these alpha emitters by various detergent combinations, when applied to human palms, does not present any undue difficulties.

During the visit at Mound Laboratory, there were also available for study, three subjects whose hands were contaminated in the normal course of work. A one-minute massage with Detergent SC on subject V did not significantly reduce the count below the initial 1475 counts per minute. However, one minute's brushing with the same detergent reduced the count by 50%. Further brushing for one minute with Detergent DC-1 lowered the count to 325 counts per minute, giving a total per cent removed of 88%. Still further brushing for one minute with Detergent SC brought down the count slightly.

The results on subject VI were not quite so heartening. One minute's brushing of the left hand with Detergent NC reduced the count from 375 to 325 counts per minute.

Massaging All as a paste, for one minute, the count on subject VII's hand was reduced from 4980 to 3980 counts per minute... per cent removed equals 20%. With CP Cleaner as the detergent, the count was reduced further to 2980 counts per minute. The left thumb of this subject was tenaciously contaminated; one minute's brushing with Detergent SC

reduced the activity from over 475 to 175 counts per minute. Brushing for two minutes with Detergent SC lowered the count still further to 75 counts per minute.

Although the work described in this section is very limited in scope, it supplements the work described in the body of this report in that the use of proper decontamination technics with effective detergent mixtures prove very effective in removing radioactive contamination. Working with radioactivity does not necessitate the use of harsh decontaminants and decontamination procedures.

4. Conclusions and Recommendations.

The most obvious conclusion that may be made from all the data obtained on both human subjects and inert surfaces is that, of the various contaminants used, only the fission products - synthetic soil suspension - presented a real problem. A carbon-labeled synthetic soil, a neutron-irradiated synthetic soil, a soil from the Nevada test grounds, and three radiological warfare agents all proved readily removable. The reason for this was undoubtedly the fact that, except for the fission products mixtures, the radioactive component of the soils was in the form of relatively large particles which could be washed away without much difficulty. The removal of the fission products contaminant, however, does present a real problem. It is here that the greatest contribution has been made by the present study, although without exhausting the field by any means.

One of the most important variables encountered, and the most difficult to deal with has been the character of the skin. Very early in the program it was discovered that the palms of the hands were much more difficult to decontaminate than the forearms or the backs of the hands. Furthermore, it was found that the texture of the skin was extremely important. In general, the rougher and thicker the skin, the more difficult decontamination becomes.

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Particularly remarkable is a certain type of skin that looks very thin and tight, often crossed by many thin lines. That seems to have practically no retentivity. Often, however, this type of skin seemed to hold a very small amount of residual activity most tenaciously indeed. After some experience had been gained, it became possible to predict, in a general way, the retentivity of each subject. Unfortunately, no satisfactory way was found to describe in words or symbols the character of the skin or to classify unambiguously the various types.

No correlation whatever was found to exist between retentivity and age, sex, pigmentation, right or left handedness, whether the individual's skin was oily, dry or normal, perspiration or degree of hirsuteness. In almost one hundred cases, the left hand was contaminated and washed without any preliminary treatment, while the right hand was given a thorough wash prior to contamination. Again, however, no correlation was found between retentivity and cleanliness.

The bulk of the work concerned the efficiency of scores of detergents. This included chemical agents like $KMnO_4$ - $NaHSO_3$, household soaps and syndets, advertised radiological decontaminants, and special formulations.

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The chemical agents were found to be largely unsatisfactory. They did not perform as well as the best detergents and their prolonged or repeated use will irritate the skin.

The household products may be classified into light and heavy duty soaps and light and heavy duty syndets. Without question, the best of these are the heavy duty syndets, of which Tide is an excellent example. However, the addition of a good sequestrant to a soap or light duty syndet generally provides a formulation whose efficiency is approximately that of the best heavy duty syndets. No extensive experimentation was carried out to determine the optimum detergent:sequestrant ratio for each individual product, but it was found that, in the vast majority of cases, one part of detergent to two parts of sequestrant provided an excellent decontaminant.

None of the advertised radiological decontaminants used lived up to their impressive claims. Some, as a matter of fact, proved rather mediocre. A notable exception was CP Cleaner, a product which, if not quite the miraculous substance it claims to be, is nevertheless a superb decontaminant that may be recommended without hesitation.

Scores of special formulations were prepared and tested. These were of two types; the first, formulations to be used with water like most

common detergents, and the second, hand creams to be used alone, without the further addition of any water.

The basic formulations of the first type consisted of 30% detergent, 65% sequestrant, and 5% carboxymethyl cellulose or 23% of one detergent, 23% of another, 50% sequestrant, and 4% carboxymethyl cellulose. A 5% solution was used when the formulation contained only one detergent and a 6.5% solution when the formulation contained two detergents. The per cent compositions given are in terms of weight of active ingredient.

The detergents used in these formulations included soap (Ivory) and syndets in all of the major classifications - anionic, cationic, nonionic and amphoteric. Excellent detergents were found in each of these classifications, particularly among the anionics and nonionics. It is felt that, as a class, the nonionics were probably slightly superior, although this view could perhaps be challenged.

It was found that, in many cases, two surfactants performed better than one. This was particularly true in the cases of Alkanol WXN or Dispersant NIW used in conjunction with other detergents.

These two products are better as dispersants than as detergents, and when used with powerful detergents, often gave extremely effective

formulations. At times, however, they actually hindered the cleaning action.

The sequestrants used included various sodium salts of ethylene diamine tetraacetic acid, sodium polyphosphates, citric acid, and sodium citrate. Under the experimental conditions used, it was found that there was little difference among tetrasodium ethylene diamine tetraacetate, sodium tripolyphosphate, and sodium hexametaphosphate whose pH had been adjusted to 8.4 (Calgon). Definitely inferior to these were all others - - other sodium salts of EDTA, unadjusted hexametaphosphate, citric acid, and sodium citrate. There is a rather extensive body of literature concerning the great sequestering power of EDTA. There is good reason to believe that it is superior to the polyphosphates in many cases. However, semi-quantitative experiments undertaken in connection with this project have shown adjusted sodium hexametaphosphate to be considerably more effective, weight for weight, for the sequestration of rare earths. It was hoped that the combination of EDTA and hexametaphosphate would be superior to either one alone, but a few runs made with such a combination showed exactly the opposite.

The small amount of low-viscosity carboxymethyl cellulose used in these formulations served the primary purpose of helping prevent

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redeposition. The extent to which redeposition or spread of contamination might be a problem was investigated. The conclusion was reached that, with the formulations developed, redeposition and spread of contamination was negligible. Mention should also be made of the fact that carboxymethyl cellulose is also thought to have a beneficial effect on the skin.

Three types of hand creams were prepared and tested. These were based on Bentonite, Vee-Gum, or carboxymethyl cellulose. Every one of them performed admirably. The main advantage of these creams is that they do not require any additional water, and so are particularly suited for field use.

In no case were any irritations or adverse effects noted. The activity levels used were, of course, extremely low. With a few exceptions, the detergents used were relatively mild in their effect on the skin, and since all subjects chosen were in good health, with no skin disorders whatever and with no known skin allergies, no difficulties were encountered. The more violent decontaminants used, like the $KMnO_4$ - $NaHSO_3$ treatment, were used only once on each subject.

No evidence was ever found of any percentaneous absorption, even when the contaminant was allowed to remain on the skin for half an hour and more. Counts taken at the time of contamination and at the end of the waiting

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period agreed within experimental error. This should not be taken to mean that no percentaneous absorption would ever occur -- had the contaminant been in different chemical or physical form, absorption may easily have been important.

One interesting and rather puzzling finding that has been substantiated time and time again is that, within the limits of these experiments, there appears to be no correlation between initial activity and per cent removed by any one agent. Such a correlation would doubtedly exist if a sufficiently extensive range of activities had been used. It seems, however, that, for the ranges of activities actually employed, other uncontrolled variables completely masked this effect. This may be seen clearly in Fig. 1, where initial activities is plotted as abscissas against per cent removed as ordinates. The case of 5% Tide on human hair was used because it offered the largest number of runs made under the same conditions.

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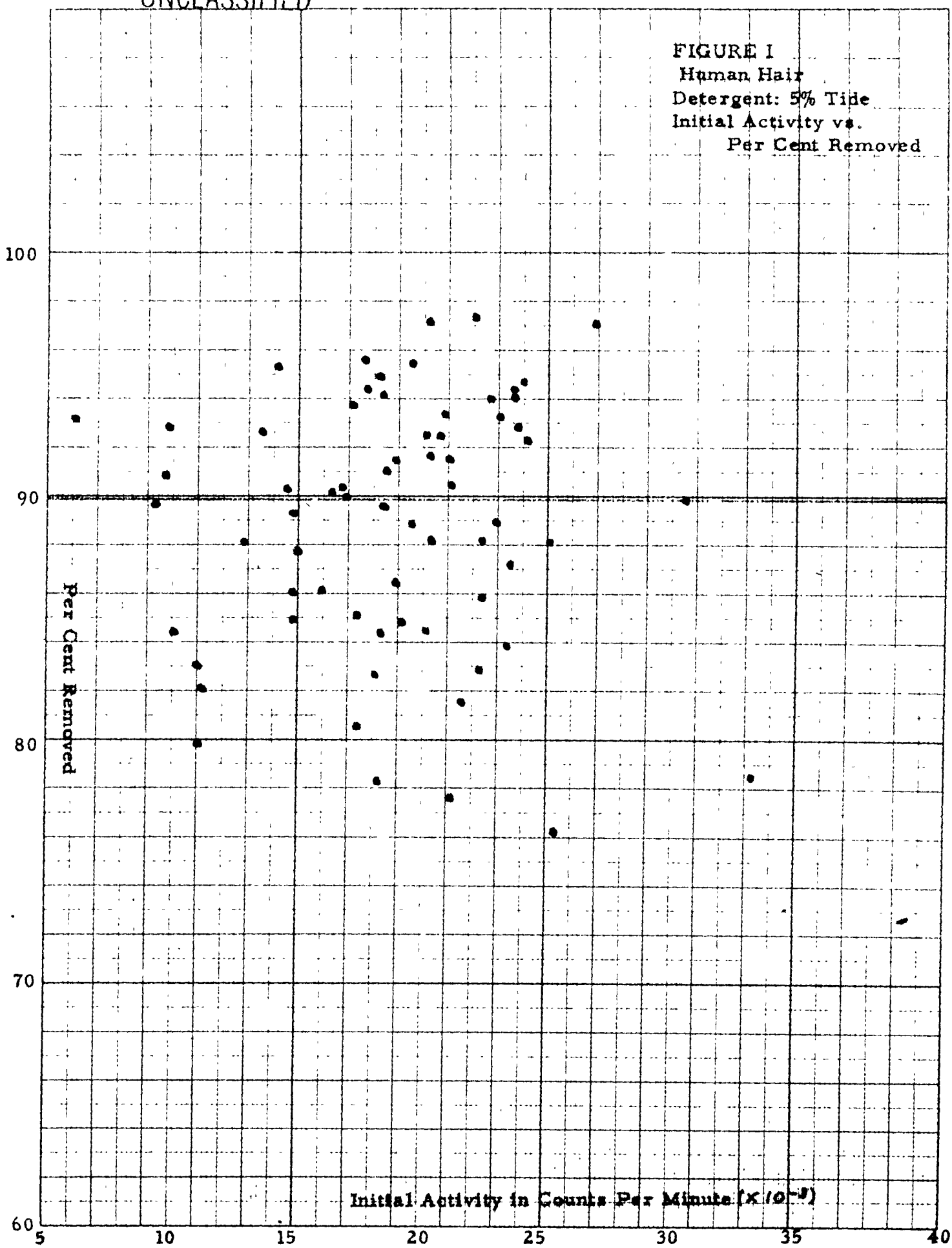
FIGURE I
Human Hair
Detergent: 5% Tide
Initial Activity vs.
Per Cent Removed
100
90
80
70
60
Per Cent Removed
Initial Activity in Counts Per Minute (X 10⁻³)
5
10
15
20
25
30
35
40

It is not possible at the present time to state with absolute assurance that one particular product or formulation is the best for the removal of radioacitve material from the human skin. It is possible, however, to recommend a number of products and formulations all of which are definitely extremely efficient for the removal of contaminants of the types studied in this project. All of these products are of approximately equal efficiency, and, unless further studies are undertaken, a final choice would have to be based on factors other than efficiency alone.

Of the common household products, the heavy duty syndets as a class were definitely superior to light duty syndets and to soaps. Although a definite choice among the heavy duty syndets is difficult, it may be said in all confidence that Tide is at least as good as the best.

In a category all by itself is All, an excellent nonionic product for household use.

Of the products advertised as radiological decontaminents, only CP Cleaner was found to be really effective. The experiments made with this product indicate that it is the equal of the best household detergents.

Many of the formulations specially designed in this laboratory proved to be extremely efficient. Those formulations contained 30% detergent, 65% sequestrant, and 5% low viscosity carboxymethyl cellulose

or, if two detergents were used, 23% of one detergent, 23% of the other detergent, 50% sequestrant, and 4% low viscosity carboxymethyl cellulose. Although Calgon was the sequestrant actually used, all of our experimental evidence indicates that sodium tripolyphosphate or tetrasodium ethylene diamine tetraacetate would be equally effective. It should also be noted that the percentages given are by weight of active component so that twice as much actual weight of a 50% active detergent is needed as of a 100% active detergent.

The detergents that, used in the formulations given above, proved to be superior or at least equal to Tide were:

Ultrawet 30 DS + Alkanol WXN

Nacconol NR + Alkanol WXN

Sorapon SF + Alkanol WXN

Alrosol C + Alkanol WXN

Antarox A-400 + Alkanol WXN

Dianol G

Dianol G + Alkanol WXN

Ethomid HT-15 + Alknaol WXN

Ethomid HT-15 + Dispersant NIW

Onyxol 336

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Sterox AJ + Alkanol WXN

Sterox SK + Alkanol WXN

Sterox SK + Dispersant NIW

Triton X-100

Triton X-100 + Alkanol WXN

Katapol VP-532

Miranol CM + Alkanol WXN

Miranol SM + Alkanol WXN

Although many of these formulations appear to be considerably more effective than Tide. it must be borne in mind that, in many cases, only one or two runs were made. Considering all of the factors involved, it is felt that a final decision on the definite superiority of one of the above formulations over all of the rest must await sufficient data so that statistical methods may be applied. At the present time, all that may be said in absolute confidence is that every one of them is an excellent formulation that equals or surpasses the very best commercial products available.

Practically all of the cleansing creams prepared proved to be extremely efficient. They were formulated with one or two detergents, a sequestrant, and a base consisting of either Bentonite, Vee-Gum, or low viscosity carboxymethyl cellulose. The sequestrant was tetrasodium

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ethylene diamine tetraacetate in every case because of its stability. As in the case of the other formulations, the data available was not sufficient enough to be subjected to statistical analysis. Therefore, it is again impossible to state with absolute certainty which of the various creams formulated is the best. With the data available at present, the only statement that may be made with the utmost confidence is that these creams are all superb decontaminants. The best were those whose components other than the sequestrant were the following:

Ethomid HT-15 and Bentonite

Ethomid HT-15, Alkanol WXN and Bentonite

Dianol G and Bentonite

Dianol G, Dispersant NIW and Bentonite

Glucaterge and Bentonite

Santomerse D and Vee-Gum

Stepanol WAT and Vee-Gum

Triton X-100 and Vee-Gum

It would appear then, from the point of view of the soldier in the field, the most practical decontaminant would be one of these creams, since they do not require water to be available. It could be issued in jars

or collapsible tubes and carried by the soldier on his person.

No careful study has been made on the cost of these formulations. Rough estimates indicate that these creams would cost considerably less, on a weight basis, than household products like Tide, perhaps half as much or even less. Naturally, the cost will depend on the actual formulation finally chosen. Although every one of the creams will perform extremely well, it is most strongly recommended that further studies be undertaken to determine which one should be adopted. The relevant factors to be considered include, in addition to simple efficiency, cost, availability, stability and possibility of skin irritation. A study of this sort could be conducted with small expenditure of time and money, while the results obtained would be invaluable indeed.

Very little work has been done on decontaminating procedures as such. Since the most important aspect of the project to date has been a comparative evaluation of various products, the procedures chosen were those that would simplify this comparison, rather than the most efficient. Accordingly, it is urged that decontaminating procedures as such be investigated. Again, this could be done cheaply in terms of both time and money, particularly in view of all the work already done, and the results would more than justify the small expense.

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Certain general recommendations for decontamination procedures may be given now, however. There is no question but that mechanical action is extremely important. Vigorous brushing or rubbing is strongly recommended, but it should not be so vigorous as to damage the skin in any way, for this may lead to absorption of the contaminant. Three successive washes of about one minute each with a thorough removal of the detergent after each wash would probably be satisfactory. Should an ordinary detergent of the type requiring water be used, the contaminated regions must not be dried between washes, for this makes the residual contamination much more difficult to remove. More than three washes with detergents of this type would probably be useless. The cleansing creams, however, seem to keep on removing more and more material, even after five treatments. It is essential, however, to remove all of the cream after each treatment. This may be accomplished with any suitable material at hand, such as cloth, paper, or even leaves. The use of water with these creams is discouraged, except perhaps as a final rinse.

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Summary.

The most efficient decontaminants found among the common household products are the heavy duty syndets like Tide and the non-ionic All. Of the commercial radiological decontaminants, CP Cleaner is far and away the best. Eighteen different formulations are offered, every one of which is at least the equal of the best commercial products. Eight cleansing cream formulations which do not require the use of water are given. Each one of these creams is at least the equal of the best commercial products.

It is strongly recommended that further studies be undertaken to determine which of the many formulations given should be adapted. Some further work on decontaminating procedures appears likewise desirable.

Respectfully submitted,

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FA:SS:GS:RLM:sc:pmw
10 c oz.

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APPENDIX A

Detergents

(Except Common Household Products)

Trade Name	Manufacturer	Class	Type
Acidolate	White Laboratories, Inc.	Sulfonated oils, etc.	anionic
Advawet NA-6	Advance Solvents & Chemical Corp.	Polyglycol ester	nonionic
Aerosol 22	American Cyanamid Co.	N-octa decyldisodium sulfosuccinamate	anionic
Ahcowet RS	Arnold, Hoffman & Co.	Sulfated fatty acid ester	anionic
Alkanol WXN	E. I. du Pont de Nemours & Co., Inc.	Sodium alkyl aryl sulfonate	anionic
Alro Amine C	Alrose Chemical Co.	Heterocyclic tertiary amine	cationic
Alro Amine O	Alrose Chemical Co.	Heterocyclic tertiary amine	cationic
Alro Amine S	Alrose Chemical Co.	Heterocyclic tertiary amine	cationic
Alrosol C	Alrose Chemical Co.	Fatty alkylol amide condensate	nonionic
Antaron L-135 *	Antara Chemical Div. General Dyestuff Corp.	Sodium-n-methyl-n-oleyl taurate	anionic

* Same as Igepon T-73

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Trade Name	Manufacturer	Class	Type
Antarox A-400 *	Antara Chemical Div. General Dyestuff Corp.	Alkyl phenoxy polyoxy ethylene ethanol	nonionic
Cerfax-1300	E. F. Houghton & Co.	Alkyl polyoxyethylene thioether	nonionic
Carolite 1000	Carlstadt Chemical Co.	Unknown	unknown
CRL-34452	Atlas Powder Co.	Unknown	cationic
CP Cleaner	Enley Products, Inc.	Unknown	unknown
Dergon MF	Arkansas Co.	Alkoxy polyglycol fatty acid ester	nonionic
Detergent 77	Peck's Products Co.	Alkanolamine condensate	nonionic
Detergent 80	Peck's Products Co.	Alkanolamine condensate	nonionic
Detergent T-12	Victor Chemical Works	Nonionic organic phosphate + inorganic phosphate builder	nonionic
Dianol G	Quaker Chemical Products Corp.	Fatty amide condensate	nonionic
Dispersant NIW	Oronite Chemical Co.	Condensation product of ethylene oxide and an alkyl phenol	nonionic
Duponol ME	E. I. du Pont de Nemours & Co., Inc.	Technical lauryl sodium sulfate	anionic

* Same as Igepal CO-630

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Trade Name	Manufacturer	Class	Type
Energetic	Armour & Co.	Polyoxyethylene ester of fatty acids	nonionic
Ethofat	Armour & Co.	Fatty and rosin acids condensed with ethylene oxide	nonionic
Ethomeen C-15	Armour & Co.	Tertiary amines	cationic
Ethomid HT-15	Armour & Co.	An ethylene oxide condensation product of an amide	nonionic
Ethomid HT-25	Armour & Co.	An ethylene oxide condensation product of an amide	nonionic
Ethomid HT-60	Armour & Co.	An ethylene oxide condensation product of an amide	nonionic
G-808	Geigy Co., Inc.	Unknown	anionic
G-809	Geigy Co., Inc.	Unknown	anionic
Glucaterge	Commercial Solvents, Inc.	N-methyl-n-lauryl glucamine	nonionic
Hyamine 1622	Rohm & Haas Co.	Diisobutyl phenoxy ethoxy ethyl dimethyl benzyl ammonium chloride	cationic
Igepal CO-630	Antara Chemical Div. General Dyestuff Corp.	Alkyl phenoxy polyoxyethylene ethanol	nonionic
Janusol	Synethtic Chemical Co.	Mixture of lauryl and myristyl esters containing both primary amino and sulfated groups	nonionic

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Trade Name	Manufacturer	Class	Type
Katapol VP-532	Antara Chemical Div. General Dyestuff Corp.	Alkyl polyoxyethylene glycol amine	cationic
Lipal 450	E. F. Drew & Co.	Fatty acid ester of a poly ether alcohol	nonionic
Maypon 4C	Maywood Chemical Works	Protein condensation product with oleyl chloride	anionic
Maypon SK	Maywood Chemical Works	Protein condensation product with a fatty chloride	anionic
Miranol CM	Miranol Chemical Co.	Derivative of dihydroimidazole	amphoteric
Miranol SM	Miranol Chemical Co.	Derivative of dihydroimidazole	amphoteric
Miranol LF	Miranol Chemical Co.	Derivative of dihydroimidazole	amphoteric
Nacconol NR	National Aniline Div. Allied Chemical & Dye Corp.	Alkyl aryl sulfonate	anionic
Neoprene R	Ultra Chemical Works	Ethylene oxide fatty acid condensate	nonionic
Nonic 218	Sharples Chemicals, Inc.	Polyethylene glycol tertdodecyl thioether	nonionic
Nopcogen 14-L	Nopco Chemical Co.	Fatty amino compound	nonionic
Onyxol 336	Onyx Oil & Chemical Co.	Complex organic amide	cationic
Oronite D60	Oronite Chemical Co.	Alkyl aryl sodium sulfonate	anionic

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Trade Name	Manufacturer	Class	Type
Pax-Lano-Sav	G. H. Packwood Manufacturing Co.	Unknown	soap
Permalene A-100	Refined Products Corp.	Fatty amide condensate	nonionic
pHisoderm	Winthrop-Stearns, Inc.	Sulfonated ether, etc.	anionic
Renex	Atlas Powder Co.	Polyoxyethylene ester of mixed fatty and rosin acids	nonionic
Repcol A-100	Refined Products Corp.	Modified fatty amine condensate	nonionic
RN-600	Riches - Nelson Co.	Fatty amide derivative	nonionic
Santomerse D	Monsanto Chemical Co.	Decyl benzene sodium sulfonate	anionic
SBS-310	Sugar Beet Corp.	Unknown	unknown
Sorapon SF-73	Antara Chemical Div. General Dyestuff Corp.	Sodium alkyl aryl sulfonate	anionic
Stepanol WAT	Stepan Chemical Co.	Triethanol amine salt of lauryl sulfate	anionic
Sterox AJ	Monsanto Chemical Co.	Aliphatic nonionic polyoxyethylene ether	nonionic
Sterox SK	Monsanto Chemical Co.	Polyoxyethylene thioether	nonionic
Sulframin DT	Ultra Chemical Works	Sodium salt of an alkyl amino sulfate	anionic

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Trade Name	Manufacturer	Class	Type
Sulframin E	Ultra Chemical Works	Modified Alkyl aryl sulfonate	anionic
Sulframin LW	Ultra Chemical Works	Sodium salt of an alkyl amino sulfate	anionic
Triton NF	Rohm & Haas Co.	Alkyl aryl polyether alcohol	nonionic
Triton X-100	Rohm & Haas Co.	Alkyl aryl polyether alcohol	nonionic
Tween 20	Atlas Powder Co.	Polyoxyethylene sorbitan monolaurate	nonionic
Tween 21	Atlas Powder Co.	Polyoxyethylene sorbitan monolaurate	nonionic
Ultrawet 30 DS	Atlantic Refining Co.	Alkyl benzene sodium sulfonate	anionic

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APPENDIX B

Human Subjects Characteristics

Subject	Sex	Age	Color	Complexion	Skin	Hair
A	m	35	w	fair	oily	brown
B	m	32	w	dark	oily	brown
C	m	26	w	dark	normal	black
D	m	50	w	fair	normal	blond
E	m	29	w	fair	normal	black
F	m	45	w	freckled	normal	blond
G	f	22	w	freckled	normal	brown
H	m	38	w	fair	oily	brown
I	f	22	w	fair	normal	brown
J	m	24	w	fair	normal	black
K	f	23	w	dark	normal	black
L	m	30	w	fair	normal	black
M	m	25	w	dark	normal	black
N	f	19	w	fair	normal	black
O	m	24	w	fair	normal	brown
P	m	33	w	fair	normal	brown
1	m	19	w	very light	normal	blond
2	m	23	w	reddish	normal	light brown
3	m	18	w	fair	normal	black

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Appendix B (cont)

Subject	Sex	Age	Color	Complexion	Skin	Hair
4	m	21	w	very light	normal	blond
5	m	35	w	dark	normal	black
6	m	29	w	fair	dry	black
7	m	25	n	dark	normal	black
8	m	42	w	sallow	normal	brown
9	m	40	w	fair	normal	brown
10	f	22	w	fair	normal	brown
11	f	20	w	fair	oily	black
12	f	23	w	freckled	dry	auburn
13	m	25	w	dark	normal	brown
14	m	27	w	very light	normal	brown
15	m	28	w	fair	normal	brown
16	m	27	w	fair	normal	brown
17	m	52	n	dark	normal	black
18	m	31	n	dark	normal	black
19	m	58	n	dark	oily	black
20	m	30	w	fair	oily	brown
21	m	55	n	dark	normal	gray
22	m	56	w	fair	normal	blond
23	m	37	w	fair	normal	brown

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Appendix B (cont)

Subject	Sex	Age	Color	Complexion	Skin	Hair
24	m	30	w	fair	oily	brown
25	m	22	n	dark	normal	black
26	m	32	w	reddish	normal	blond
27	m	46	w	fair	normal	blond
28	m	24	w	fair	normal	brown
29	f	25	w	fair	normal	brown
30	m	26	w	fair	normal	black
31	m	31	w	fair	normal	black
32	m	19	w	fair	normal	black
33	m	19	w	reddish	normal	brown
34	m	37	w	fair	normal	gray
35	m	26	w	fair	normal	blond
36	m	27	n	dark	normal	black
37	f	28	w	fair	normal	brown
38	f	23	w	very light	normal	blond
39	m	33	w	fair	normal	brown
40	m	27	w	fair	normal	brown
41	m	25	w	fair	normal	brown
42	m	24	n	dark	normal	black
43	m	28	w	fair	normal	black

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Appendix B (cont)

Subject	Sex	Age	Color	Complexion	Skin	Hair
44	m	27	w	fair	normal	blond
45	f	23	w	fair	normal	blond
46	m	29	w	fair	normal	brown
47	f	33	w	fair	dry	black
48	f	43	w	fair	normal	gray
49	f	31	w	freckled	normal	red
50	m	39	w	dark	oily	brown
51	m	23	w	sallow	normal	brown
52	f	32	w	fair	dry	gray
53	m	36	w	fair	normal	black
54	m	61	w	reddish	normal	gray
55	f	32	w	fair	normal	blond
56	f	58	w	fair	normal	gray
57	m	23	w	very light	normal	brown
58	f	35	w	fair	normal	brown
59	m	66	w	reddish	normal	gray
60	m	32	w	fair	normal	brown
61	f	25	w	olive	oily	brown
62	m	30	w	fair	normal	brown
63	m	26	w	fair	normal	brown

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Appendix B (cont)

Subject	Sex	Age	Color	Complexion	Skin	Hair
64	m	25	w	fair	normal	brown
65	m	31	w	reddish	normal	brown
66	m	31	w	dark	normal	black
67	m	32	w	fair	normal	blond
68	f	25	w	olive	dry	brown
69	f	24	w	olive	normal	brown
70	m	25	w	fair	normal	brown
71	m	28	w	fair	normal	brown
72	m	23	w	dark	normal	brown
73	f	25	n	olive	normal	brown
74	f	25	w	olive	normal	black
75	m	34	w	fair	normal	blond
76	m	21	w	olive	oily	brown
77	m	32	w	fair	normal	black
78	m	30	w	fair	normal	blond
79	f	66	w	olive	normal	gray
80	m	61	w	dark	dry	gray
81	m	25	n	olive	normal	brown
82	m	42	w	fair	normal	brown
83	m	35	w	reddish	dry	red

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Appendix B (cont)

Subject	Sex	Age	Color	Complexion	Skin	Hair
84	m	25	w	dark	oily	black
85	m	31	w	fair	normal	brown
86	f	31	w	fair	oily	brown
87	f	22	w	fair	normal	black
88	m	19	w	fair	normal	brown
89	m	27	w	reddish	dry	red
90	f	32	w	fair	normal	black
91	m	23	w	olive	oily	brown
92	f	29	n	dark	normal	black
93	f	30	w	fair	dry	blond
94	m	28	w	fair	normal	brown
95	f	31	w	sallow	normal	brown
96	m	45	w	fair	normal	brown
97	m	27	w	fair	normal	brown
98	m	26	w	fair	normal	blond
99	f	21	w	very light	normal	blond
100	m	30	w	sallow	normal	brown
101	f	49	w	fair	normal	brown
102	m	22	n	dark	normal	black

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APPENDIX C

Percutaneous Absorption of Fission Products in the Rabbit and Pig.

There is reason to believe that most skin absorption takes place within half an hour after contamination. On the other hand the count obtained from a fission products solution increases greatly as the solution evaporates. Furthermore, if the contaminant is to adhere to the skin to an appreciable degree, it must be applied in the form of a solution or suspension. In order to circumvent these difficulties, the synthetic aoil-fission products contaminant was applied in alcoholic or ethereal rather than aqueous suspensions. In this way, the contaminant adhered strongly and dried thoroughly in a minute or two so that absorption could be measured almost from the moment of application.

For these experiments, the hair was removed with fine animal clippers, circles about one inch in diameter drawn on the skin, and the contaminant placed within these circles. A thin mica end-window Geiger tube was placed in a tight-fitting cardboard cylinder extending about one centimeter beyond the end-window. Counting was done by placing the end of the cardboard cylinder lightly but firmly around the contaminated area. Counts were taken at various intervals. With rabbits, the following results were obtained:

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TABLE I

Percutaneous Absorption of Fission Products in the Rabbit

Time Since Contamination In Minutes	Test Areas (Expressed as Counts Per Minute)										
	1	2	3	4	5	6	7	8	9	10	11[2]
0	45800	3540	10600	10200	5140	7870	10100	11800	8830	7570	25600
10	45400	3680	10900	9280	4820	7280	10200	11300	---	---	---
20	45700	3290	9220	8970	4370	7670	9480	10900	---	---	---
30	45400	3100	9400	9060	4210	7800	9570	---	8700	7440	25500
40	45900	3310	---	---	---	---	---	---	---	---	---
50	44000	3840[2]	---	---	---	---	---	---	---	---	---
60	44800	3452[3]	---	---	---	---	---	---	8660	7240	---
70	---	3970[2]	---	---	---	---	---	---	---	---	---
80	---	3630[3]	---	---	---	---	---	---	---	---	---
90	---	---	---	---	---	---	---	---	9430	7900	---
105	---	---	---	---	---	---	---	---	9190	---	---
Per Cent Difference Between First And Last Counts	-2.3	+2.5	-11.0	-11.0	-18.1	-0.9	-5.2	-7.5	+4.0	+4.3	-0.4

Note:

1. No soil was mixed with the fission products for this one run.
2. The skin was crowded together for counting.
3. The skin was stretched out for counting.

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A few similar experiments were performed on a young pig. Because of the difficulties encounted in handling the animal, only two counts were taken each time, one as soon as the contaminant had dried and the other one hour later,

TABLE II

Percutaneous Absorption of Fission Products in the Pig.

Initial Count	Count After One Hour	Per Cent Change
12700	12800	+ 1.0
15500	15200	- 2.1
18400	18600	+ 0.9
20000	19200	- 4.0

The reproducibility of these experiments was somewhat lower than had been hoped for. On the other hand, it must be considered that live rabbits and pigs are quite lively subjects that often refuse to remain still for any length of time, and many activity determinations had to be made while the animal was moving. In addition, the extreme looseness of the skin of the rabbit introduces an additional error by altering the counting geometry. This effect is evident in the last four figures in the second column of Table I. There, the two low counts were obtained when

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the skin was stretched, and the two high counts when the skin was crowded together. These two skin conditions, although produced manually, approached fairly closely the effect on the skin of various positions assumed by the animals during the course of an experiment.

A careful consideration of the data obtained as well as of the nature of the experimental difficulties involved indicates that percutaneous absorption of the contaminant used probably does not exceed two or three per cent in either the rabbit or the pig.

In order to determine whether there was any selective absorption of the contaminant by the various organs of the rabbit, a series of experiments was performed. The backs of the animals were clipped as usual, a measured amount of fission products solution, equivalent to about 1.06×10^6 counts per minute, was place thereon and allowed to remain for varying lengths of time. The animals were then anesthesized with Nembutal administered intravenously, washed, and sacrificed. The organs chosen for study were removed, dissolved in hot nitric acid, partially ashed, finely ground, thoroughly mixed, and weighed. A sample weighing from 10 to 50 mg was then placed in a planchet and counted.

The portion of skin used consisted of the entire contaminated area and about as much more surrounding area. The bones were femur, tibiae,

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and fibulae. The amount of blood used varied from 20 to 30 ml. and is indicated in each individual case. Asterisks indicate that the uncorrected activity of the aliquot counted was less than twice background, and hence not entirely reliable. The figures in the third column were obtained by multiplying the specific activity found by the total weight of the organ. The first three runs were made using fission products alone; the last three, using the usual synthetic-soil fission products suspension.

TABLE III

Percutaneous Absorption in the Rabbit Skin Washed With 1:6 Radiacwash

Hours Elapsed Between Contamination and Sacrifice	Organ	Counts Per Minute	Per Cent of Applied Activity
4	Skin	1.01×10^5	10.4
	Bones	1.31×10^3	0.12 *
	Liver	4.95×10^2	0.05 *
	Blood (20 ml)	2.53×10^2	0.02 *
	Urine (40 ml)	1.61×10^2	0.015

Table III (cont)

Hours Elapsed Between Contamination and Sacrifice	Organ	Count Per Minute	Per Cent of Applied Activity
67.5	Skin	1.72×10^5	16.2
	Bones	2.09×10^3	0.20
	Liver	2.37×10^3	0.22
	Blood (20 ml)	1.77×10^3	0.17 *
	Kidneys	3.90×10^2	0.04
124	Skin	1.75×10^5	16.2
	Bones	1.27×10^3	0.12 *
	Liver	8.18×10^2	0.08 *
	Blood (40 ml)	4.25×10^2	0.04 *
2	Skin	4.15×10^4	5.5
	Liver	Background	0
	Blood (40 ml)	2.41×10^3	0.32
26.5	Skin	2.58×10^3	0.24
	Bones	1.24×10^2	0.01 *
	Liver	6.76×10^2	0.06 *
	Blood (40 ml)	Background	0

Table III (cont)

Hours Elapsed Between Contamination and Sacrifice	Organ	Count Per Minute	Per Cent of Applied Activity
95	Skin	3.23×10^4	3.05
	Bones	2.00×10^4	1.97
	Liver	1.10×10^3	0.10 *
	Blood (21 ml)	Background	0

These figures substantiate the earlier conclusion that percutaneous absorption of fission products in the rabbit is small.