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Operation

SUN BEAM

SHOTS LITTLE FELLER I, II, JOHNIE BOY, AND SMALL BOY

PROJECT OFFICERS REPORT—PROJECT 7.17

RADIOLOGICAL WATER DECONTAMINATION STUDY (U)

Don C. Lindsten, Project Officer

U.S. Army Engineer Research and
Development Laboratories
Fort Belvoir, Virginia

Issuance Date: April 29, 1963

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PROJECT OFFICERS REPORT — PROJECT 7.17

RADIOLOGICAL WATER DECONTAMINATION STUDY (U)

by Don C. Lindsten, ~~Project Officer~~

U.S. Army Engineer Research and Development Laboratories
Fort Belvoir, Virginia

DEPARTMENT OF DEFENSE
WASHINGTON 25, D.C.

ABSTRACT

In the event of a future world conflict, it is not only possible, but probable, that nuclear weapons will be used. It is imperative, therefore, that the U. S. Army establish defensive measures of all types against nuclear attack. The assigned responsibilities of the Corps of Engineers in the field of water supply and sanitation require that special consideration be given to the problems associated with the contamination of water supplies. It is mandatory that potable and uncontaminated water be furnished Army troops for drinking, washing, culinary, bathing, laundering, and dehydrated-food-reconstitution purposes. To meet this requirement, the Corps of Engineers has conducted a continuing research program through the years to determine effective methods of decontaminating water contaminated with radioactive materials. It was the purpose of this study to extend the state-of-the-art to areas of uncertainty, or to areas in which little, if any, data were available. In particular, the objectives of Project 7.17 were to study (1) the solubility of radioactive debris in water, (2) emergency methods of removing radioactive materials from water, (3) field methods of determining the concentration

of radioactive materials in water, and (4) a squad type universal CBR method of water decontamination.

From the results obtained under this study it is concluded that:

(1) The solubility of radioactive debris increased with a decrease in pH and an increase in temperature, but the change was not significant in the pH and temperature variations for normal drinking water supplies.

(2) The solubility of radioactive debris was not markedly affected by contact time. Increases in solubility with time were alleviated by decreases in contamination through radioactive decay.

(3) The solubility of radioactive debris was significant enough to require water demineralization to produce drinking water within the acceptable one year and one month drinking water tolerance levels.

(4) Radioactive debris from surface detonations can be colloidal and remain in suspension in water for extended periods of time and be readily transported to downstream water sources.

(5) Emergency type water purification methods such as filtration through clay and paper, batch coagulation, filtration through a cellulose filter disc, and molded

filter candles effectively reduced radioactive contaminants to short range (less than 30 day) drinking water tolerance levels. Higher removals of activity (approaching 100 percent) were obtained by the addition of an ion exchange process as a post-treatment to the above methods.

6. The standard IM-141/PDR-27J Radiacmeter and the CDV-700 meter can be used satisfactorily in the field to qualitatively determine whether water supplies are above or below the drinking water tolerance levels and to assist water point operation relative to adequacy of the operating water decontamination procedures.

PREFACE

This study was sponsored jointly by the Defense Atomic Support agency and the U. S. Army Corps of Engineers. Financing was accomplished under Corps of Engineers project 8M75-05-001, task 8M75-05-001-07, "Removal of CBR Contaminants from Water"; and also by Office of Civil Defense project 3103C, "Use of Clay Materials for Emergency Decontamination of Water Supplies."

The analysis of the water used in all tests was furnished by the U. S. Geological Survey.

CONTENTS

TABLES

FIGURES

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The objectives of Project 7.17 were: (1) to study the effect of pH, temperature, and time of contact upon the solubility of radioactive bomb debris in water; (2) to evaluate proposed emergency methods of removing radioactive materials from water; (3) to evaluate Army and Civil Defense field type methods of determining the concentration of radioactive materials in water; and (4) to evaluate a proposed Army squad type general CBR decontamination method for removing radioactivity from water.

1.2 BACKGROUND

The assigned responsibilities of the U. S. Army Corps of Engineers in the field of water supply and sanitation require that special consideration be given to the decontamination problems associated with the use of nuclear weapons. It is mandatory that potable and uncontaminated water be furnished in the field for drinking, washing, culinary, bathing, laundering, and dehydrated-food-reconstitution purposes. To meet this requirement, the Corps of Engineers established Research and Development Project "Removal of

CBR Contaminants from Water," currently designated Task 8M75-05-001-07. Most of the initial research was accomplished at the Sanitary Sciences Branch Test Station at the Oak Ridge National Laboratory (ORNL), operational from 1950 to 1957. At ORNL, numerous decontamination experiments were conducted using reactor-produced mixed fission products and a wide variety of individual radioisotopes. Some limitations were placed on this work, however, since true bomb debris or fallout probably differs appreciably from the reactor-produced materials actually used. Radiological decontamination work was also conducted with the cooperation of the Atomic Energy Commission (AEC) and the Defense Atomic Support Agency (DASA) at the Nevada Test Site (NTS) under Operations Buster, Jangle, and Plumbbob, and with the radioactive material obtained from Hardtack II. Formal U. S. Army Engineer Research and Development Laboratories (USAERDL) reports 1275, 1313, 1357, 1396, 1404, 1406, 1451, 1492, 1569, 1613, 1673, and 1702 were written covering the results of the studies. A synopsis of each of these reports, plus availability at the Armed Services Technical Information Agency and the Office of Technical Services is given in the Appendix. The results obtained under Buster and Jangle are contained in DASA reports under these operations. Certain areas, where only limited information is presently available, still needed investigation; These were: (1) Solubility of nuclear bomb debris in water, (2) Emergency methods of water decontamination, (3) Field type water monitoring, and (4) Efficacy of a proposed CBR squad-type water purification method of removing radioative materials from water.

CHAPTER 2

PROCEDURE AND RESULTS

2.1 SOIL SAMPLING

Radioactive debris for the study was obtained from each of four nuclear bursts. The technique of obtaining the debris was as follows:

Little Feller II. Detonated 7 July 1962. Soil sample taken from center of crater 12 July 1962.

Johnie Boy. Detonated 11 July 1962. Soil sample taken from surface of ground at 10r/hour line 12 July 1962.

Small Boy. Detonated 14 July 1962. Soil sample scraped from surface of ground at 10r/hour line 18 July 1962.

Little Feller I. Detonated 17 July 1962. Soil sample taken from center of crater 19 July 1962.

In each instance, the soil sample was removed to an area of low radiation and sieved through a U. S. Standard sieve number 40. The coarse fraction was rejected, and the fine fraction retained in sample bottles, for use. The sample bottles were stored in a locked magazine (Figure 2.1). The specific activity of each sample was determined as a function of time (Figure 2.2).

2.2 GENERAL

The experimental work under this project was conducted in the vicinity of the AEC-operated Radiological Safety Decontamination Station in the mountain pass between Frenchman and Yucca Flats, NTS. Figure 2.3 is an overall photographic view of the test installation. The installation consisted primarily of a Mobile Chemical Laboratory and a Mobile Radiac Laboratory.

All chemical tests and jar test experiments were conducted in the Chemical Laboratory, and all counting was conducted in the Radiac Laboratory. Both laboratories were electrified by means of a hook-up to the local power system. In addition, the Chemical Laboratory was provided with domestic fresh water. The waste line from the sink in the Chemical Laboratory drained into a retention pond receiving run-off from the AEC decontamination pad.

Sample preparation was accomplished by evaporation to dryness under an infra-red lamp of an appropriate volume of sample water in a planchet. The residue in the planchet was counted by placing the planchet into the top shelf of a Nuclear-Chicago shield containing a Model DS-5 anthracene crystal beta detector connected to a Model 151A Decade

Scaler (Figure 2.4). The geometry of the instrument was established at 7.1 percent, with a standard thallium-204 solution.

The general area background was monitored continuously by means of a Nuclear-Chicago Model DS-5 sodium iodide (thallium activated) gamma scintillation detector connected to a Model 1620 Count Rate Meter and a Texas Instrument continuously recording Rectiriter (Figure 2.5).

2.3 SOIL SOLUBILITY

The water used for conducting the soil solubility studies, and all subsequent studies, had the analysis shown in Table 2.1. The water had a total dissolved solid content of 254 ppm. It was high in silica (76 ppm). The principal cations were sodium (39 ppm), calcium (20 ppm), and magnesium (11 ppm). The principal anions were bicarbonate (189 ppm) and sulfate (23 ppm). It was low in chlorides (6.5 ppm). The beta radiological activity was 12 pc/liter.

The procedures for conducting the soil solubility studies are given in Tables 2.2 through 2.7. The results are also given in Tables 2.2 through 2.7.

2.4 CIVIL DEFENSE WATER DECONTAMINATION

The procedures for conducting the Civil Defense water decontamination studies are given in Tables 2.8 through 2.15. The equipment used in the Flower Pot Procedure is shown in Figure 2.6. An exploded view of a flower pot set-up is shown in Figure 2.7. The equipment used in the Paper Procedure is shown in Figure 2.8.

The results of these studies are given in Tables 2.8 through 2.15.

2.5 FIELD DETECTION

The procedures for conducting the field detection studies are given in Tables 2.16 through 2.18. Figure 2.9 shows the IM-141/PDR-27J Radiacmeter in use. Figure 2.10 shows the CDV-700 meter in use.

The results of the field detection studies are also given in Tables 2.16 through 2.18.

2.6 CBR SQUAD DECONTAMINATION

The procedure for conducting the CBR squad decontamination is given in Table 2.19. Figure 2.11 shows the CBR squad decontamination equipment.

The results of the CBR squad decontamination study are given in Table 2.19.

TABLE 2.1 WATER ANALYSIS, WELL 3, NTS

Sample Collected 19 December 1961

Chemical Components	PPM
Silica (SiO_2)	76
Aluminum (Al)	0.27
Iron (Fe)	0.00
Manganese (Mn)	0.00
Calcium (Ca)	20
Magnesium (Mg)	11
Sodium (Na)	39
Potassium (K)	7.6
Lithium (Li)	0.00
Bicarbonate (HCO_3)	189
Carbonate (CO_3)	0
Sulfate (SO_4)	23
Chloride (Cl)	6.5
Fluoride (F)	0.9
Nitrate (NO_3)	7.4
Phosphate (PO_4)	0.12

Physical Characteristics and computed values	
Dissolved solids (ppm) Res. on evap. (180°C)	254
Calculated	285
Hardness ($CaCO_3$)(ppm) Total	95
Non-carbonate	0
Specific Conductance (μmhos at 25°C)	376
pH	7.5
Radiochemical Data	
Beta activity (pc/l) as of 3/22/62	12 ± 2
Strontium 90 (pc/l)	< 0.4

TABLE 2.2 SOLUBILITY OF LITTLE FELLER II DEBRIS AS A FUNCTION OF PH, RUN NO. 1 (24 July 1962)

Procedure:

1. Add 70 grams Little Feller II debris (17 days old, specific activity 45 uc/gram) to 35 liters of water in 11-gallon plastic drum. Agitate.

2. Add 600 ml of the suspension to each of 4, 1000-ml beakers.

3. Agitate, and add the following: (1) beaker 1, 1 ml conc. hydrochloric acid, (2) beaker 2, 0.2 ml conc. hydrochloric acid, (3) beaker 3, nothing, and (4) beaker 4, 20 ml N/10 NaOH solution.

4. Stir for 1 hour at high speed.

5. Sample suspensions, filter through Whatman paper, and check filtrate for pH, alkalinity, hardness, and radioactivity count.

Radiological Data

Beaker	Radioactivity Concentration: Suspension (pc/l)	Radioactivity Concentration: Filtrate (pc/l)	Percent Solubility
1	90,000,000	4,600,000	5.1
2	90,000,000	3,600,000	4.0
3	90,000,000	6,300,000	7.0
4	90,000,000	3,600,000	4.0

Chemical Data

Beaker	pH	Alkalinity (ppm)	Hardness (ppm)
1	2.1	-820	108
2	3.5	-14	108
3	8.4	163	103
4	10.0	300	66

TABLE 2.3 SOLUBILITY OF JOHNIE BOY DEBRIS AS A FUNCTION OF PH, RUN NO. 2 (25 JULY 1962)

Procedure:

Same as run number 1 (see Table 2.2). Johnie Boy debris 14 days old, specific activity 5.2 μc/gram.

Radiological Data

Beaker	Radioactivity Concentration Suspension (pc/l)	Radioactivity Concentration Filtrate (pc/l)	Percent Solubility
1	10,000,000	550,000	5.5
2	10,000,000	460,000	4.6
3	10,000,000	340,000	3.4
4	10,000,000	260,000	2.6

Chemical Data

Beaker	pH	Alkalinity (ppm)	Hardness (ppm)
1	2.1	-859	142
2	4.5	4	136
3	8.5	174	104
4	10.1	298	55

TABLE 2.4 SOLUBILITY OF SMALL BOY DEBRIS AS A FUNCTION OF PH, RUN NO. 3 (26 JULY 1962)

Procedure:

Same as run number 1 (see Table 2.2). Small Boy debris 12 days old, specific activity 22 μc/gram.

Beaker	Radiological Data: Radioactivity Concentration, Suspension (pc/l)	Radiological Data: Radioactivity Concentration, Filtrate (pc/l)	Percent Solubility
1	44,000,000	3,600,000	8.2
2	44,000,000	2,000,000	4.6
3	44,000,000	2,200,000	5.0
4	44,000,000	1,700,000	3.9

Chemical Data

Beaker	pH	Alkalinity (ppm $CaCO_3$)	Hardness (ppm $CaCO_3$)
1	2.4	-342	292
2	8.2	94	241
3	8.6	183	114
4	10.0	279	42

TABLE 2.5 SOLUBILITY OF LITTLE FELLER I DEBRIS AS A FUNCTION OF PH, RUN NO. 4 (26 JULY 1962)

Procedure:

Same as run number 1 (see Table 2.2), except separate 1.2 gram quantities of debris were weighed directly into each beaker (specific activity of 9 day old Little Feller I debris; 45 μc/gram).

Radiological Data

Beaker	Radioactivity Concentration		Percent Solubility
	Suspension (pc/1)	Filtrate (pc/1)	
1	90,000,000	13,000,000	14
2	90,000,000	9,900,000	11
3	90,000,000	12,000,000	13
4	90,000,000	8,300,000	9

Chemical Data

Beaker	pH	Alkalinity (ppm $CaCO_3$)	Hardness (ppm $CaCO_3$)
1	2.1	-181	194
2	6.5	20	154
3	8.5	178	106
4	10.0	240	60

TABLE 2.6 SOLUBILITY OF SMALL BOY DEBRIS AS A FUNCTION OF TIME, RUN NO. 5 (24 JULY 1962)

Procedure:

1. Add 1.2 grams of Small Boy debris (10 days old, specific activity 28 μc/gram) to 600 ml water in a 1,000-ml beaker.

2. Agitate at high speed, sample, filter and count: 1 min, 10 min, 1 hour, and 24 hour contact time.

3. Analyze 24 hour filtrate for pH, alkalinity, and hardness.

	Radiological Data		
	Radioactivity Concentration		
Contact Time	Suspension (pc/l)	Filtrate (pc/l)	Percent Solubility
1 min	56,000,000	3,100,000	5.5
10 min	56,000,000	3,400,000	6.1
1 hour	56,000,000	3,800,000	6.8
24 hour	56,000,000	3,300,000	5.9

Chemical Data	
24 hour Filtrate	
pH	8.6
Alkalinity (ppm)	189
Hardness (ppm)	113

TABLE 2.7 SOLUBILITY OF SMALL BOY DEBRIS AS A FUNCTION OF TEMPERATURE, RUN NO. 6 (27 JULY 1962)

Procedure:

1. Weigh out three 1.2-gram portions of debris.
2. Add 600 ml tap water to each of three 1000-ml beakers.
3. Chill beaker 1 in ice bath; maintain beaker 2 at room temperature; and heat beaker 3 to boiling point.
4. Stabilize temperatures, add debris to each beaker, and stir for 1 hour.
5. Sample, centrifuge, and count supernatant.

Radiological Data

Beaker	Water Temperature (°F)	Radioactivity Concentration Suspension (pc/1)	Radioactivity Concentration Centrifugate (pc/1)	Percent Solubility
1	36	44,000,000	1,900,000	4.3
2	79	44,000,000	2,200,000	5.0
3	212	44,000,000	3,000,000	6.8

TABLE 2.8 DECONTAMINATION OF WATER CONTAMINATED WITH NUCLEAR BOMB DEBRIS BY THE FLOWER POT PROCEDURE, RUN NO. 7

DATE: 30 July 1962

OBJECTIVE: To evaluate the effectiveness of the flowerpot procedure for removing radioactivity from well water contaminated with debris from shot LITTLER FELLER I.

CONTAMINATED WATER: Suspension of 70 grams of debris (specific activity, 28 μc/gram) in 35 liters of water.

CONTAMINATED WATER ANALYSIS: Activity 56,000,000 pc/l, turbidity 110 units, pH 8.4, total hardness 103 ppm ($CaCO_3$) alkalinity 163 ppm ($CaCO_3$).

PROCEDURE:
1. Prepare flower pot filter as follows:
   a. Cut circular piece of metal screen to cover bottom of pot.
   b. Lay 2 sheets of toilet tissue over screen.
   c. Carefully add soil to minimum depth of 5 cm.
   d. Cover soil with layer of small stones.
2. Filter 1 liter of well-mixed contaminated water.
3. Measure filtrate volume and collection time.
4. Analyze filtrate for activity, pH, total hardness, alkalinity, turbidity.
5. Filter most turbid and least turbid filtrate thru steam iron demineralizer; check activity.

Flower Pot(a) Number	Soil (b)	Filtrate Volume (ml)	Time (min)	Filtration Rate (ml/min)	pH	Total Hardness (ppm $CaCO_3$)	Alkalinity (ppm $CaCO_3$)	Turbidity Units	Activity (pc/l)	Activity Removal (%)	Thru Steam Iron Unit Activity	Thru Steam Iron Unit Total Removal (%)
1	Leon	720	10	72	5.2	22	20	120	4,100,000	92.7	1,500,000	96.3
2	Sassafras	250	200c	1	7.6	168	102	4	930,000	98.3		
3	Trumbull	[illegible]00	200c	1	5.5	84	26	5	890,000	98.4		
4	Diablo	600	130	5	7.6	224	192	4	2,200,000	96.1		
5	Hagerstown	600	120	5	7.3	172	136	4	970,000	98.3		
6	Belvoir	650	35	19	5.1	20	16	2	890,000	98.4		
7	Belvoir	530	35	15	4.9	26	12	2	760,000	[illegible]	0	100

(a) Dimensions: Diameter, top 15cm, bottom 10 cm; height 17cm
(b) Volume - #1 thru #6 - 600 ml; #7, 800 ml.
(c) Filtration stopped at 200 min.

TABLE 2.9 DECONTAMINATION OF WATER CONTAMINATED WITH NUCLEAR BOMB DEBRIS BY THE PAPER PROCEDURE, RUN NO. 8

DATE: 31 July 1962

OBJECTIVE: To evaluate the effectiveness of the paper procedure for removing radioactivity from well water contaminated with debris from shot LITTLE FELLER I.

CONTAMINATED WATER: Suspension of 70 grams of debris (specific activity, 28 μc/gm) in 35 liters of water.

CONTAMINATED WATER ANALYSIS: Activity 50,000,000 pc/l, turbidity 110 units, pH 8.4, total hardness 103 ppm ($CaCO_3$), alkalinity 103 ppm ($CaCO_3$).

PROCEDURE:
1. Add to 1 liter of contaminated water in an erlenmeyer flask 1 gm of soil.
2. Shake intermittently for 30 minutes.
3. Settle 15 minutes.
4. Decant into second flask.
5. Add 10 sheets of shredded toilet tissue.
6. Shake vigorously, to pulp, for 5 minutes.
7. Filter thru household strainer (16 mesh) lined with paper towel, collecting filtrate in saucepan.
8. Analyze this first filtrate for volume, collection time turbidity, and activity.
9. Return filtrate to flask.
10. Add 10 sheets shredded toilet tissue.
11. Shake vigorously, to pulp, for 5 minutes.
12. Filter thru clean paper towel into saucepan.
13. Analyze product for volume, collection time, pH, turbidity, hardness, alkalinity and activity.

TABLE 2.9 (CONTINUED)

Chemical Data

Test Number	Soil	First Filtrate Volume (ml)	First Filtrate Turbidity (units)	Second Filtrate Volume (ml)	Second Filtrate Turbidity (units)	pH	Total Hardness (ppm $CaCO_3$)	Alkalinity (ppm $CaCO_3$)
1	Leon	890	10	760	5	7.6	126	212
2	Sassafras	860	10	780	5	8.1	130	212
3	Trumbull	810	10	700	5	8.2	128	218
4	Chester	[illegible]	10	700	5	3.2	123	214
5	Hagerstown	820	10	700	5	8.2	132	224
6	Belvoir	830	10	710	5	8.1	130	224

Collection time - First filtrate - 85 min, Second filtrate - 40 mins - total 125 mins.

Radioactivity Data

Test Number	First Filtrate pc/l	First Filtrate Activity Removal Percent	Second Filtrate pc/l	Second Filtrate Activity Removal Percent
1	6,800,000	86	5,800,000	88
2	6,400,000	87	5,500,000	89
3	5,600,000	[illegible]	5,300,000	89
4	6,200,000	8[illegible]	5,500,000	89
5	7,100,000	86	5,600,000	[illegible]
6	6,600,000	87	6,200,000	[illegible]

NOTE: Passing second filtrate of Test Number 2 thru household steam iron water treatment unit gave a total activity removal of 99.[illegible] percent.

TABLE 2.10 DECONTAMINATION OF WATER CONTAMINATED WITH NUCLEAR BOMB DEBRIS BY THE PAPER PROCEDURE MODIFIED, RUN NO. 9

DATE: 31 July 1962

OBJECTIVE: To determine the effects of not adding 1 gm of soil in the paper procedure as described in Table 2.9.

CONTAMINATED WATER: Same as Table 2.9.

PROCEDURE:
1. Take 1 liter of contaminated water in an erlenmeyer flask.
2. Settle 15 minutes.
3. Decant into second flask.
4. Add 10 sheets of shredded toilet tissue.
5. Shake vigorously, to pulp, for 5 minutes.
6. Filter thru household strainer (16 mesh) lined with paper towel, collecting filtrate in saucepan.
7. Check filtrate for activity.

Sample Number	Filtrate Activity (pc/l)	Activity Removal (Percent)
1	8,100,000	84
2	7,400,000	85

NOTE: An average removal of 97 percent was obtained with the paper procedure with soil addition (1000 ppm Belvoir soil) (Table 2.9).

TABLE 2.11 EFFECT OF ADDED SOIL IN THE DECONTAMINATION BY FILTRATION OF WATER CONTAMINATED WITH NUCLEAR BOMB DEBRIS, RUN NO. 10

DATE: 31 July 1962

OBJECTIVE: To evaluate the benefit of adding soil to contaminated water before filtration.

CONTAMINATED WATER: Same as Table 2.9.

PROCEDURE:
1. Take five 1-liter quantities of contaminated water in erlenmeyer flasks.
2. To each of three flasks add 1 gm of Belvoir soil and shake intermittently for 30 minutes.
3. Filter all samples through membrane filter (0.45 micron).
4. Analyze filtrate for activity.

Sample Number	Belvoir Soil Added (ppm)	Filtrate Activity Activity (pc/l)	Activity Removal (Percent)
1	0	4,600,000	91
2	0	5,100,000	90
3	1,000	4,500,000	91
4	1,000	4,200,000	92
5	1,000	4,900,000	90

TABLE 2.12 DECONTAMINATION OF WATER CONTAMINATED WITH NUCLEAR BOMB DEBRIS BY FILTRATION THROUGH VARIOUS MEDIA, RUN NO. 11

DATE: 1 August 1962

OBJECTIVE: To evaluate the activity removal efficiency of the flower pot filter containing as filter medium various common household materials.

CONTAMINATED WATER: Suspension of 70 grams LITTLE FELLER II debris (specific activity, 25 $\mu c/gm$) in 35 liters of well water - activity 50,000,000 pc/l.

PROCEDURE:
1. Prepare flower pot filter as follows:
   a. Cut circular screen and fit over bottom of pot.
   b. Lay 2 sheets of toilet tissue over screen.
   c. Cover with filter medium to level of 21 cm.
   d. Lay screen over medium (except sand), compress with heavy rock.
2. Pour 1 liter of contaminated water thru filter.
3. Check activity of filtrate.

Sample Number	Filter Medium	Filtrate Activity (pc/l)	Activity Removal (Percent)
1	Vermiculite	3,500,000	93
2	Peat Moss	4,000,000	92
3	Aquarium Sand	3,500,000	93
4	Shredded Wheat Biscuits (Crushed)	7,200,000	86

NOTE: Filtration of a clarified water (membrane filter) of 2,100,000 pc/l activity through a vermiculite flower pot filter produced an activity removal of 5 percent.

TABLE 2.13 DECONTAMINATION OF WATER CONTAMINATED WITH NUCLEAR BOMB DEBRIS BY A DIATOMACECUS CANDLE FILTER, RUN NO. 12

DATE: 25 July 1962

OBJECTIVE: To evaluate the effectiveness of a diatomaceous candle filter for removing radioactivity from well water contaminated with shot Little Feller II debris.

CONTAMINATED WATER: Suspension of 70 gms of debris (18 days old, specific activity 41 μc/gm) in 35 liters of water.

CONTAMINATED WATER ANALYSIS: Activity 83,000,000 pc/l, turbidity 190 units, pH 8.4, total hardness 103 ppm ($CaCO_3$), and alkalinity 163 ppm ($CaCO_3$).

PROCEDURE:
1. Stir suspension vigorously during entire pumping operation.
2. Sample and measure turbidity and count.
3. Collect 500 ml fractions of filtrate.
4. Operate unit until pumping becomes difficult.
5. Analyze filtrate for turbidity and activity.

Beaker	Volume (ml)	Turbidity (units)	Activity (pc/l)	Activity Removal (%)
1	500	--	3,000,000	96
2	500	1	2,[illegible]00,000	97
3	500	--	3,000,000	96
4	500	--	2,500,000	97

TABLE 2.14 DECONTAMINATION OF WATER CONTAMINATED WITH NUCLEAR BOMB DEBRIS BY A RESIN-CARBON FILTER UNIT, RUN NO. 13

DATE: 27 July 1962

OBJECTIVE: To evaluate the effectiveness of a resin-carbon filter unit, combining ion exchange, carbon adsorption and filtration, for removing radioactivity from well water contaminated with Shot Small Boy debris.

CONTAMINATED WATER: Supernatant from slurry of Small Boy debris after settling 48 hours.

CONTAMINATED WATER ANALYSIS: Activity 3,200,000 pc/l, turbidity 140 unit, pH 8.6, total hardness 114 ppm ($CaCO_3$), and alkalinity 183 ppm ($CaCO_3$).

PROCEDURE:
1. Add 1 liter of contaminated water to bag of unit.
2. Mix water and solids in bag 1/2 hour.
3. Suspend bag.
4. Collect 200 ml fractions of product in calibrated beakers, recycling first 800 ml before sampling for analysis.
5. Analyze each fraction for pH, turbidity, conductivity, and activity.

Beaker	Volume (ml	pH	Turbidity (units)	Conductivity (mg/l NaCl)	Activity (pc/l)	Activity Removal (%)
1	200	7.6	5	1.1	12,700	99.6
2	200	7.6	2	0.8	12,700	99.6
3	200	7.6	1	1.0	3,800	99.9
4	35	7.6	1	1.6	5,100	99.8

TABLE 2.15 DECONTAMINATION OF WATER CONTAMINATED WITH NUCLEAR BOMB DEBRIS BY A STANDARD ARMY 1/4-GPM WATER PURIFICATION UNIT, RUN NO. 14

DATE: 4 August 1962

OBJECTIVE: To evaluate the effectiveness of the standard Army Set No. 1 water purification unit (Hand-Operated, Knapsack-Pack, Filter-Pad-Type, 1/4 GPM) for removing radioactivity from well water contaminated with Shot Small Boy debris.

CONTAMINATED WATER: Suspension of 126 gms of debris (specific activity, 11 μc/gm) in 50 liters of water allowed to stand overnight, agitated, and settled for 1 hour. Activity 28,000,000 pc/l.

PROCEDURE:
1. Mix suspension well.
2. Settle 1 hour; sample supernatant.
3. Pump supernatant through unit.
4. Measure activity of supernatant and filtrate.

Sample	Acitivity (pc/l)	Process	Activity Removal (%)
Raw Water, mixed	28,000,000		
Supernatant	4,600,000	Settling	84
Supernatant, centrifuged	990,000		
Filtrate	1,100,000	Settling plus filtration	96
		Filtration of settled water (considering supernatant as raw water)	76

TABLE 2.16 FIELD DETECTION WITH IM-141/PDR-27J RADIACMETER, RUN NO. 15 (27 JULY 1962)

Procedure:

1. Add 1000-, 100-, and 1-gram quantities of Small Boy debris (13 days old, specific activity 22 μc/gram) to each of four 20-gallon plastic drums containing 50 liters of tap water.

2. Agitate.

3. Leave beta shield of IM-141/PDR-27J Radiacmeter intact and cover the entire probe assembly with a rubber surgeon's glove. Wrap and tape the loose fingers of the glove around the probe to give a neat appearance. Insert sheathed probe vertically into water. Take reading in mr/hr.

Time After Detonation (days)	IM-141/PDR-27J Reading (mr/hr)	Concentration of Radioactivity (pc/l)
13	0.2	440,000
13	1.0	4,400,000
13	15.	44,000,000
13	72.	440,000,000
17	0.15	320,000
17	0.6	3,200,000
17	9.	32,000,000
17	40.	320,000,000

NOTE: U. S. Army emergency maximum permissible concentration of radioactive material in drinking water for 1-year consumption: 300,000 pc/l.

TABLE 2.17 FIELD DETECTION WITH 1M 141-PDR-27J RADIACMETER AND CDV-700 METER, RUN NO. 16 (4 AUGUST 1962)

Procedure:

1. Add 1.3, 4.2, 12.6, 42, 126, and 416 grams of Small Boy soil (specific activity 11 μc/gram) to each of six 20 gallon plastic drums containing 50 liters of tap water.

2. Agitate.

3. Take reading with meters as indicated.

Tank	Concentration of Radioactivity (pc/l)	1M141-PDR-27J Meter: Surgeons Glove around probe assembly. Beta shield closed (mr/hr)	1M141-PDR-27J Meter: Condom on each probe (separated). Beta shield open. (mr/hr)	CDV-700: Condom on probe. Beta shield open (mr/hr)
1	290,000	0.10	0.14	0.13
2	920,000	0.23	0.23	0.18
3	2,800,000	0.55	0.65	0.45
4	9,200,000	1.65	1.85	1.60
5	28,000,000	4.8	6.0	4.7
6	92,000,000	14.5	19.0	18.0

Age of nuclear debris: 21 days

General area background: 0.07 mr/hr

TABLE 2.18 EVALUATION OF CIVIL DEFENSE 10-DAY WATER STANDARD UNIT CD V-787, RUN NO. 17

DATE: 1 August 1962

OBJECTIVE: To evaluate a Civil Defense unit used on a "go - no go" basis to determine whether the radioactivity of contaminated drinking water exceeds the 10-day water tolerance level.

CONTAMINANT: Debris from Shot Little Feller II (25 days old, specific activity 25 uc/gram)

PROCEDURE:

1. Weigh out the desired weight of debris into unit container
2. Add 76 ml well water (to level of indentation)
3. Place open probe of Civil Defense survey meter #CD V-787 over container.
4. Compare reading with reading over 10-day standard.
5. Measure area background.

Measurement No.	Debris Weight (gram)	Activity in Water (pc/l)	Meter (CD V-700) Reading (mr/hr)
Standard	—	—	2.8
Background	—	—	0.1
1	0.003	1,000,000	0.1
2	0.152	50,000,000	0.9
3	0.304	100,000,000	1.5
4	1.52	500,000,000	7.0

TABLE 2.19 USE OF SQUAD CBR DECONTAMINATION PROCEDURE FOR REMOVAL OF NUCLEAR DEBRIS FROM WATER, RUN NO. 18 (1 AUGUST 1962)

Procedure:

1. Fill Lyster bag to 36 gallon mark with water. Water sample analysis; pH 7.9, alkalinity 160 ppm, hardness 104 ppm, temperature 56°F.

2. Add 273 grams Little Feller I soil to water (2000 ppm, specific activity 23 μc/gram). Agitate for 1/2 hour. Turbidity 200 ppm. Water sample analysis after centrifugation: pH 8.2, alkalinity 112 ppm, hardness 166 ppm.

3. Add 20 grams 70-percent strength calcium hypochlorite (100 ppm available chlorine). Agitate for 30 minutes.

4. Add 82 grams activated carbon nuchar C-115 (600 ppm). Agitate for 45 minutes.

5. Add 28 grams powdered limestone (200 ppm) and 21 grams ferric chloride (150 ppm). Give 5 minutes fast mix and 5 minutes slow mix, and settle 1 hour.

6. Take sample. Note: Supernatant very clear. Water sample analysis: pH 6.2, alkalinity 54 ppm, hardness 228 ppm.

7. Filter supernatant through Set No. 1. Collect 20 liters filtrate. Filtrate water analysis: pH 6.2, alkalinity 40 ppm, hardness 224 ppm.

8. Pass filtrate through mixed bed ion exchanger. Final effluent analysis: 0.1 ppm TDS (as NaCl).

9. Chlorinate effluent from mixed bed ion exchanger to 2 ppm residual. (Finished product was used for drinking purposes by a member of the test team.)

TABLE 2.19 (CONTINUED)

RADIOLOGICAL DATA

Sample	Radioactivity Concentration (pc/l)
Raw contaminated water	46,000,000
(Soluble portion of raw contaminated water)	4,400,000
After coagulation	3,200,000
(Soluble portion after coagulation)	2,100,000
After filtration	1,900,000
After mixed bed ion exchange	0

PROCESS REMOVAL

Process	Per Cent Removal
Coagulation	93%
Coagulation plus filtration	96%
Coagulation plus filtration plus mixed bed ion exchange	100%

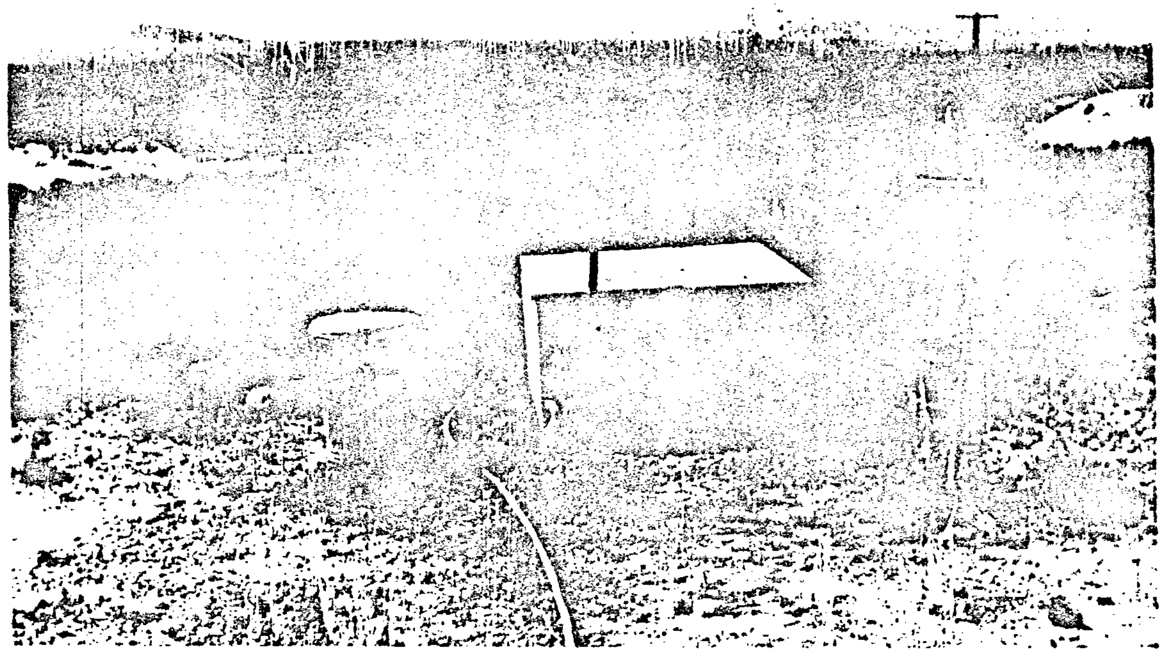

Figure 2.1 Magazine used for storage of radioactive soil samples. (ERDL Photo J-11112)

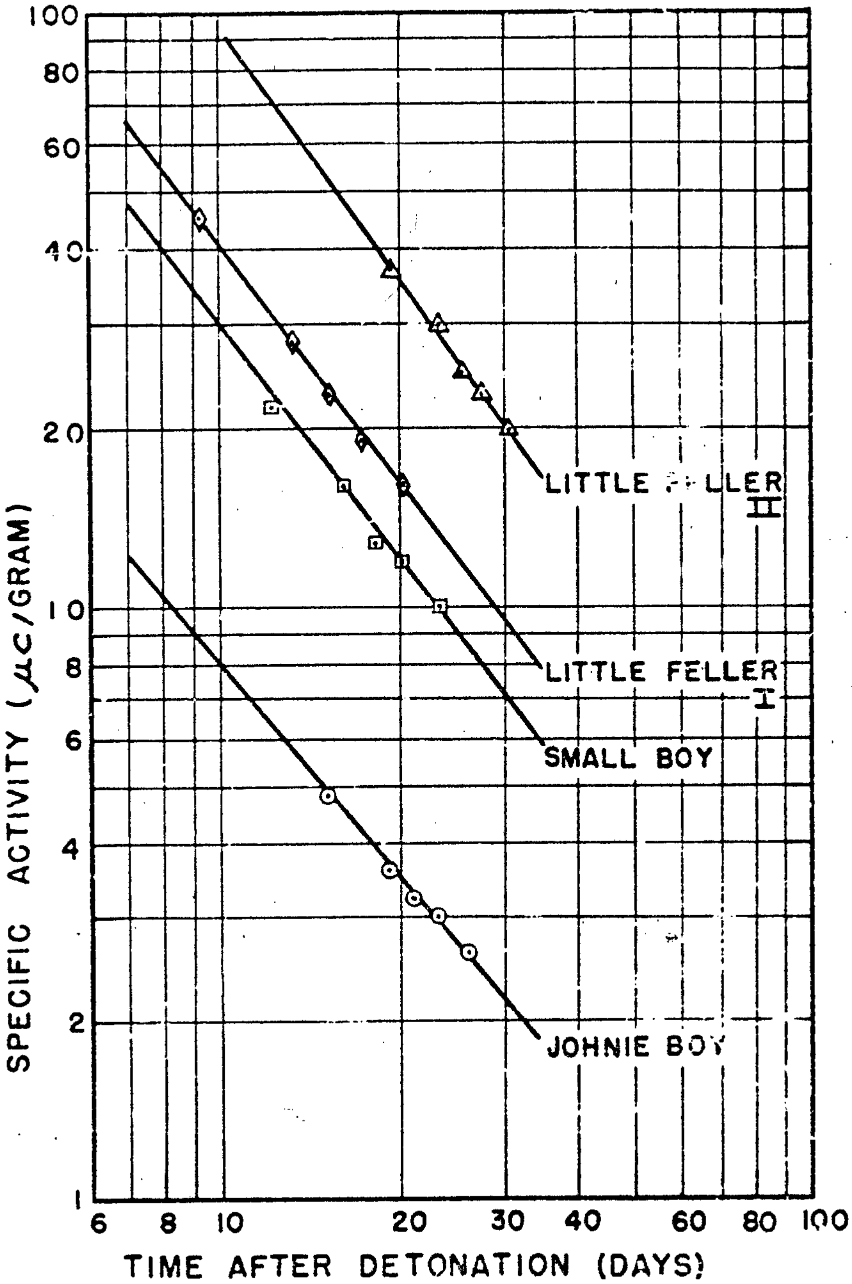

Figure 2.2 Specific activity of radioactive soil samples as a function of time for four nuclear detonations.

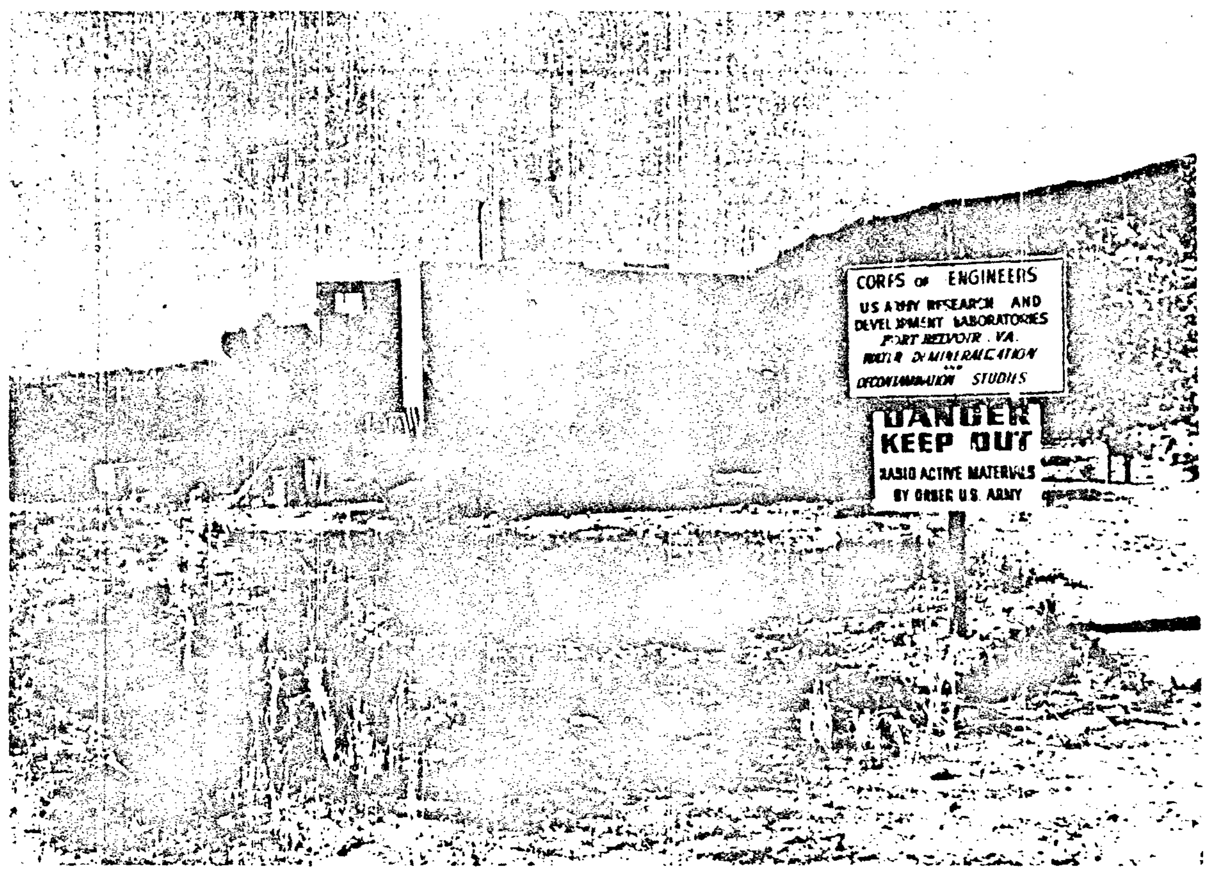

Figure 2.3 Overall view of test installation, Nevada Test Site. (ERDL Photo J-11107).

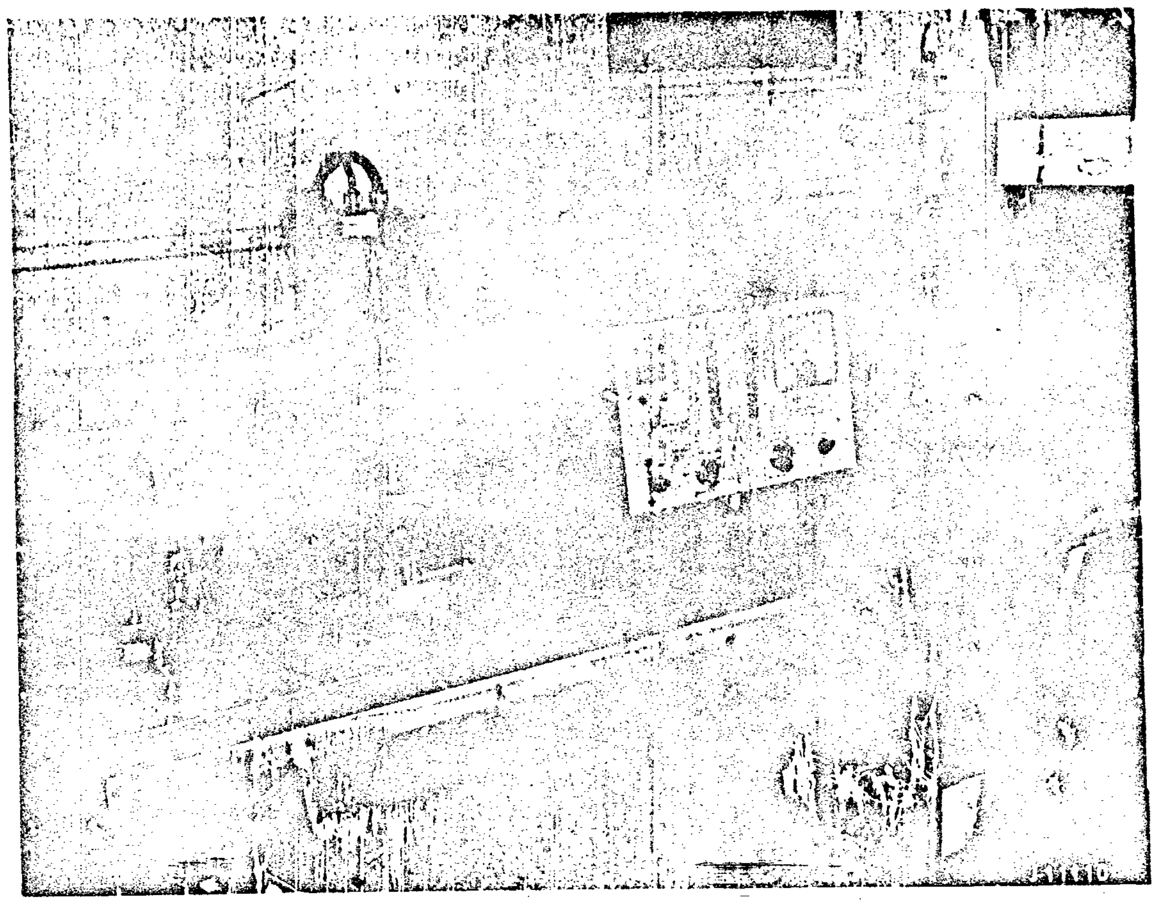

Figure 2.4 System for counting beta particles (on left, Nuclear-Chicago Model DS-5 anthracene detector head in shield; on right, Nuclear-Chicago Model 151-A decade scaler). (ERDL Photo J-11110)

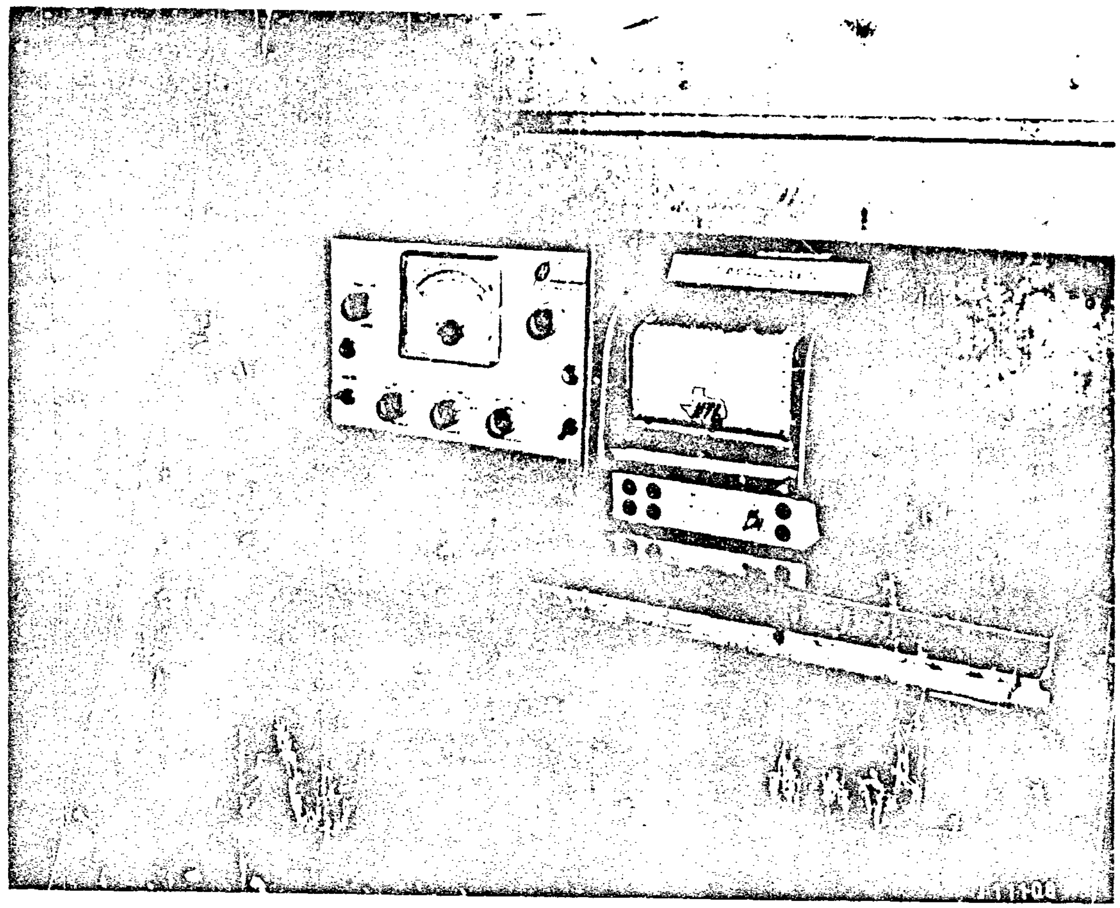

Figure 2.5 System for continuously recording gamma background (on left, Nuclear-Chicago Model DS-5 sodium iodide detector; center, Nuclear-Chicago Model 1620 count rate meter; on right, Texas Instrument Recti/riter). (ERDL Photo J-11108)

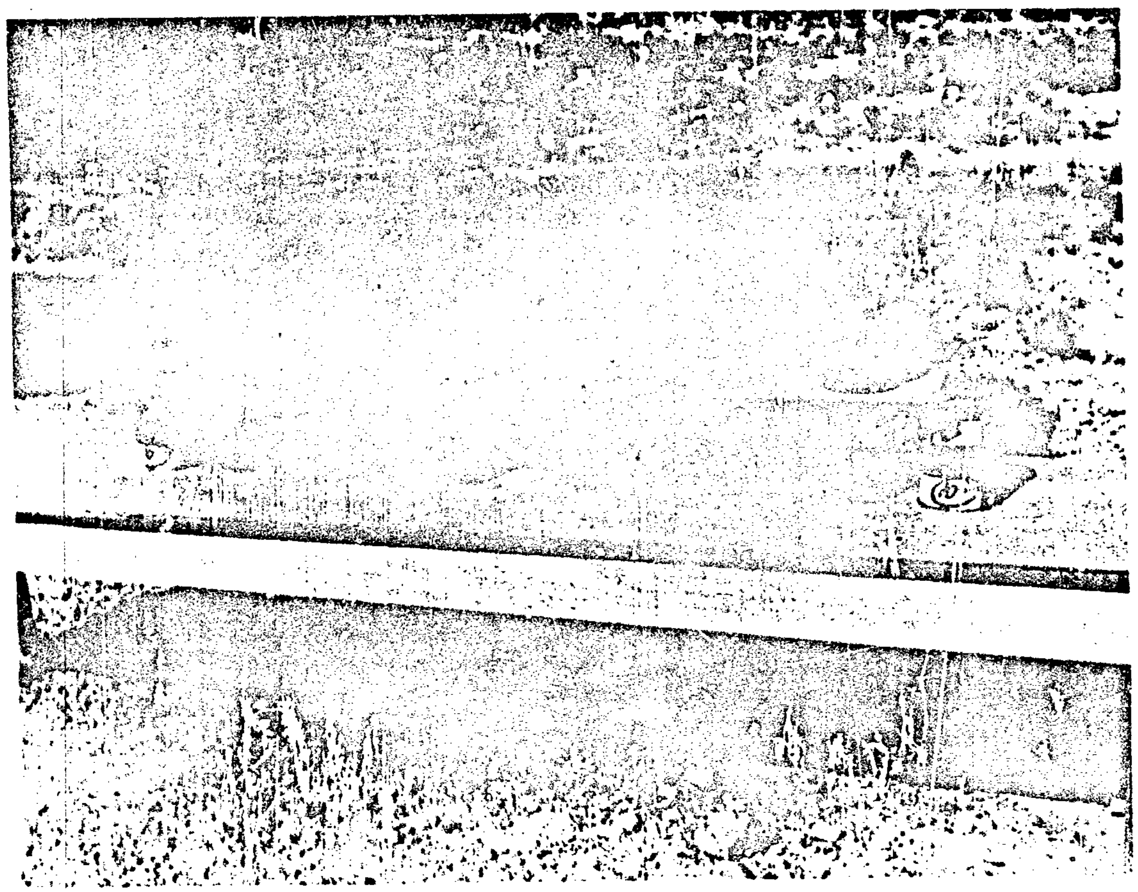

Figure 2.6 Flower pot procedure equipment used in Civil Defense water decontamination studies. (ERDL Photo J-11111)

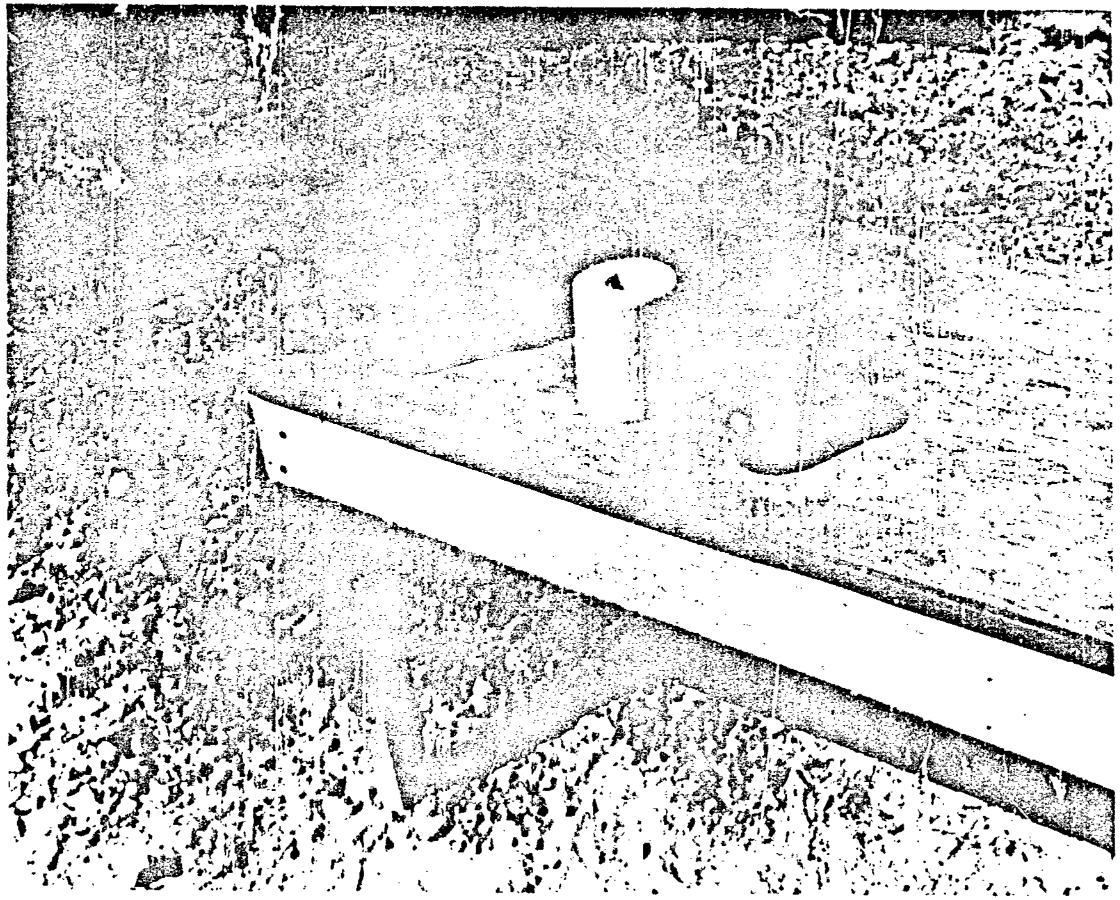

Figure 2.7 Exploded view of flower pot procedure setup used in Civil Defense water decontamination studies. (ERDL Photo J-11114)

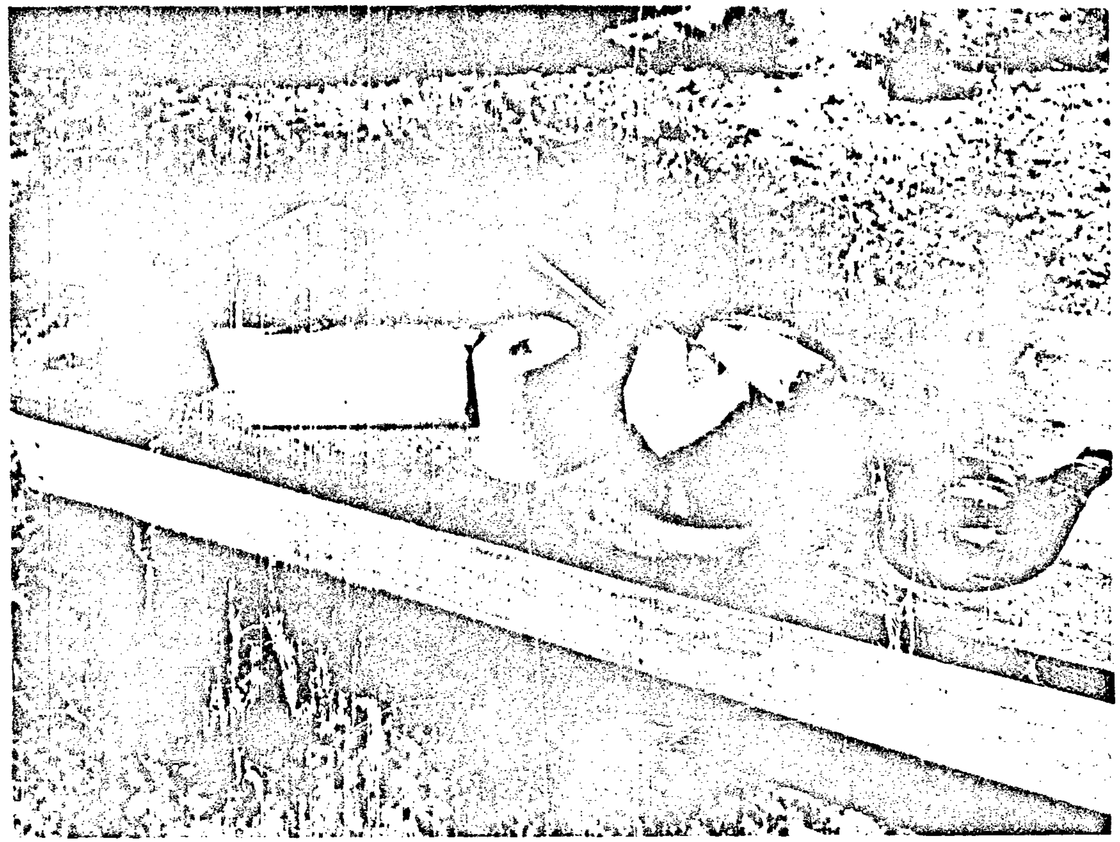

Figure 2.8 Paper procedure equipment used in Civil Defense water decontamination studies. (ERDL Photo J-11113)

Figure 2.9 IM-141/PDR-27J Radiacmeter in use for determining concentration of radioactive materials in water.
(ERDL Photo J-11116)

Figure 2.10 CDV-700 beta-gamma survey meter in use for determin acceptability of radioactively contaminated water on a go-no-go basis for 10-day consumption. (ERDL Photo J-11115)

Figure 2.11 Equipment used for squad method of purifying water contaminated with CBR materials. (ERDL Photo J-11109)

CHAPTER 3

DISCUSSION

In regard to the solubility of nuclear debris in water, it was found the material was soluble in the range of 3 to 14 percent. The soluble portion dissolved very quickly and was essentially unaffected by prolonged contact. In the test on Small Boy soil, the material was 5.5 percent soluble in one minute (in regard to its radioactive component) and only 5.9 percent soluble after 24 hours. Temperature had only a small effect on solubility. Small Boy soil was 4.3 percent soluble at 36°F (1 hour contact) and 6.8 percent soluble at 212°F (1 hour contact). The pH had surprisingly little effect on the solubility, although there was a trend toward higher solubility in acidic solution. This was most pronounced for the soil from Little Feller I, where the solubility went from 9 percent at pH 10 to 14 percent at pH 2.1. The results of all solubility tests would indicate that there is a surface coating of activity on the soil particles which goes very quickly into solution, essentially independent of pH, temperature, or time of contact. The radioactivity on the inside of the particle, due to melting and solidification of the soil during the fire-ball period, or due to in situ neutron activation, is not soluble.

In further discussion of this solubility characteristic of nuclear debris in water, it is noted that the effectiveness of current Corps of Engineers water purification equipment in removing radioactive contaminants from water is directly dependent upon this factor. Engineer equipment utilizes the processes of coagulation and filtration, which are designed to remove suspended matter; therefore, if radioactive substances are present in the form of turbidity, the removal is essentially complete. A much greater problem is encountered when the radioactive contaminant is in true solution. In general, dissolved radioisotopes are difficult to remove from water by coagulation and filtration. The most effective method of removing dissolved radioisotopes is by the ion exchange process. The Corps of Engineers has under development a mobile ion exchange unit for in-series operation with the coagulation-filtration equipment.

The results of this study indicate that there can be appreciable soluble contamination of radioactive nuclear debris in water, above maximum permissible concentration, and that the development of the mobile ion exchange unit should be expedited.

The emergency or Civil Defense decontamination results indicate that the Flower Pot Procedure is capable of removing 92.7 to 98.6 percent radioactivity in water. If the effluent is clear, a subsequent mixed bed ion exchange treatment will remove the remaining activity. The Civil Defense Paper Procedure removed from 88 to 89 percent of the activity in the water. A commercial diatomaceous silica candle type device removed from 96 to 97 percent of the activity from the water. A commercial batch treatment device containing activated resin-carbon granules removed from 99.6 to 99.9 percent of the activity. The U. S. Army knapsack filter removed 76 percent of the activity.

In evaluating these results, it is noted that the choice of a water supply for a survival shelter for Civil Defense use must be based on numerous factors, including the capacity of the shelter, the length of the emergency, and the availability of water locally. It is conceivable that some shelters could be built without providing for local water supply. Such shelters would be serviceable in protecting against blast, heat, and prompt radiation but would provide only limited utility as fallout shelters. Man's ability to survive without water is quite limited, and the use of shelters without some provision for water should probably be restricted to periods of no greater than 3 days. In consideration of the cost of any formal shelter, it is probably unrealistic to build any shelter without providing for some means of water supply. Such means could be bulk storage, canned water, ground water, or the provision of a means for purifying surface water, such as outlined in this report.

The results on field detection indicated that either the IM-141/PDR-27J Radiacmeter or the CDV-700 can be used satisfactorily for their purpose. The meters are responsive to changes of concentration of radioactivity in water. However, the method is inoperative in a high radiation field. The Corps of Engineers has a requirement for a method of this type that is simple, rapid, and reasonably accurate. This is necessary to establish proper water treatment procedures at Engineer water points and to assist in the control of continuous operation methods.

Detection of the concentration of radiological materials in water is, of course, directly related to the allowable Maximum Permissible Concentrations (MPC's) in water. The MPC established by the U. S. Army is shown below, along with other significant MPC's for comparative purposes:

Item	Radioactivity Concentration (picocuries per liter)
Lifetime Maximum Permissible Concentration (National Bureau of Standard Handbook 69)	100
OCD Recommended Acceptable Maximum Permissible Concentration for 30-day consumption	30-300,000
OCD Recommended Acceptable Maximum Permissible Concentration for 10-day consumption	90,000,000
U. S. Army Emergency Maximum Permissible Concentration for 1-year consumption	300,000

In reference to the Army tolerance, individual variations in the amount of water consumed do not change the value and for greater or lesser periods of consumption the value may be adjusted proportionally in accordance with the time involved.

Two Civil Defense home expedient methods of removing radioactive materials from water are satisfactory. One procedure, utilizing a filter made of a flower-pot or comparable container, toilet tissue, a piece of screening and a column of subsoil 5 cm deep, removed from 93 to 99 percent of the radioactivity from contaminated water. A second procedure, based on the use of toilet tissue as a filter aid and filtration through a household sieve lined with a paper towel, removed 88 to 89 percent of radioactivity from similarly contaminated water. A simplified variation of this latter procedure produced a removal of [illegible] percent. Various household materials such as vermiculite, peat moss, aquarium sand, and cereal were evaluated as filter media but gave inferior results for clarification and activity removal compared with a subsoil column. Small, portable water treating devices investigated for activity removal proved that the process utilizing activated carbon-ion exchange granules followed by filtration gave the best results. All devices which effectively removed turbidity effectively removed radioactivity. All methods of civil defense significance showed even higher removal of activity by the utilization of a post ion exchange treatment, such as by a home type steam iron demineralizer.

Equipment available for providing water for the individual or squad is intended primarily for emergency treatment of fresh water supplies when it is impossible to obtain water from Corps of Engineers water production units. If raw water sources are contaminated with CBR agents, however, the first alternative is to attempt to find an uncontaminated source. This may be difficult in view of certain military situations, especially where large areas may be contaminated. In this case, contaminated water must be subjected to decontamination procedures. As normally practiced, raw water from a fresh water source is disinfected in the canteen with FSN 6850-264-5904, Tablet, Water Purification Individual (commonly known as globaline, chemically known as tetraglycine hydroperiodide). Although this globaline-canteen procedure would be of definite benefit in chemical and biological agent decontamination, it would be of no value in removing radiological material from water. Sustained boiling of water by the individual soldier would kill all microorganisms but would probably be of little value in removing or destroying chemical agents and of no value in destroying radiological agents in water. In fact, boiling could actually concentrate radiological agents in water.

Water Purification Unit, Hand-Operated, Kanpsack-Pack, Filter-Pad-Type, 1/4-GPM (Set No. 1) is a direct-filtration device, consisting essentially of a hand-operated diaphragm pump in combination with a housing to support two cellulose filter pads. This device would be of limited value in removing chemical agents from water. It would be reasonably effective in removing most microorganisms from water, especially when used with globaline disinfection tablets. The device would be effective in removing suspended radioactive particles from water but would be ineffective for removing certain dissolved radioactive materials. Preliminary investigations were conducted relative to supplementing this unit with other manually operated equipment to provide an emergency squad-size unit with CBR water decontamination capability. Accordingly, a system was developed consisting of a Lyster bag for superhypochlorination, dechlorination, and batch coagulation; the 1/4-gpm pad filter for filtration of the supernatant from the Lyster bag; and an ion exchange cartridge filter for demineralization of the filter effluent. The system proved very successful in this study, removing 100 percent of the radioactive contamination from water.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

From the results obtained under this study it is concluded that:

1. The solubility of radioactive debris increased with a decrease in pH and an increase in temperature, but the change was not significant in the pH and temperature variations for normal drinking water supplies.

2. The solubility of radioactive debris was not markedly affected by contact time. Increases in solubility with time were alleviated by decreases in contamination through radioactive decay.

3. The solubility of radioactive debris was significant enough to require water demineralization to produce drinking water within the acceptable one year and one month drinking water tolerance levels.

4. Radioactive debris from surface detonations can be colloidal and remain in suspension in water for extended periods of time and be readily transported to downstream water sources.

5. Emergency type water purification methods such as filtration through clay and paper, batch coagulation, filtration through a cellulose filter disc, and molded filter candles effectively reduced radioactive contaminants to short range (less than 30 day) drinking water tolerance levels. Higher removals of activity (approaching 100 percent) were obtained by the addition of an ion exchange process as a post treatment to the above methods.

6. The standard IM-141/PDR-27J Radiacmeter and the CDV-700 meter can be used satisfactorily in the field to qualitatively determine whether water supplies are above or below the drinking water tolerance levels and to assist water point operation relative to adequacy of the operating water decontamination procedures.

4.2 RECOMMENDATIONS

It is recommended that the following additional studies be made:

1. Soil Solubility as a Function of Soil Type. Expose different representative soils to the effects of a nuclear detonation to ascertain the degree of water solubility of the resulting radioactive component.

2. Fate of Fallout in a Moving Stream. Admit radioactive fallout to the headwater of a moving stream and determine its destiny, including the established radiation field.

APPENDIX

SYNOPSIS OF PERTINENT REFERENCE REPORTS

Formal USAERDL Reports Pertaining to Decontamination of Water Contaminated with Radioactive Materials

(U. S. Army Engineer Research and Development Laboratories Fort Belvoir, Virginia)

USAERDL REPORT NO.	TITLE OF REPORT WITH BRIEF DESCRIPTION
1275	"Purification of Water Contaminated with Radioactive Material." 24 December 1952. Describes jar test studies at the Oak Ridge National Laboratory using powdered metals, clay, coagulants, and ion exchange resins for the removal of reactor-produced fission products and selected radioisotopes from water. Also evaluates Water Purification Set No. 2, an experimental Erdlator, and mixed bed ion exchange column for decontaminating contaminated water.
1313	"Removal of Radioactive Materials from Contaminated Water by Thermocompression Distillation." 28 August 1953. Describes the use of a 60 GPH thermocompression

distillation unit for removing fission products and significant individual radioisotopes from water at the Oak Ridge National Laboratory.

1357 "Removal of Radioactive Substance from Water by Ion Exchange Processes." 11 June 1954. Describes laboratory ion exchange studies and a pilot size ion exchange column for removing fission products and significant radioisotopes from water.

1396 "Removal of Radiological Warfare Agents from Water." 22 April 1955. Describes the removal of aged fission products and selected radioisotopes of radiological warfare significance from water by coagulation, by clay absorption, and by ion exchange. Equipment evaluated includes 60 GPH thermocompression distillation unit, Water Purification Set No. 1, and a field expedient.

1404 "Removal of Radioactive Materials from Water by Water Purification Unit, Hand-Operated, Knapsack-Pack, Filter-Pad-Type, 1/4 GPM, and by a Field Expedient." 19 May 1955. Describes evaluation of Water Purification Set No. 1 for removing radioactive substances from water. Removals of 85-95 percent of fission products indicated with clay pretreatment. Also describes a field expedient consisting of a column packed with clay, humus, and vegetation which removed 85-95 percent of fission product activity.

1406 "Removal of Radioactive Contaminants from Water with the Corps of Engineers Mobile Water Purification Unit." 27 May 1955. Describes field operation of 1800 GPH Mobile Water Purification Unit at the Oak Ridge National Laboratory for removing fission product activity from water by conventional processing, by pretreatment with clay, and by post-treatment with ion exchange resins.

1451-RR "The Removal of Radioactive Material from Water by Serial Coagulation, by Ion Exchange and by Charcoal Adsorption." 22 June 1956. Describes laboratory studies at the Oak

Ridge National Laboratory for removing radioactive substances from water by serial coagulation with various coagulant combinations, by ion exchange, by adsorption on activated bone charcoal.

1492-RR "Ion Exchange for Removal of Radionuclides from Water." 7 August 1957.
Describes the use of ion exchange equipment for removing fission product activity from water.

1569-TR "Solubility Characteristics of Radioactive Bomb Debris in Water and Evaluation of Selected Decontamination Procedures."
12 February 1959.
Describes work conducted at the Nevada Test Site under Operation Plumbbob using bomb debris obtained from Shot Priscilla. Debris was subjected to a laboratory study of its solubility characteristics in water, followed by an evaluation of coagulation, adsorption, ion exchange, and other processes for removing the debris from water.

1613-RR "Decontamination of Water Contaminated with Plutonium." 12 January 1960.

Describes experiments conducted at the Los Alamos Scientific Laboratory evaluating the 1500 GPH Mobile Water Purification Unit for removing plutonium from water. Also describes pilot scale work on the decontamination efficiency of softening, carbon adsorption, and ion exchange processes.

1673-RR "Removal of Nuclear Bomb Debris, Strontium 90 - Yttrium 90, and Cesium 137 - Barium 137 from Water with Corps of Engineers Mobile Water Treating Equipment." 23 May 1961.

Covers experiments conducted at the Nevada Test Site studying the 1500 GPH Mobile Water Purification Unit and the 1500 GPH Mobile Ion Exchange Unit for removing from water 1-year old nuclear bomb debris ground to 3 microns average particle size. Also covers the removal of soluble Strontium 90 - Yttrium 90 and Cesium 137 - Barium 137.

1702-RR "Removal of Chemical, Biological, and Radiological Contaminants from Water with Corps of Engineers Field Water Supply Equipment." 12 December 1961.

Summarizes and applies to field use, research data obtained on the removal of chemical, biological, and radiological agents from water. Discusses the problem and covers maximum permissible concentrations, detection, water decontamination equipment and methods, protective clothing, and equipment decontamination.

Ordering from ASTIA

Address

Armed Services Technical Information Agency (ASTIA)

Arlington Hall

Arlington 12, Virginia

USAERDL NO.	ASTIA NO.
1275	AD 14230
1313	AD 28983
1357	AD 144599
1396	AD 73435
1404	AD 82052
1406	AD 105037
1451-RR	AD 113180
1492-RR	AD 142961
1569-RR	AD 212440
1613-RR	AD 234[illegible]
1673-RR	AD 26[illegible]
1702-RR	AD 274300

Ordering from Department of Commerce

Address

Office of Technical Services (OTS)

Department of Commerce

Washington 25, D. C.

USAERDL NO.	OTS NO.
1275	PB 136037
1313	PB 136038
1357	PB 136024
1396	PB 136025
1404	PB 140084
1406	PB 135996
1451-RR	PB 128495
1492-RR	PB 136482
1569-RR	PB 152650
1613-RR	PB 147816
1673-RR	Not available OTS
1702-RR	Not yet available OTS

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1 U S ARMY CBR WEAPONS SCHOOL
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2 CHIEF OF NAVAL OPERATIONS OP03EG
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1 CHIEF OF NAVAL OPERATIONS OP-922G2
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2 U S NAVAL CIVIL ENGINEERING LAB
1 U S NAVAL ACADEMY
1 U S NAVAL SCHOOLS COMMAND TREASURE ISLAND
1 U S NAVAL POSTGRADUATE SCHOOL
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1 MILITARY LIAISON COMMITTEE
1 WEAPONS SYSTEM EVALUATION GROUP
1 ASST SECRETARY OF DEFENSE INSTALLATION & LOGISTICS
1 INDUSTRIAL COLLEGE OF THE ARMED FORCES
1 ARMED FORCES STAFF COLLEGE
4 DEFENSE ATOMIC SUPPORT AGENCY
1 FIELD COMMAND DASA
1 FIELD COMMAND DASA FCTG
2 FIELD COMMAND DASA FCWT
2 DEFENSE INTELLIGENCE AGENCY
1 U S COAST GUARD
1 JOINT TASK FORCE-8
1 COMMANDER-IN-CHIEF EUCOM
1 COMMANDER-IN-CHIEF PACIFIC
1 COMMANDER-IN-CHIEF ATLANTIC FLEET
1 STRATEGIC AIR COMMAND
1 CINCONAD
3 ASST SECRETARY OF DEFENSE CIVIL DEFENSE

ATOMIC ENERGY COMMISSION ACTIVITIES

3 AEC WASHINGTON TECH LIBRARY
2 LOS ALAMOS SCIENTIFIC LAB
5 SANDIA CORPORATION
10 LAWRENCE RADIATION LAB LIVERMORE
1 NEVADA OPERATIONS OFFICE,LAS VEGAS
1 DTIC OAK RIDGE,MASTER
30 DTIE OAK RIDGE SURPLUS