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Report 1904

FIELD EXPEDIENTS FOR DECONTAMINATING WATER CONTAINING NUCLEAR BOMB DEBRIS

by

Don C. Lindsten
and
Maurice Pressman

July 1967

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U. S. ARMY ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES
FORT BELVOIR, VIRGINIA

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FIELD EXPEDIENTS FOR DECONTAMINATING WATER CONTAINING NUCLEAR BOMB DEBRIS

Task 1M624101D55107

July 1967

Distributed by

The Commanding Officer
U. S. Army Engineer Research and Development Laboratories

Prepared by

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and
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Military Technology Department

SUMMARY

This report covers a field study conducted by the Sanitary Sciences Laboratory of the U. S. Army Engineer Research and Development Laboratories (USAERDL) at the Nevada Test Site during the summer of 1962. The purpose of the investigation was to study the following:

a. The solubility of radioactive debris in water.

b. Field methods of determining the concentration of radioactive materials in water.

c. Field expedient methods for removing radioactive materials from water.

d. A squad-type, universal method for the removal of chemical, biological, and radiological (CBR) agents from water.

The results of this study indicate that:

a. The solubility of radioactive debris in water increases with a decrease in pH and an increase in temperature, but the change is not significant in the range of pH and temperature variations of normal drinking water supplies.

b. The solubility of radioactive debris in water is not markedly affected by contact time. Increases in solubility with time are offset by decreases in contamination resulting from radioactive decay.

c. The solubility of radioactive debris in water may be significant enough to require demineralization to produce water safe for drinking.

d. 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.

e. Field expedient water purification methods such as filtration through clay, paper, cellulose pads, and molded filter candles; and batch coagulation and filtration can effectively accomplish radioactivity removals of about 75 percent or more. Higher removals of activity approaching 100 percent are obtainable by ion exchange demineralization following filtration.

f. The standard military IM-141/PDR-27J Radiacmeter and the Civil Defense CDV-700 meter can be used satisfactorily in the field to determine the radioactivity content of water at levels higher than 1,000,000 picocuries per liter (pc/l).

FOREWORD

The study covered by this report was sponsored jointly by USAERDL and the Defense Atomic Support Agency. Funding was provided under USAERDL Task 8M75-05-001-07, "Removal of CBR Contaminants from Water" (now Task 1M624101D55107), and also by Office of Civil Defense Project 3103C, "Use of Clay Materials for Emergency Decontamination of Water Supplies."

The study was conducted during the summer of 1962.

The following personnel of the Sanitary Sciences Laboratory, USAERDL, were responsible for conducting the study:

Don C. Lindsten - Project Officer

Richard P. Schmitt - Sanitary Engineer

Maurice Pressman - Chemist

Frederick W. Wolfes - Water Supply Technician

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

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FIELD EXPEDIENTS FOR DECONTAMINATING WATER CONTAINING NUCLEAR BOMB DEBRIS

I. INTRODUCTION

1. Subject. The objectives of the investigation covered by this report were to study the following: (1) The effect of pH, temperature, and contact time upon the solubility of radioactive bomb debris in water; (2) emergency, small-scale methods of removing radioactive contaminants from water; (3) emergency, field-type methods of determining the concentration of radioactive contaminants in water; and (4) a proposed Army squad-type, general, CBR decontamination method for removing radioactivity from water.

2. Background and Previous Investigation. One of the assigned responsibilities of USAERDL is the development of processes and equipment for the treatment of field Army water supplies contaminated with CBR agents. Since 1948, numerous laboratory and field studies on the removal of radioactive materials from natural waters have been conducted by the Sanitary Sciences Laboratory of USAERDL. Most of the information derived from these studies has been summarized in a report by Lindsten and Schmitt, published in 1961.[1] The present study was a continuation of this work into areas where limited information is available. These areas are: (1) Solubility of nuclear bomb debris in water; (2) emergency, small-scale methods of water decontamination; (3) water monitoring with field radiation survey instruments; and (4) efficiency of a proposed batch water purification method for removing radioactive materials from water.

II. INVESTIGATION AND DISCUSSION

3. General. The experimental work was conducted at the Nevada Test Site in the vicinity of the AEC-operated Radiological Safety Decontamination Station in the mountain pass between Frenchman Flat and Yucca Flat. The installation consisted primarily of a mobile chemical laboratory and a mobile radiac laboratory.

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1. Don C. Lindsten and Richard P. Schmitt, Removal of Chemical, Biological, and Radiological Contaminants from Water with Corps of Engineers Field Water Supply Equipment, PBAD 274300, OTS (12 December 1961).

All chemical tests and jar test experiments were conducted in the chemical laboratory. Analytical procedures used were those given in "Standard Methods for the Examination of Water and Wastewater."[2] All counting was done in the radiac laboratory. Both laboratories were electrified by means of a connection to the local power system. Fresh water was supplied to the chemical laboratory by connection to the local drinking water line. The wastewater line from the chemical laboratory drained into a retention pond receiving runoff from a nearby decontamination pad.

Sample preparation for counting was accomplished in the chemical laboratory by evaporating to dryness under an infrared lamp an appropriate volume of sample water in a planchet. The residue was counted by placing the planchet on the top shelf of a Nuclear-Chicago shield containing a Model DS-5 anthracene crystal beta detector connected to a Model 151A decade scaler. 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 Recti/riter.

4. Contaminants. The radioactive soils used as contaminants in all experiments were obtained at the indicated locations after the following four nuclear bursts:

a. Shot 1. The soil sample was taken from the center of the crater.

b. Shot 2. The soil sample was taken from the surface of the ground at the 10-roentgen-per-hour (r/hr) line.

c. Shot 3. The soil sample was scraped from the surface of the ground at the 10-r/hr line.

d. Shot 4. The soil sample was taken from the center of the crater.

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2. Standard Methods for the Examination of Water and Wastewater, American Public Health Association, American Water Works Association, Water Pollution Control Federation, New York, 11th edition (1960).

After each batch of soil was collected, it was taken to an area of low radiation and sieved through a U. S. Standard Number 40 sieve. The material retained on the sieve was rejected. The material passing the sieve was placed into several 1-qt bottles and stored in a locked magazine for use as the water contaminant. Figure 1 shows the characteristic decay (in microcuries per gram (μc/gm)) versus time curve for each soil sample.

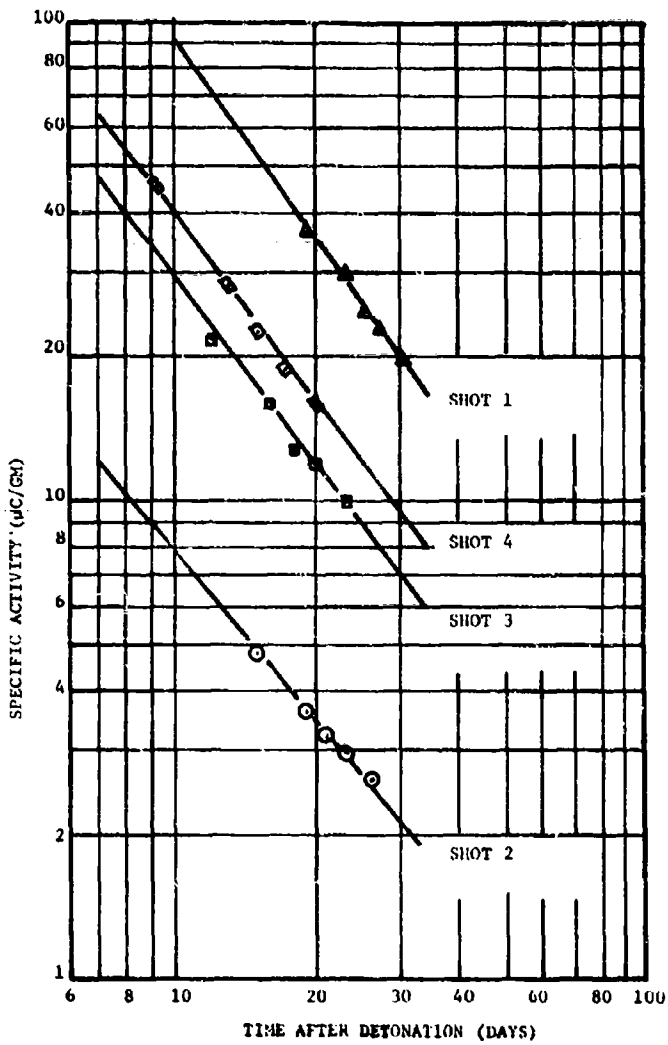


Fig. 1. Specific activity of radioactive soil samples as a function of time for four nuclear detonations.

5. Test Water. The water used for all experiments was taken from Well No. 3, Nevada Test Site. An analysis of the water is shown in Table I.

Table I. Water Analysis,* Well No. 3, Nevada Test Site

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)	
Residue on Evaporation (180° C)	254
Calculated	285
Hardness ($CaCO_3$) (ppm)	
Total	95
Noncarbonate	0
Specific Conductance (μ mhos 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

* From U. S. Geological Survey, Nevada Test Site. (Sample collected 19 Dec 61.)

6. Solubility Study.

a. Procedure. Four experiments were conducted to determine the soluble activity of the four soil samples as a function of pH. Two experiments were conducted to determine the solubility of Shot 3 soil activity as a function of time, and as a function of temperature. The detailed procedures are given in the appendix, Tables II through Table VII.

b. Results. The results obtained in the six experiments of this solubility study are given in the appendix, Tables II through Table VII.

c. Discussion. The results of the solubility study indicated that the soluble radioactive component of the soil dissolved in water in the pH range of 10.1 to 2.1 to the extent of 2.6 to 14 percent. Most of the solution took place within minutes following the contact of debris and water. Prolonged contact increased the solubility only insignificantly. The soluble radioactivity of Shot 3 debris was 5.5 percent of the total activity after 1-min contact and only 5.9 percent after 24 hr. Temperature had only a small effect on solubility. Shot 3 debris was 4.3 percent soluble at 36° F (1-hr contact) and 6.8 percent soluble at 212° F (1-hr contact). The pH had surprisingly little effect on the solubility, although there was a trend toward higher solubility under acidic conditions. This was most pronounced for the Shot 4 soil, where the soluble activity went from 9 percent at pH 10 to 14 percent at pH 2.1. The results of all solubility tests indicate that there is probably a surface coating of radioactive material on the soil particles which goes into solution very quickly, essentially independent of pH, temperature, and time of contact. The radioactive material on the inside of the particle is not soluble, probably because of encapsulation by inert, fused soil produced by melting and subsequent solidification of soil during the fireball period.

These solubility considerations are important factors in field Army water purification practice. The efficiency of the standard Army Erdlator water purification unit in removing radioactive contaminants from water is dependent on whether the contaminant is soluble or insoluble. These units utilize the processes of coagulation and filtration, which are designed to remove insoluble suspended matter; therefore, if radioactive substances are present in the form of turbidity, the contaminant removal is essentially complete. If the radioactive contaminant is present in soluble form, very little soluble activity removal is accomplished by coagulation and filtration. One of the most effective methods of removing dissolved radioisotopes from water is by the ion exchange process. The Army has

under development a mobile ion exchange unit for in-series operation with the coagulation-filtration Erdlator equipment.

The results of this study indicate that there can be appreciable soluble radioactivity imparted to a water supply by the presence of nuclear bomb debris. The essentially complete removal of particulate matter from this turbid water may still leave the water contaminated to a significant degree by the soluble component of the debris.

7. Emergency Decontamination Methods Study.

a. Procedure. Eight experiments were conducted to study various emergency, small-scale water decontamination procedures. These procedures entailed the filtration of a few liters of water contaminated with radioactive soil through the following filters:

(1) Flowerpots filled with various soils and other media.

(2) Various paper filters.

(3) A diatomaceous candle filter (Fig. 2).

(4) A resin-carbon filter unit (Fig. 3).

(5) Cellulose pads in a 1/4-gpm Army unit (Fig. 4).

The detailed procedures for these experiments are given in the appendix, Tables VIII through XV.

b. Results. The results obtained in the eight experiments of this part of the study are given in the appendix, Tables VIII through XV.

c. Discussion. The procedures enumerated in paragraph 2 could be used in emergency situations by small groups of soldiers in the field when drinking water from an engineer water point was not available. Radioactivity removals attained by the various devices ranged from 76 percent for a standard 1/4-gpm Army unit using cellulose pad filtration to 99.9 percent for the device utilizing activated carbon and ion exchange resin granules.

The various emergency methods used materials readily available in the civilian economy. One procedure, utilizing a filter made of a flowerpot or comparable container, toilet tissue, a piece of screening,

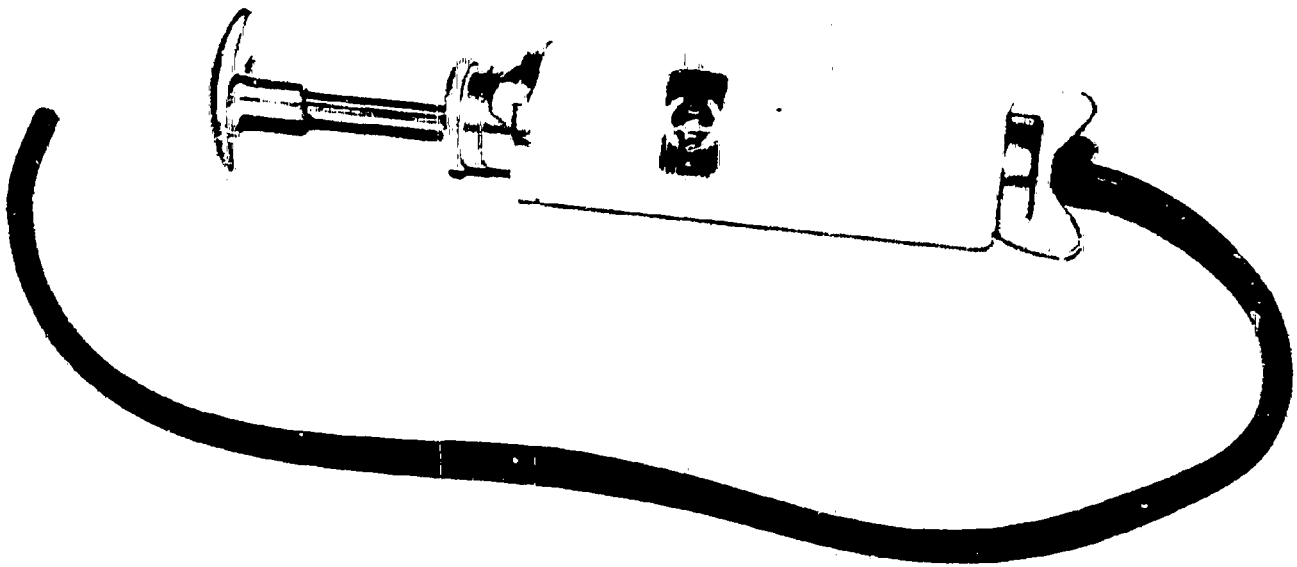
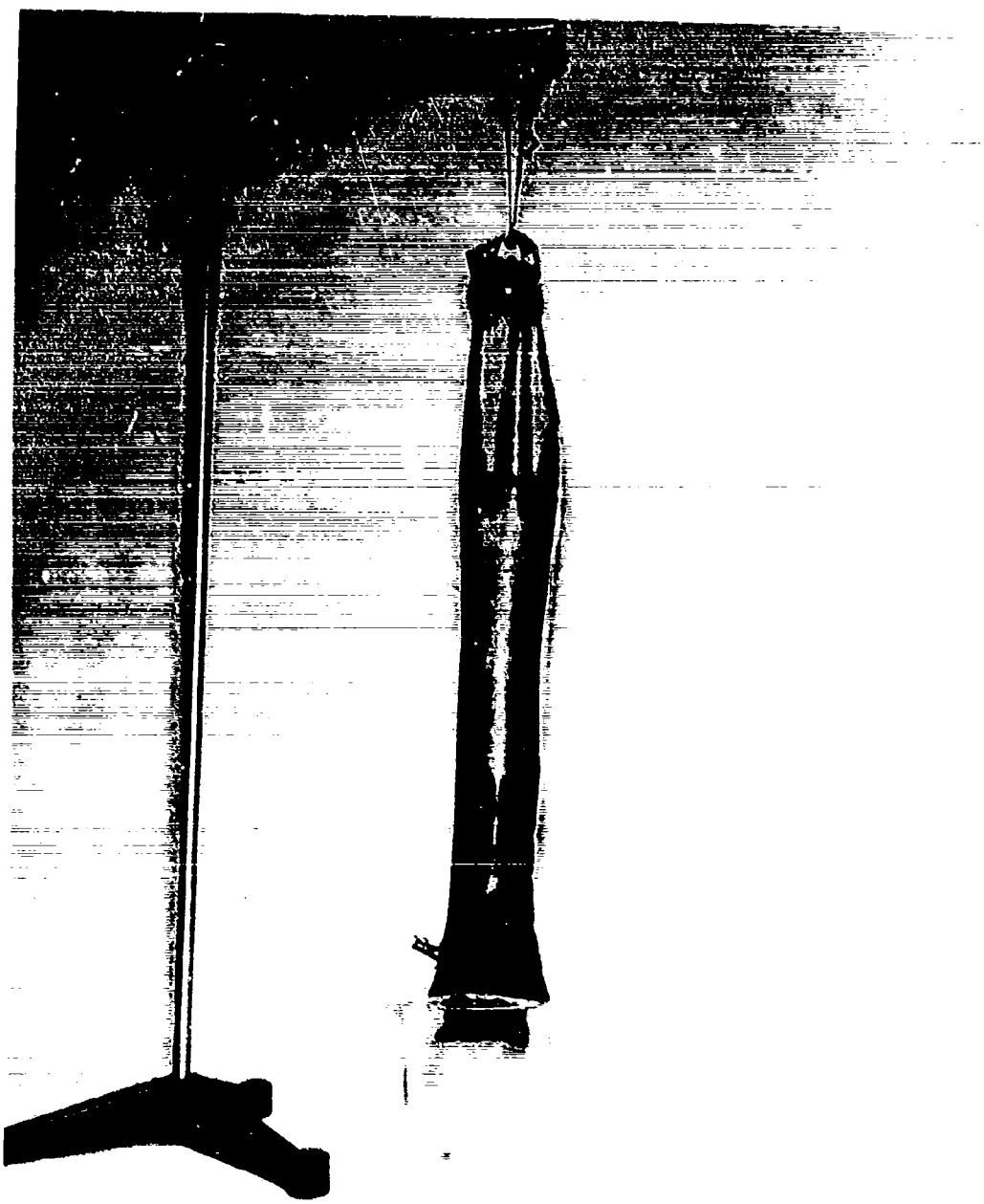
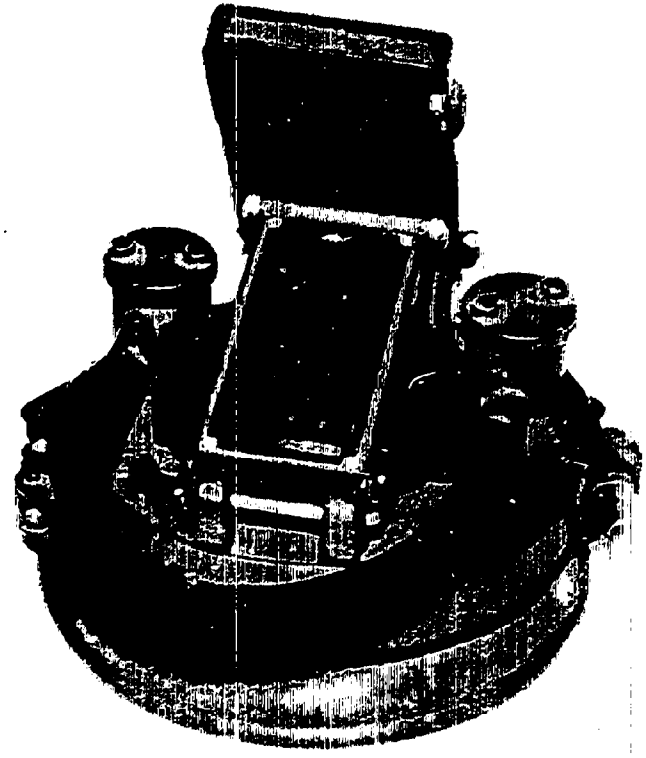


Fig. 2. Diatomaceous candle filter. N7289



N7292

Fig. 3. Resin-carbon filter unit.



N7284

Fig. 4. United States Army 1/4-gpm filter unit.

and a column of subsoil 5 cm deep, removed from 92.7 to 98.6 percent of the radioactivity from contaminated water. A second procedure, based on the use of toilet tissue as a filter and filtration through a household sieve lined with a paper towel, removed 88 to 89 percent of the radioactivity from similarly contaminated water. A simplified variation of this latter procedure produced a removal of 84 percent. Various household materials such as vermiculite, peat moss, aquarium sand, and cereal, when used as filter media in flowerpots, gave inferior results for clarification and activity removal compared with a subsoil column.

In tests with the three commercially available units, the unit employing activated carbon and ion exchange resins was the most effective. The lowest radioactivity removal efficiency was exhibited by the U. S. Army 1/4-gpm filter unit.

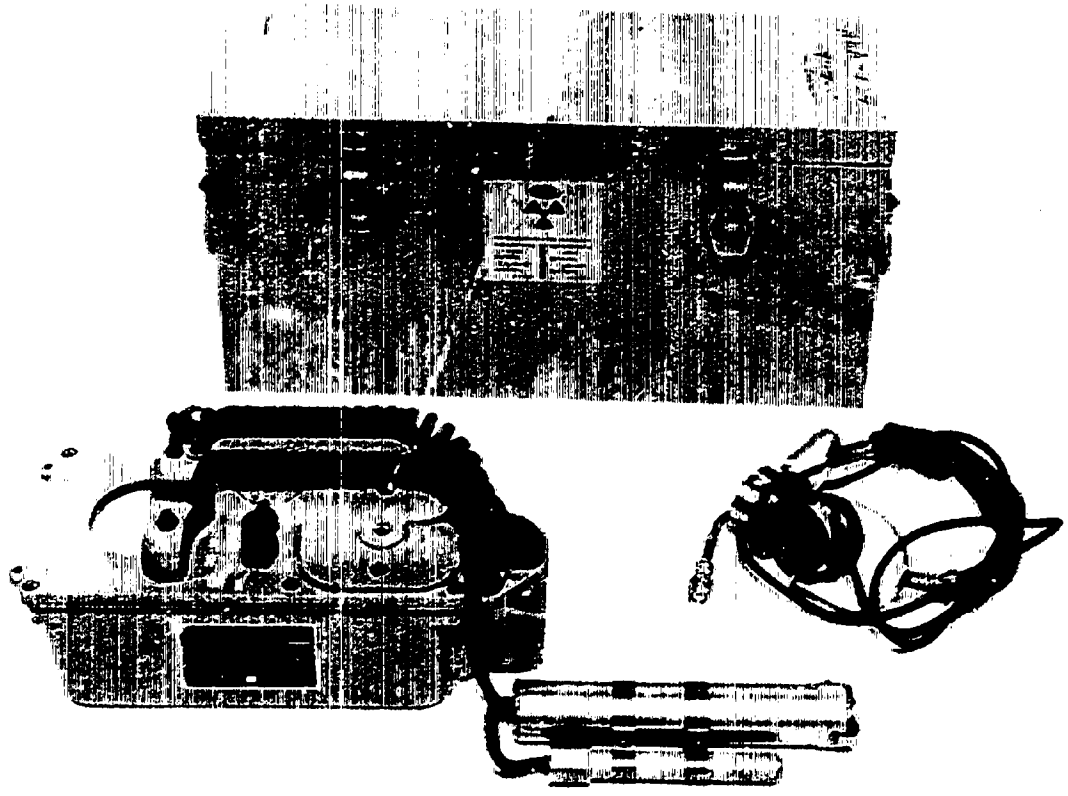
In general, the degree of decontamination accomplished in these small-scale studies was dependent on the effectiveness of turbidity removal of the filter and the ion exchange or activity adsorption characteristics of the filter media. The use of a small ion exchange cartridge commonly used for demineralizing water for steam irons effectively removed all soluble radioactivity remaining in water which had been passed through the small-scale filtration devices.

In the tests with the resin-carbon unit and the U. S. Army 1/4-gpm unit, feedwater to the units was water which had been contaminated with Shot 3 debris and allowed to settle for 48 hr and 1 hr, respectively. The activity values of these two settled waters were 3,200,000 pc/l and 28,000,000 pc/l. The turbidity of the water which had settled 48 hr was still 140 units. This indicated that radioactive debris from surface detonations can be colloidal and remain in suspension for extended periods of time and be readily transported to downstream water sources.

8. Field Detection Study.

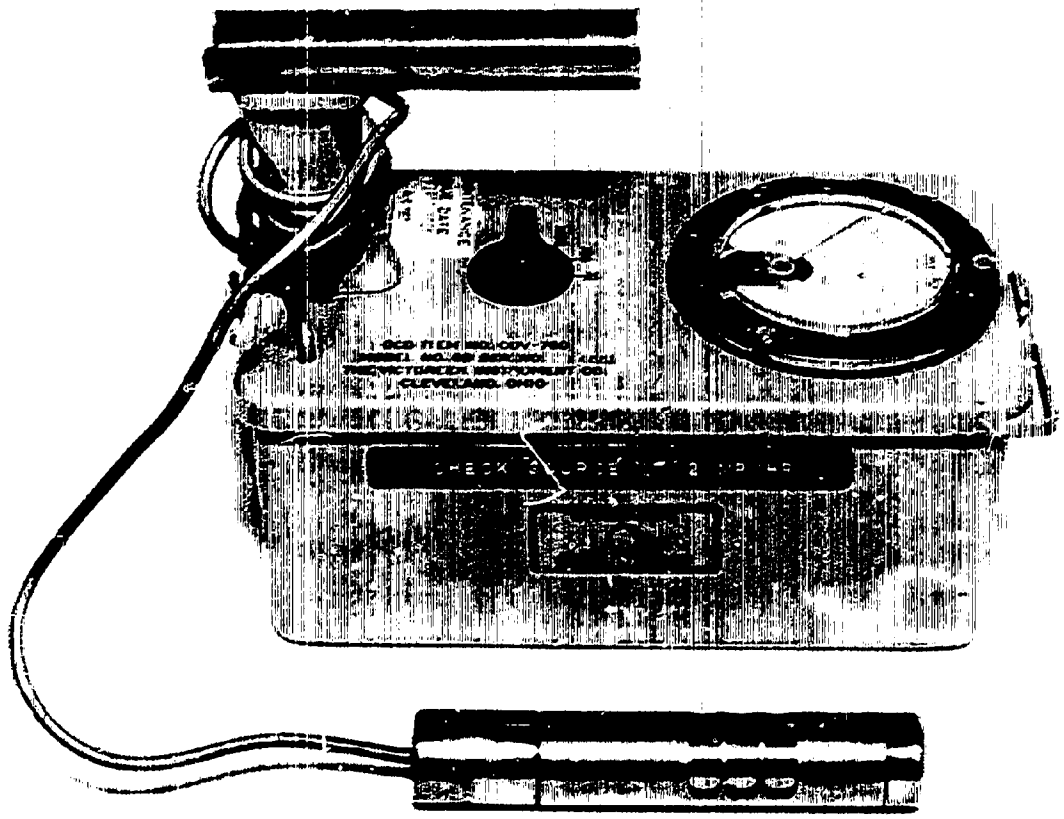
a. Procedure. The two radiation detection meters used in the field detection study to determine radioactivity in water were the standard Army IM-141/PDR-27J Radiacmeter and the Office of Civil Defense CDV-700 beta-gamma survey meter. The meters are shown in Figs. 5 and 6. The detailed procedures used in these tests are outlined in the appendix, Tables XVI, XVII, and XVIII.

b. Results. The results obtained in the experiments with the two field detection instruments are given in the appendix, Tables XVI, XVII, and XVIII.



P3186

Fig. 5. United States Army IM-141/PDR-27J Radiacmeter.



P3187

Fig. 6. Office of Civil Defense CDV-700 beta-gamma survey meter.

c. Discussion. The results of the field detection study indicated that both the IM-141/PDR-27J Radiameter and the CDV-700 meter were adequately responsive to changes in radioactivity content in water contaminated above the level of 1,000,000 pc/l. Figures 7 and 8 show the linear response (in milliroentgens per hour (mr/hr)) of these two meters to changes in radioactivity concentration. It should be noted, however, that their use would be subject to severe limitations in a high radiation field.

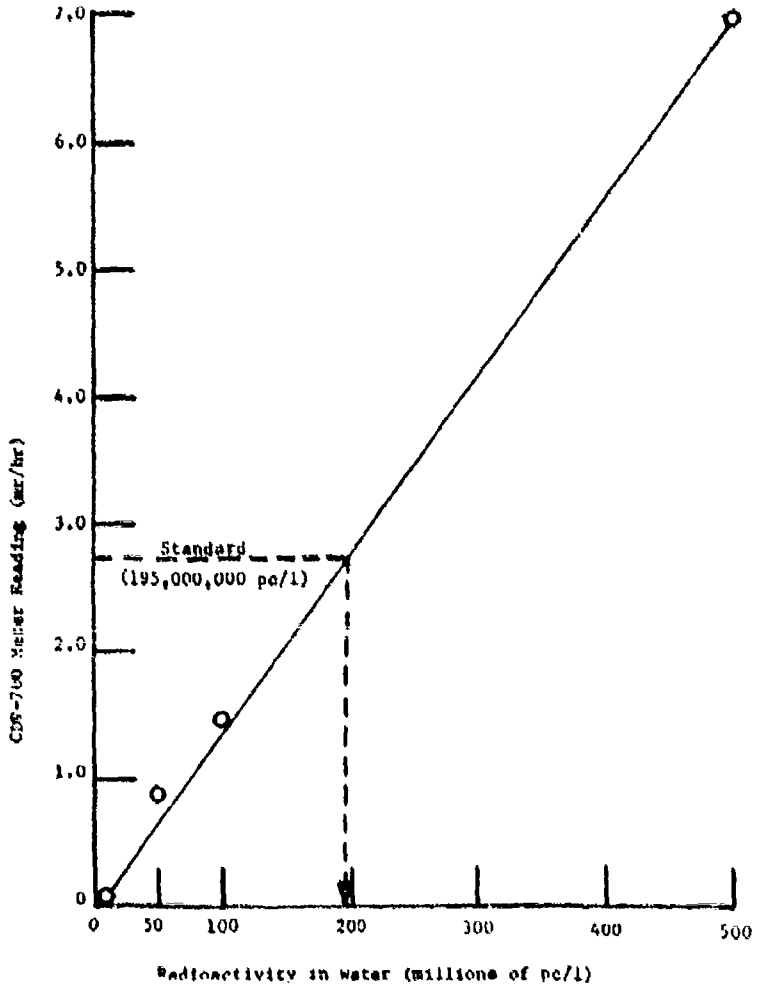


Fig. 7. Response of the CDV-700 survey meter using the CDV-787 comparator source (background 0.1 mr/hr).

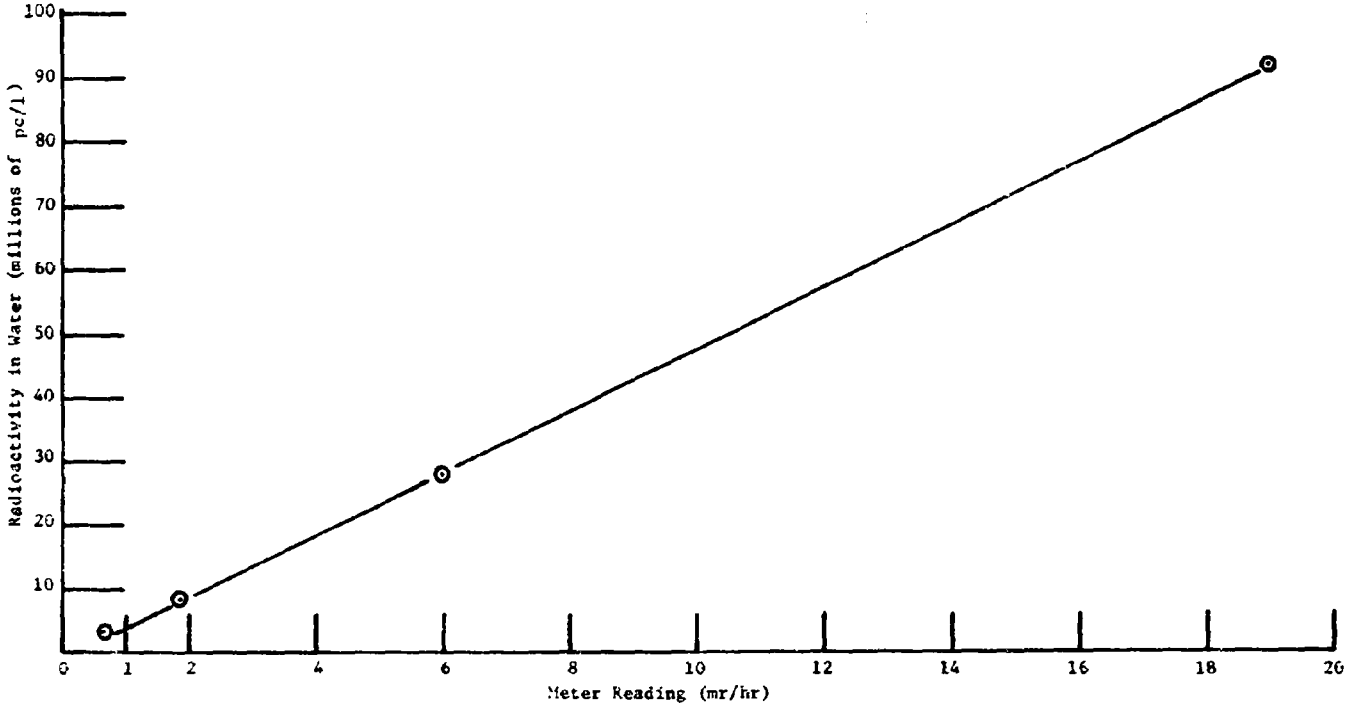


Fig. 8. Response of the IM-141/PDR-27J Radiacmeter.

For determining radioactivity in water with the CDV-700 meter, a standard long-lived source, designated as CDV-787, is used on a "go - no go" basis as a 10-day water standard unit. If the response of the CDV-700 meter placed over the water in the container provided with the source exceeds the response obtained when the meter is placed over the CDV-787 standard unit, the activity of the water exceeds the tolerance level for 10-day consumption. The data illustrated in Fig. 7 indicated that the standard CDV-787 activity corresponded to a water activity of 195,000,000 pc/l.

9. Squad CBR Decontamination Study.

a. Procedure. The procedure used in the squad CBR decontamination study entailed the decontamination of a Lyster bag quantity (36 gal) of water by means of a method proposed for the treatment of water contaminated with CBR materials. The method consists of a series of steps: (1) Chlorination with calcium hypochlorite, (2) dechlorination with powdered carbon, (3) coagulation with ferric chloride and limestone, (4) settling, and (5) filtration through the standard U. S. Army 1/4-gpm filter and a mixed-bed ion exchange cartridge. Details of the procedure are given in the appendix, Table XIX.

b. Results. The results obtained in this study are given in the appendix, Table XIX.

c. Discussion. The method proved to be very effective for reducing radioactivity to an undetectable level, indicating essentially complete removal. Coagulation and filtration removed 96 percent of the activity. Passage of the filtrate through a mixed-bed ion exchange cartridge removed the remaining 4 percent of activity. Even though 96 percent of the activity was removed by coagulation and filtration, the remaining 4 percent represented a soluble radioactivity concentration of 1,900,000 pc/l. The removal of this soluble activity by a mixed-bed ion exchange resin column demonstrates the usefulness of ion exchange resins for removing soluble radioactivity from water.

III. CONCLUSIONS

10. Conclusions. From the results of this study, the following conclusions are made:

a. The solubility of radioactive debris increases with a decrease in pH and an increase in temperature, but the change is not significant in the range of pH and temperature variations of normal drinking water supplies.

b. The solubility of radioactive debris in water is not markedly affected by contact time. Increases in solubility with time are offset by decreases in contamination resulting from radioactive decay.

c. Soluble radioactivity imparted to water contaminated with radioactive bomb debris can be removed effectively by ion exchange resins.

d. 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.

e. Field expedient water purification methods such as filtration through clay, paper, cellulose pads, and molded filter candles; and batch coagulation and filtration can effectively accomplish radioactivity removals of about 75 percent or more. Higher removals of activity approaching 100 percent are obtainable by ion exchange demineralization following filtration.

f. The standard military IM-141/PDR-27J Radiacmeter and the Civil Defense CDV-700 meter can be used satisfactorily in the field to determine the radioactivity content of water at levels higher than 1,000,000 pc/l.

APPENDIX

DETAILED TEST DATA

Table II. Solubility of Shot 1 Debris as a Function of pH, Run 1

PROCEDURE:

1. Add 70 gm Shot 1 debris (17 days old, specific activity 45 μc/gm) to 35 liters of water in an 11-gal plastic drum. Agitate.

2. Add 600 ml of the suspension to each of four, 1,000-ml beakers.

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

4. Stir for 1 hr at high speed.

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

Radiological Data			
	Radioactivity Concentration		
Beaker	Suspension (pc/l)	Filtrate (pc/l)	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 III. Solubility of Shot 2 Debris as a Function of pH, Run 2

PROCEDURE: Same as Run 1 (Table II). Shot 2 debris 14 days old, specific activity 5.2 μc/gm.

Radiological Data			
	Radioactivity Concentration		
Beaker	Suspension (pc/l)	Filtrate (pc/l)	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	4.6	4	136
3	8.5	174	104
4	10.1	298	55

Table IV. Solubility of Shot 3 Debris as a Function of pH, Run 3

PROCEDURE. Same as Run 1 (Table II). Shot 3 debris 12 days old, specific activity 22 μc/gm.

Radiological Data			
	Radioactivity Concentration		
Beaker	Suspension (pc/l)	Filtrate (pc/l)	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	592
2	8.2	94	241
3	8.6	183	114
4	10.0	279	42

Table V. Solubility of Shot 4 Debris as a Function of pH, Run 4

PROCEDURE: Same as Run 1 (Table II), except weigh separately 1.2 gm quantities of debris directly into each beaker (specific activity of debris 45 μc/gm).

Radiological Data			
	Radioactivity Concentration		
Beaker	Suspension (pc/l)	Filtrate (pc/l)	Solubility (%)
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 VI. Solubility of Shot 3 Debris as a Function of Time, Run 5

PROCEDURE:

1. Add 1.2 gm of Shot 3 debris (10 days old, specific activity 28 μc/gm) to 600 ml water in a 1,000-ml beaker.

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

3. Analyze 24-hr filtrate for pH, alkalinity, and hardness.

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

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

Table VII. Solubility of Shot 3 Debris as a Function of Temperature, Run 6

PROCEDURE:

1. Weigh out three 1.2-gm portions of debris.

2. Add 600 ml tap water to each of three 1,000-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 hr.

5. Sample, centrifuge, and count supernatant.

Beaker	Water Temperature (°F)	Radioactivity Concentration		Solubility (%)
		Suspension (pc/l)	Centrifugate (pc/l)	
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 VIII. Decontamination of Water Contaminated with Nuclear Bomb Debris by the Flowerpot Procedure, Run 7

OBJECTIVE: To evaluate the effectiveness of the flowerpot procedure for removing radioactivity from well water contaminated with debris from Shot 4.

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

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

PROCEDURE:
1. Prepare flowerpot filter as follows:
   a. Cut circular piece of metal screen to cover bottom of pot.
   b. Lay two 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, and turbidity.
5. Filter most turbid and least turbid filtrate thru steam iron demineralizer, check activity.

Flowerpot[a] No.	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 (pc/l)	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	200[c]	1	7.6	168	102	4	930,000	98.3	-	-
3	Trumbull	200	200[c]	1	5.5	84	26	5	890,000	98.4	-	-
4	Diablo	600	120	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	98.6	0	100

(a) Dimensions. Diameter, top 15 cm, bottom 10 cm; height 17 cm.
(b) Volume. Nos. 1 thru 6, 400 ml; No. 7, 600 ml.
(c) Filtration stopped at 200 min.

Note: Dashes indicate no determinations were made.

Table IX. Decontamination of Water Contaminated with Nuclear Bomb Debris by the Paper Procedure, Run 8

OBJECTIVE: To evaluate the effectiveness of the paper procedure for removing radioactivity from well water contaminated with debris from Shot 4.

CONTAMINATED WATER: Suspension of 70 gm 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 ($CaCO_3$), and alkalinity 163 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 min.
3. Settle 15 min.
4. Decant into second flask.
5. Add 10 sheets of shredded toilet tissue.
6. Shake vigorously, to pulp, for 5 min.
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 min.
12. Filter thru clean paper towel into saucepan.
13. Analyze product for volume, collection time, pH, turbidity, hardness, alkalinity, and activity.

Table IX (cont'd)

Test No.	Soil	Chemical Data						
		First Filtrate		Second Filtrate				
		Volume (ml)	Turbidity (units)	Volume (ml)	Turbidity (units)	pH	Total Hardness (ppm $CaCO_3$)	Alkalinity (ppm $CaCO_3$)
1	Leon	890	10	760	5	7.6	128	212
2	Sassafras	860	10	780	5	8.1	130	212
3	Trumbull	810	10	700	5	8.2	128	218
4	Chester	810	10	700	5	8.2	123	214
5	Hagerstown	820	10	700	5	8.2	132	224
6	Belvoir	830	10	710	5	8.1	130	224

Note: Collection time - first filtrate 85 min; second filtrate 40 min; total 125 min.

Test No.	Radiological Data			
	First Filtrate		Second Filtrate	
	Activity (pc/l)	Activity Removal (%)	Activity (pc/l)	Activity Removal (%)
1	6,800,000	86	5,800,000	88
2	6,400,000	87	5,500,000	89
3	5,600,000	89	5,300,000	89
4	6,200,000	88	5,500,000	89
5	7,100,000	86	5,600,000	89
6	6,600,000	87	6,200,000	88

Note: Passing second filtrate of Test 2 through household steam iron water treatment unit gave a total activity removal of 99.99 percent.

Table X. Decontamination of Water Contaminated with Nuclear Bomb Debris by the Paper Procedure Modified, Run 9

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

CONTAMINATED WATER: Same as Table IX.

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

Sample No.	Filtrate Activity (pc/l)	Activity Removal (%)
1	8,100,000	84
2	7,400,000	85

Note: An average removal of 87 percent was obtained with the paper procedure with soil addition (1,000 ppm Belvoir soil) (Table IX).

Table XI. Effect of Added Soil in the Decontamination by Filtration of Water Contaminated with Nuclear Bomb Debris, Run 10

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

CONTAMINATED WATER: Same as Table IX.

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 min.
3. Filter all samples through membrane filter (0.45 μ).
4. Analyze filtrate for activity.

Sample No.	Belvoir Soil Added (ppm)	Filtrate Activity (pc/l)	Activity Removal (%)
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 XII. Decontamination of Water Contaminated with Nuclear Bomb Debris by Filtration through Various Media, Run 11

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

CONTAMINATED WATER: Suspension of 70 gm Shot 1 debris (specific activity 25 μc/gm) in 35 liters of well water, activity 50,000,000 pc/l.

PROCEDURE:
1. Prepare flowerpot filter as follows:
   a. Cut circular screen and fit over bottom of pot.
   b. Lay two 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 No.	Filter Medium	Filtrate Activity (pc/l)	Activity Removal (%)
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 flowerpot filter produced an activity removal of 5 percent.

Table XIII. Decontamination of Water Contaminated with Nuclear Bomb Debris by a Diatomaceous Candle Filter, Run 12

OBJECTIVE: To evaluate the effectiveness of a diatomaceous candle filter for removing radioactivity from well water contaminated with Shot 1 debris.

CONTAMINATED WATER: Suspension of 70 gm of debris (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	2,200,000	97
3	500	--	3,000,000	96
4	300	--	2,500,000	97

Note: Dashes indicate no determinations were made.

Table XIV. Decontamination of Water Contaminated with Nuclear Bomb Debris by a Resin-Carbon Filter Unit, Run 13

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 3 debris.

CONTAMINATED WATER: Supernatant from slurry of Shot 3 debris after settling 48 hr.

CONTAMINATED WATER ANALYSIS: Activity 3,200,000 pc/l, turbidity 140 units, 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 hr.
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	85	7.6	1	1.6	5,100	99.8

Table XV. Decontamination of Water Contaminated with Nuclear Bomb Debris by a Standard Army 1/4-gpm Water Purification Unit, Run 14

OBJECTIVE: To evaluate the effectiveness of the standard Army Set No. 1 water purification unit for removing radioactivity from well water contaminated with Shot 3 debris.

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

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

Sample	Activity (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 XVI. Field Detection with IM-141/PDR-27J Radiacmeter, Run 15

PROCEDURE:

1. Add 1,000-, 100-, and 1-gm quantities of Shot 3 debris (13 days old, specific activity 22 μc/gm) to each of four 20-gal 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 surgeon's rubber 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 milliroentgens per hour.

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

Table XVII. Field Detection with IM-141/PDR-27J Radiacmeter and CDV-700 Meter, Run 16

PROCEDURE:
1. Add 1.3, 4.2, 12.6, 42, 126, and 416 gm of Shot 3 soil (specific activity 11 μc/gm) to each of six 20-gal plastic drums containing 50 liters of tap water.
2. Agitate.
3. Take reading with meters as indicated.

Tank	Concentration of Radioactivity (pc/l)	IM-141/PDR-27J Meter		CDV-700
		Surgeon's Glove Around Probe Assembly, Beta Shield Closed (mr/hr)	Rubber Sheath on Each Probe (Separated), Beta Shield Open (mr/hr)	Rubber Sheath 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

Note: General area background 0.07 mr/hr.

Table XVIII. Evaluation of Civil Defense 10-Day Water Standard Unit CDV-787, Run 17

OBJECTIVE: To determine the radioactivity in water corresponding to the radioactivity of the Civil Defense CDV-787 10-day water standard unit.

CONTAMINANT: Debris from Shot 4 (specific activity 25 μc/gm).

PROCEDURE:
1. Weigh out the desired weight of debris into CDV-700 unit container.
2. Add 76 ml well water (to level of indentation).
3. Place probe of CDV-700 meter over container and record reading for each weight of debris.
4. Place probe of CDV-700 meter over CDV-787 standard unit and record reading.
5. Measure area background.
6. Plot meter response for each weight of debris versus calculated water activity.
7. From plot, determine radioactivity of water corresponding to the 10-day standard unit CDV-787.

Measurement No.	Debris Weight (gm)	Activity in Water (pc/l)	Meter (CDV-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 XIX. Use of Squad CBR Decontamination Procedure for Removal of Nuclear Debris From Water, Run 18

PROCEDURE:

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

2. Add 273 gm Shot 4 soil to water (2,000 ppm, specific activity 23 μc/gm). Agitate for 1/2 hr. Turbidity 200 ppm. Water sample analysis after centrifugation: pH 8.2, alkalinity 112 ppm, hardness 166 ppm.

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

4. Add 32 gm activated carbon Nuchar C-115 (600 ppm). Agitate for 45 min.

5. Add 28 gm powdered limestone (200 ppm) and 21 gm ferric chloride (150 ppm). Give 5 min fast mix and 5 min slow mix, and settle 1 hr.

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 water purification unit. 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 total dissolved solids (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 XIX (cont'd)

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	Removal (%)
Coagulation	93
Coagulation plus filtration	96
Coagulation plus filtration plus mixed-bed ion exchange	100

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13 ABSTRACT This report covers a field study conducted by the Sanitary Sciences Laboratory of the U. S. Army Engineer Research and Development Laboratories at the Nevada Test Site during the summer of 1962. The purpose of the investigation was to study the following: (a) The solubility of radioactive debris in water. (b) Field methods of determining the concentration of radioactive materials in water. (c) Field expedient methods for removing radioactive materials from water. (d) A squad-type, universal method for removal of chemical, biological, and radiological agents from water. The results of this study indicate that: (a) The solubility of radioactive debris in water increases with a decrease in pH and an increase in temperature, but the change is not significant in the range of pH and temperature variations of normal drinking water supplies. (b) The solubility of radioactive debris in water is not markedly affected by contact time. Increases in solubility with time are offset by decreases in contamination resulting from radioactive decay. (c) The solubility of radioactive debris in water may be significant enough to require demineralization to produce water safe for drinking. (d) 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. (e) Field expedient water purification methods such as filtration through clay, paper, cellulose pads, and molded filter candles; and batch coagulation and filtration can effectively accomplish radioactivity removals of about 75 percent or more. Higher removals of activity approaching 100 percent are obtainable by ion exchange demineralization following filtration. (f) The standard military IM-141/PDR-27J Radiacmeter and the Civil Defense CDV-700 meter can be used satisfactorily in the field to determine the radioactivity content of water at levels higher than 1,000,000 picocuries per liter.

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