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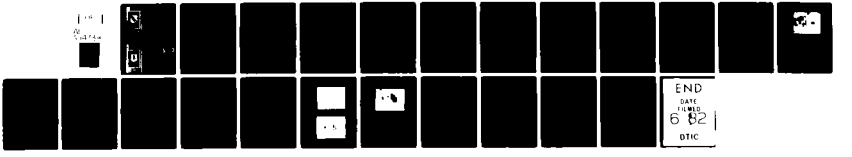

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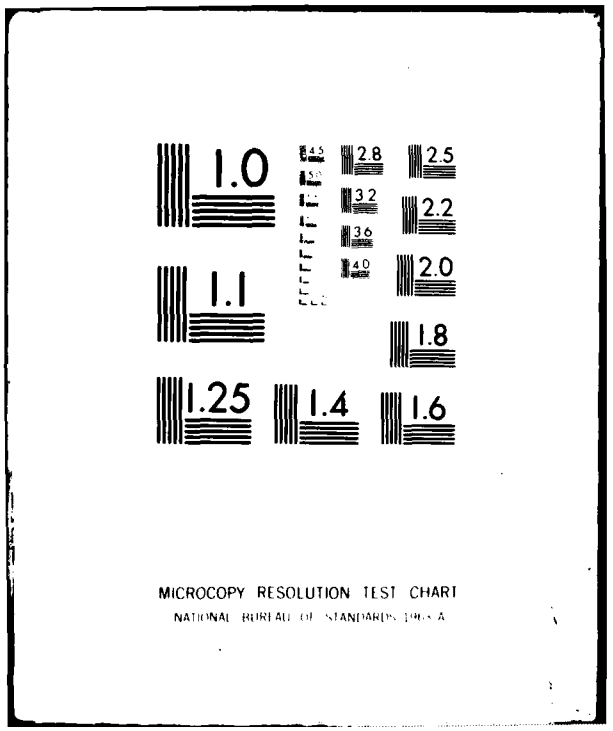
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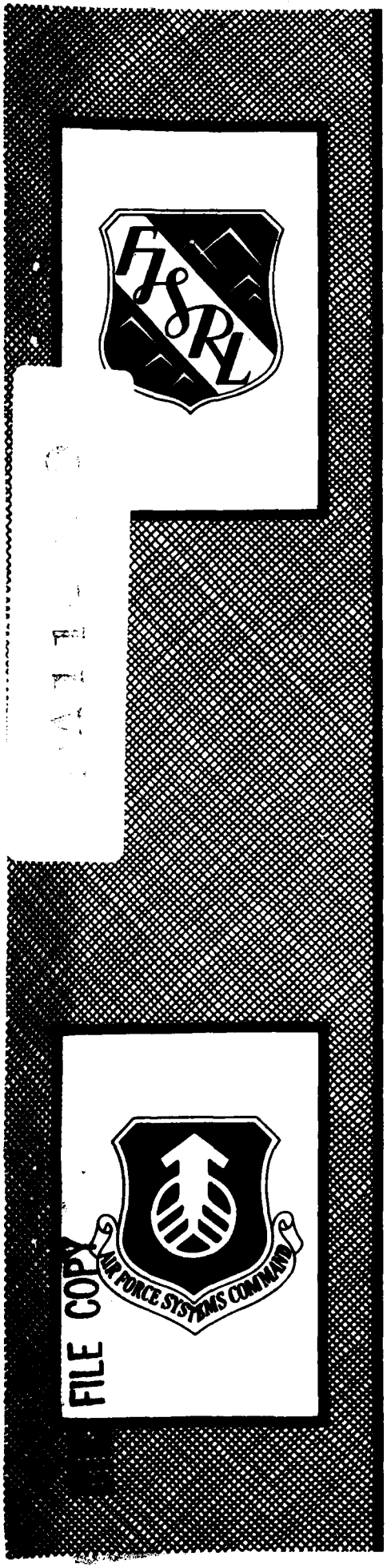

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FRANK J. SEILER RESEARCH LABORATORY

FJSRL TECHNICAL REPORT 81-0009

AUGUST 1981

A SUMMARY REPORT ON THE SOLUBILITY OF DEPLETED U_3O_8 IN SIMULATED LUNG FLUID, RINGER'S SOLUTION AND RINGER'S LACTATE

WILLIAM D. BUTLER

PROJECT 2303

AIR FORCE SYSTEMS COMMAND

UNITED STATES AIR FORCE

FJSRL-TR-81-0009

This document was prepared by the Faculty Research Division, Directorate of Chemical Sciences, Frank J. Seiler Research Laboratory, United States Air Force Academy, Co. The research was conducted under Project Work Unit Number 2303-F1-13, A Summary Report on the Solubility of Depleted U_3O_8 in Simulated Lung Fluid, Ringer's Solution, and Ringer's Lactate. Captain William D. Butler was the Project Scientist in charge of the work.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Arguments have arisen over the solubility of Depleted U_3O_8 in lung and other interstitial fluids. Knowing that Depleted U_3O_8 was insoluble in water, this study was undertaken to determine the relative solubilities, if any, in biological fluids. Results show very low solubility (less than 12%) for the biological fluids studied.

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A SUMMARY REPORT ON THE SOLUBILITY OF DEPLETED U_3O_8 IN SIMULATED LUNG FLUID RINGER'S SOLUTION, AND RINGER'S LACTATE

By

Captain William D. Butler

AUGUST 1981

Department of Biology, USAF Academy, CO 80840

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INTRODUCTION

Recent Air Force involvement with depleted U_3O_8 (triuranium octaoxide as an armor penitrator munition has resulted in questions being raised as to the possible aerosol hazards around an A-10 crash site or a depleted U_3O_8 storage explosion area. Solubility studies using simulated lung fluid have been carried out on a number of uranium compounds exhibiting aerosol properties. Simulants of lung interstitial fluid have been used as solvents in estimating the dissolution of inhaled radioactive compounds in previous studies but have been looked at only sparingly with regard to the solubility of heavy metals, particularly depleted U_3O_8. A few reports have been circulated (some published and some not) discussing heavy metal solubility. Questions by colleagues have been raised concerning the actual solubility of depleted U_3O_8 and the credibility of some of the previous reports. Since depleted U_3O_8 is insoluble in hot or cold water (1,7), it is the purpose of this investigation to support or refute previous determinations of the relative solubility of depleted U_3O_8 in simulated lung fluids, and to further examine depleted U_3O_8 solubility in other physiological fluids.

METHODS AND MATERIALS

Composition of Simulated Lung Fluid

The simulated lung fluid used was developed from a model of interstitial fluid as reported by Diem (2), and Morrow (4). In this study, protein was omitted from the fluid since investigations indicated that the presence of small amounts of protein (≥.4% w/v) rendered the fluid almost unfilterable (1). Acetate

was substituted for all organic acid anions. All solutes were added to glass distilled water. Table 1 gives the composition of the lung simulant fluid.

Other Physiological Fluids

Ringer's solution and Ringer's Lactate solution were obtained already mixed from Travenol Laboratories, Inc., Deerfield, IL 60015. The solutions were prepackaged and sterile upon receipt. Table 2 gives the compositions of these two solutions.

TABLE 1 COMPOSITION OF SIMULATED LUNG FLUID (5)

(Order of Ingredients)

COMPOUND	CHEMICAL FORMULA	CONCENTRATION (mg/ml of H2O)
Magnesium Chloride Hexahydrate	$MgCl_2\ 6H_2O$	203.3
Sodium Chloride	NaCl	6019.3
Potassium Chloride	KCl	298.2
Sodium Sulfate Dibasic (anhydrous)	Na_2HSO_4	142.0
Sodium Sulfate (anhydrous)	Na_2SO_4	71.0
Calcium Chloride Dihydrate	$CaCl_2\ 2H_2O$	367.6
Sodium Acetate Trihydrate	$NaCH_3COO\ 3H_2O$	952.6
Sodium Bicarbonate	$NaHCO_3$	2604.3
Sodium Citrate	$Na_3C_6H_5O_7$	9

NOTE: Be extremely careful when adding calcium chloride dihydrate to the solution. Ca++ is notorious for precipitating out. Solute must be added very slowly and at room temperature.

TABLE 2 OTHER PHYSIOLOGICAL FLUIDS

COMPOUND	CHEMICAL FORMULA	CONCENTRATION (mg/100ml H20)
Ringer's Solution:		
Sodium Chloride	NaCl	860
Potassium Chloride	KCl	30
Calcium Chloride	$CaCl_2$	33
Ringer's Lactate Solution:		
Sodium Chloride	NaCl	600
Sodium Lactate	$NaC_3H_5O_3$	310
Potassium Chloride	KCl	30
Calcium Chloride	$CaCl_2$	20

Particle Size of Depleted Triuranium Octaoxide

At the beginning of the investigation, the uranium chosen for the study was 99% pure depleted U_3O_8. This heavy metal is an olive green powder obtained from the Alfa Division of Ventron Corporation in Danvers, MA. Plate I is a scanning electron photomicrograph of depleted U_3O_8, and shows the relative size and average distribution of the particles before the solubility tests. Note that the clumping of the particles is primarily due to static electricity when placed on the viewing stub.

Solubility Studies

Solubility determinations were made via strict analytical chemistry techniques, based on total percent weight of the solute. Total fluid volume of the three test solutions was also closely controlled (6). Each test solution was maintained in an enclosed, thermostatically controlled beaker atop a Corning PC

PLATE I

Depleted Uranium Powder Sample Before Addition To Test Solutions

351 hot plate-stirrer. The desired temperature was to approximate that of higher reptiles' and mammals' body core temperatures. Therefore, the test solutions were maintained between 27 and 39 degrees centigrade. Table 3 shows the body core temperatures for the two Classes of animals discussed above.

TABLE 3 BODY CORE TEMPERATURES (3)

CLASS/EXAMPLE	TEMPERATURE (CENTIGRADE)
REPTILIA - Crocodilians	26-37
- Turtles	19.8 $\pm$ 0.2
MAMMALIA - Mice	36.8
- Rats	36.9
- Rabbits	38.8

CLASS/EXAMPLE	TEMPERATURE (CENTIGRADE)
- Sheep	39
- Pigs	38.4
- Cows	38
- Cats	38
- Dogs	38.4
- Rhesus Monkeys	37.3

Each solubility experiment lasted for four days. For each determination, the following procedures were performed:

(a) A known amount of depleted U_3O_8 powder was added to each of the three test solutions of 250 ml. Each solution contained two drops of dispersing agent (sodium lauryl sulfate) (1).

(b) The depleted U_3O_8 powder was circulatd in each test solution by a magnetic stirrer. To maintain dispersion of the solute, air was also bubbled into each solution at the rate of approximately 2 ml/min through a glass pipette. This was done during the entire test period.

This modified dispersion technique (1) was adopted in order to disperse any clumped particles and to minimize the buildup of aggregates. Air injection also served to aid mixing the solute in the beaker, to increse the solute surface area for maximum exposure to each test solution, and, to simulate the oxidizing effects within the lung.

(c) At the end of the four day test period, each solution containing the depleted U_3O_8 solute was carefully vacuum filtered through a 0.45 micron type HA millipore filter. Rubber policemen as well as washes containing extra solutions of lung

simulant, Ringer's, and Ringer's Lactate were used to insure complete removal of the test material from the beakers, thermometers, and dispersion pipettes.

(b) Each millipore test filter containing depleted U_3O_8 was then transferred to a glass drying dish and placed in a 100 degree fahrenheit oven for 24 hours. Upon completion of the drying period, each test filter was weighed to four significant figures on an Ainsworth 21 N balance. Attachments 1-3 show the analytical calculations of the depleted U_3O_8 weights for each of the three test solutions.

RESULTS

The results that were obtained from this study are seen in Attachments 1-3. The percentage of the depleted U_3O_8 in the test solutions were all less than 12%. Also, Plates II, III, and IV show particle size of the depleted U_3O_8 solute after the test runs in lung simulant, Ringer's, and Ringer's Lactate respectively. There appears to be no difference in the average particle size. It should be noted that the actual study period may or may not be sufficient to categorize the depleted U_3O_8 solute investigated into a solubility class used by the Task Group on Lung Dynamics from the International Commission on Radiological Protection (1). Their classification scheme adopted is:

(a) Soluble - compounds with a solubility half life of less than one to ten days inclusive.

(b) Moderately Soluble - compounds with an estimated solubility half life of greater than 10 to 100 days inclusive.

(c) Relatively Insoluble - compounds with an estimated solubility half life of greater that 100 days.

DISCUSSION

Depleted U_3O_8 is only one component of a complex mixture of radioactive waste material resulting from the testing of depleted uranium munitions. These results, therefore, relate only to the U_3O_8 portion of the complex mixture. The results of the study of this compound in various solutions are discussed below.

Lung Simulant

This study shows direct support for those who purport the relative low solubility of depleted U_3O_8, particularly the work done by Cooke and Holt. Since this investigation used pure depleted U_3O_8 powder (average size was approximately one to ten microns (Plate I)), no comment can be made as to the dependence of solubility versus particle size. In the four day study, the solubility of depleted U_3O_8 in simulated lung fluid was approximately 11%. Interpolations as to what solubility classification this would be in accordance with the ICRP Task Group leans toward the relatively insoluble class of compounds. The study of this compound in lung simulant also approximates the solubility conconclusions of Cooke and Holt even though their study was over 30 days. Though the lung simulant composition used in this experiment was different from that of Cooke and Holt, the pH change paralleled their study. In this study, the initial pH was 7.2 but rose during the four day period to about 8.7. This was most likely attributable to carbonate complex formation due to the modified aeration technique used.

Ringer's and Ringer's Lactate

Experimental results from Attachments 2 and 3 show the solubility of depleted U_3O_8 in Ringer's and Ringer's Lactate to be

approximately 9.4% and 8.5% respectively. Therefore, these test solutions, like the lung simulant, show relatively low solubility. The initial pH's for Ringer's and Ringer's Lactate were 4.6 and 6.5. As with the lung simulant, both pH's rose to 6.0 and 8.1 at the end of four days, attributing this again to the aeration technique.

> At the end of their discussion, Cooke and Holt stated:
> It is accepted that particle size of some powders studied were relatively large when compared with those normally associated with the respirable range size. It may be, therefore, that the fractional dissolution observed in some of the studies was lower than that of much smaller respirable size particles of the same material.

It is now known that the depleted U_3O_8 powder used in this experiment, Plates I-IV, was definitely in the respirable range. Therefore, the solubility findings of 11%, 9.4%, and 8.5% directly correlates with the above statement for all solutions studied.

CONCLUSIONS

Even though this study on the solubility of depleted U_3O_8 is relatively short, it directly supports and supplements the work done by Cooke and Holt. It also lends support for the work done by Steckel and West in 1966, although like Cooke's and Holt's research, it does not go into the study of thermal parameters of the heavy metals. Experimental results showed the relatively low solubility of depleted U_3O_8 in the three test solutions: 11% for lung simulant, 9.4% for Ringer's and 8.5% for Ringer's Lactate. Also, from the observation of Plates I-IV, there was negligable difference in the average particle size or effects on the particles themselves as observed under the scanning electron mic-

roscope.

It is hoped that this study will have helped to alleviate most of the debate over the relative solubility of depleted U_3O_8. Even though the results were obtained at room temperature, it would be hoped that any further solubility studies would investigate the thermal parameters of this heavy metal.

PLATE II

Depleted Uranuim Solute From Lung Simulant

PLATE III

Depleted Uranium Solute From Ringer's Solution

PLATE IV

Depleted Uranuim Solute From Ringer's Lactate

Attachment 1

LUNG SIMULANT TEST SOLUTION

Experimental Start Time - 0800, 5 Nov 1980

Experimental Stop Time - 1000, 9 Nov 1980

SPECIMEN	WEIGHT(milligrams)
Weighing Paper	298.60
Paper + Depeted U_3O_8	345.71
Paper after Depleted U_3O_8 Added to Soln	298.66
Depleted U_3O_8 Added	47.05
Weight of Filter Paper	73.80
Weight of Dried Filter Paper and Depleted U_3O_8 Solute	115.55
Depleted U_3O_8 Solute	41.75
1 - % Depleted U_3O_8 from Filtration	11.26
Weight of Kimax 400ml Beaker (BEFORE)	112.84780
Dried Beaker Weight (AFTER)	112.84786
2 - % Depleted U_3O_8 Residue	0.25
Therefore, Actual Percent Depleted U_3O_8 Solubility is	11.01

Attachment 2

RINGER'S TEST SOLUTION

Experimental Start Time - 0830, 5 Nov 1980

Experimental Stop Time - 1030, 9 Nov 1980

SPECIMEN	WEIGHT(milligrams)
Weighing Paper	295.78
Paper + Depleted U_3O_8	341.35
Paper after Depleted U_3O_8 Added to Soln	295.80
Depleted U_3O_8 Added	45.55
Weight of Filter Paper	69.56
Weight of Dried Filter Paper and Depleted U_3O_8 Solute	110.70
Depleted U_3O_8 Solute	41.14
1 - % Depleted U_3O_8 from Filtration	9.68
Weight of Kimax 400ml Beaker (BEFORE)	113.82384
Dried Beaker Weight (AFTER)	113.82395
2 - % Depleted U_3O_8 Residue	0.24
Therefore, Actual Percent Depleted U_3O_8 Solubility is	9.44

Attachment 3

RINGER'S LACTATE SOLUTION

Experimental Start Time - 0900, 5 Nov 1980

Experimental Stop Time - 1100, 9 Nov 1980

SPECIMEN	WEIGHT(milligrams)
Weighing Paper	295.80
Paper + Depleted U_3O_8	324.89
Paper after Depleted U_3O_8 Added to Soln	295.81
Depleted U_3O_8 Added	29.08
Weight of Filter Paper	83.06
Weight of Dried Filter Paper and Depleted U_3O_8	109.49
Depleted U_3O_8 Solute	26.43
1 - % Depleted U_3O_8 from Filtration	9.11
Weight of Kimax 400ml Beaker (BEFORE)	112.34427
Dried Beaker Weight (AFTER)	112.34444
2 - % Depleted U_3O_8 Residue	0.585
Therefore, actual percent Depleted U_3O_8 Solubility is	8.53

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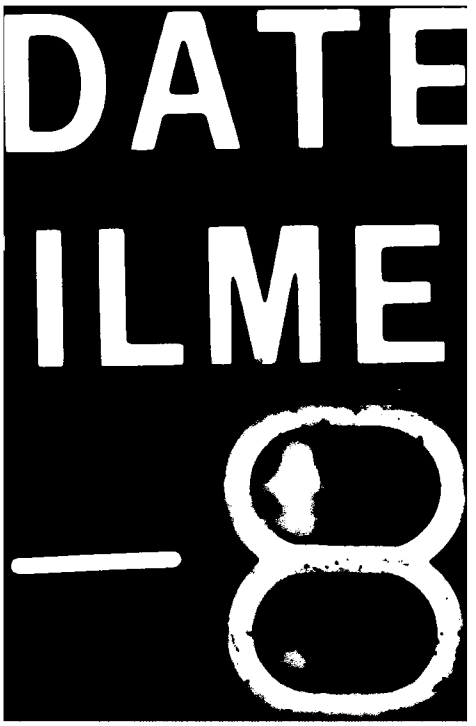
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