PREPARED TESTIMONY OF C. J. STERNHAGEN, M.D.

MATTER OF KERR-McGEE CORPORATION

AMENDMENT TO SOURCE MATERIAL LICENSE SUB-1010

ATOMIC ENERGY COMMISSION

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1.0 Introduction and Scope

This report deals with the radiation toxicity of the raffinate and disposal well at the Kerr-McGee Sequoyah facility. Radium is accepted as the radiological toxic agent of primary interest.

1.1 Radiochemistry of potential internal emitters.

In addition to radium, thorium and uranium are also present in these solutions (Fig. 1)[1] and each has toxicity of its own as well as having a radium isotope in their decay schemes.[2] Therefore, of the four naturally occurring radioactive series (thorium, actinium, uranium, neptunium) only thorium and uranium series are dealt with here since the neptunium series is concerned with the decay of $^{241}_{94}Pu$ and the actinium series involves the decay of $^{235}_{92}U$,[3] and neither of those very toxic radionuclides are present.

The uranium series: $^{238}_{92}U$ ---- $\frac{4.51 \times 10^9 \text{ yrs.}}{\text{alpha}}$ ---- $\rightarrow$ $^{226}_{88}Ra$...

Radium 226 has a half life measured by various investigators in the 1600-1622 year range.

The thorium series: $^{232}_{90}Th$ ---- $\frac{1.38 \times 10^{10} \text{ yrs.}}{\text{alpha}}$ ---- $\rightarrow$ $^{228}_{90}$Mesothorium I ---- $\frac{6.7 \text{ yrs.}}{\text{beta, gamma}}$ ---- $\rightarrow$ Mesothorium II ---- $\frac{6.13 \text{ hrs.}}{\text{beta, gamma}}$ ---- $\rightarrow$ radiothorium ---- $\frac{1.9 \text{ yrs.}}{\text{alpha, gamma}}$ ---- $\rightarrow$ Thorium X

1.2 Radiation toxicity and carcinogenesis

Uranium

^{238}U is more toxic chemically than radiologically and its decay to ^{226}Ra in the solutions here would take too long a time to be radiologically significant. The toxicity by the oral route of uranium 238 is 1/30 (UO_4) to 1/3300 (UF_4) for the rat (with even greater differences for the dog) when compared to the inhalation toxicity. Urinary catalase appears after 0.02 mg of uranyl acetate/kg in the rabbit. The kidney is the critical organ due to the chemical toxicity of uranium. For a period of 1 year the dog tolerates 0.2 mg/kg of UO_2F_2, UCl_4, $UO_2(NO_3)_2 \cdot 6H_2O$. Adverse effects appeared at 1 year from 0.2 g/kg/day of $UO_2(NO_3)_2 \cdot 6H_2O$. Borderline effects resulted from UF_4 at 5 g/kg/day while 10 g/kg/day of UO_2 was tolerated in the dog. Because of lowered pH the uranium dioxide precipitates on the renal tubular cells inhibiting vital enzyme action and injuring the cells. Nevertheless the amounts of uranium 238 which can be tolerated over long periods are obviously much greater by the oral route than by inhalation and therefore gastrointestinal absorption is in the range of about 3% to 0.03% depending upon which compound is presented to the digestive tract.[3,4,5] It is very obvious that relatively tremendous amounts of ^{238}U are tolerated by the oral route.

Thorium

Thorium seeks out the liver, spleen, blood vessels, connective tissues and causes malignancies involving the reticuloendothelial system in those sites. In general, the toxicity of thorium results mainly from its decay to thorium X. Thorium was tried medically

as thorium X in the treatment of leukemia because of its ability to lower the white blood cells as early as 1912. Later it was abandoned because it caused or was associated with the development of fatal hemorrhages, aplastic anemias and myelogenous leukemia. Thorium X, the decay product of radiothorium, has a short half life of 3.64 days and emits alpha and gamma as it decays to thoron.[3,4,5] Thoron chiefly affects the blood and in animals it is less toxic than radon.

Radiothorium has a half life of 1.9 years and decays with alpha and gamma ray emission into thorium X. Radiothorium deposits in the reticuloendothelial system, primarily the liver and spleen. Excretion is primarily renal. The maximum tolerated dose for dogs is 143 x 10^{-6} g/kg intravenously with effects lasting 4 years including leukopenia. Due to larger doses causing patient deaths from leukopenia, anemia, thrombocytopenia and fatal blood loss due to hemorrhage the use of radiothorium medically was abandoned.

Fortunately, the absorption of thorium decay products from the gastrointestinal tract is very low: less than 0.001% is absorbed at doses of 500-800 mg/kg, and 0.05% at 5 mg/kg. A recent medical survey of a Th refinery in operation 30 years at the time of the survey revealed exposures well in excess of current standards but still no evidence of occupational disease. There were 84 workers with 60 in the thorium and thoron process and half had spent 10 or more years with the thorium processing. Of 69 former employees

on whom records were available there was not a single disease occupationally related.

The worst medical exposures due to Th have been with thorium dioxide in thorotrast injections since 1929 which result in a long latent period of up to 16 years before soft tissue necrosis, aplastic anemia, bone atrophy, impaired immune system, liver abnormalities and cancer may occur. After 5 years total radioactivity is at a minimum but increases to 54% of maximum in 10 years and 90% at 25 years due to daughter products. It is anticipated that chalating agents, such as EDTA and DTPA will hasten excretion. This is important since the ingestion of mesothorium has the same general consequences as equivalent amounts of radium.

NOT SO PER FRC – 0.1 μc is occupational limit for public it is .003 μc for individual and .002 for average of suitable sample of exposed population. Ref FRC Report NO 2 dtd 9/61

Radium

The maximum permissible amount of radium fixed in the body is 0.1 microcurie. If radium enters the body through liquid media, assuming 10% of the ingested amount is retained with a mean life of 10^4 days, the MPC of the liquid is 4×10^{-8} microcuries/ml. Past work 3×10^{-8} at pt of release – 1×10^{-8} mean In the classic tragedy of the radium dial painters the fact is that 10% of the radium workers with symptomatic poisoning developed osteogenic sarcoma. These tumors were distributed randomly in the skeleton differing from "spontaneous" osteogenic sarcomas.[3,4,5,6,7,8]

Other radium poisoning complications were dental changes, spontaneous fractures through necrotic bone, osteitis, osteomyelitis (jaw primarily) and carcinoma of paranasal sinuses and mastoid air cells. Both radium and thorium products deposit irregularly in bone with hot spots 100 times the concentration of adjacent

areas. However, these tumors occurred with a sharp threshold near 1000 cumulative rads at which point a 30% tumor incidence occurred with no further significant increase when dosages increased even to the 10,000 to 100,000 rad range.[9,10,11,12,13,14]

The earth's outer crust natural background is, by weight:

Radium	2×10^{-6} ppm	(2×10^{-12} curie/g)
Thorium	12 ppm	(1.3×10^{-12} curie/g)
Uranium	6 ppm	(2×10^{-12} curie/g)

Surface soil with 1/2 these concentrations has 3 tons U, 6 tons Th, and 1 gram Ra in one square mile of earth one foot deep. The Ra content of the North Canadian River, Oklahoma City, Oklahoma, is 1.06×10^{-16} g Ra/ml raw water, 0.42×10^{-16} g Ra/ml tap water. This is much lower than the city water of Pittsburgh, Pennsylvania, coming from the Allegheny River which has 37×10^{-16} g Ra/ml raw water and 1.41×10^{-16} g Ra/ml tap water.[4] Other Ra concentrations of interest in placing these solutions in proper perspective include:[4]

Great Salt Lake, Utah	5×10^{-6} g/liter Ra
Curie Spring, Boulder, Colorado	$267{,}000 \times 10^{-12}$ g/l Ra
Normal ground water, U.S.	$0.58 - 3.90 \times 10^{-12}$ g/l Ra

Radium is eliminated very rapidly the first week after ingestion: 70% the first 24 hours and 95% in 5 days. However, later elimination is very slow and as a "bone-seeker" much of the remainder stays in the body. A calcium-free diet may speed up

the elimination of Ra. This is much worse than U where the kidney burden is the same as in bone and the biological half-life of uranium in bone and kidney is only 300 days.[15,16,17]

It is known that the city water supply of Joliet, Illinois, derived from deep wells contained 65.4 x 10^{-16} g Ra/ml raw water and 57.9 x 10^{-16} g Ra/ml tap water. The values for raw water published by the U.S. Atomic Energy Commission in 1953 varied from 0.02 x 10^{-16} to 65.4 x 10^{-16} g Ra/ml.[4]

Due to the mobility of the population and the scarcity of accurate scientific data it is difficult to state with authority whether these water sources of relatively high Ra content are implicated in Ra toxicity or the production of malignancies. It must be assumed medically prudent to expect an increase in malignancies, however, whenever the long term exposure could result in 800-1000 cumulative rads in a target[9] organ or tissue. A single ingestion of a liter of the disposal solutions would be relatively harmless since 90-95% elimination is expected within the first 5 days.[5] It would be very difficult to disprove a claim of toxicity from long term ingestion since aggravation of other medical conditions, at least, is conceivable.

Since the raffinate is measured at 340 x 10^{-8} microcuries per ml it would require a dilution of 100 times to be within limits. The well and spring solutions will need to be diluted by 350 and 360 factors to comply with water quality standards of Oklahoma. The undiluted raffinate solution also contains total Th concentration

of 3000 x 10^{-8} microcuries/ml and even though ingested absorption is very low, at these levels, combined with Ra, it would be a potential problem of chronic toxicity if consumed regularly over a period of many years.

1.3 Non-radioactive Materials

It is almost inconceivable that the other elements could be ingested on a regular basis due to the natural aversion of humans to water with the unacceptable taste these solutions would have. There is no question that long term regular drinking of such solutions would be harmful, but the exact degree would be a matter of future experimentation to determine since no data is available involving the animal or human consumption of such solutions. The metabolism and biochemistry of these elements and their salts in detail is beyond the scope of this research report.

Conclusion

In view of the solution concentrations given in Figure 1, the burning sensation and bad taste resulting from consuming any one of the liquids in its undiluted condition would make it almost impossible to receive a dose of radionuclude of any significant level. In fact, the consumption of two liters of the undiluted material, if it could be ingested at all, would produce only negligible deposition in the body.

Figure 2, attached hereto, shows the resulting concentration upon injection of raffinate or Arbuckle formation water into the Illinois and Arkansas rivers at various levels as the result of a massive fault leak. In the event of such a worst possible accident, it is apparent that the amount of water available in surface streams adjacent to the disposal fault block flow at such a rate as to provide adequate dilution of either the raffinate or the formation water to concentrations generally below permissible limits.

Based upon my understanding of the monitoring program proposed and the precision with which a leak from the reservoir can be detected, I believe it to be incredible that an accidental release through failure of the well or the reservoir would result in significant exposure to the population in this area.

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TYPICAL ANALYSIS

	Raffinate	Disposal Well
Total Dissolved Solids (ppm)		140,000
Calcium	<1	11,300
Magnesium	4	2,470
Chlorides	141	88,300
Sulfates	6,700	120
Carbonates	--	0
Bicarbonates	--	159
Total Iron	.4	22
Sodium	580	39,700
Specific Gravity @75°		1.104
pH	HNO_3 IM	7.00
Resistivity @75°	--	.093
Strontium (ppm)	--	--
Uranium	.05 - .5 g/l	<1 ppm
Radium-226 (uCi/ml)	340×10^{-8}	140×10^{-8}
Total Thorium (uCi/ml)	3000×10^{-8}	$<0.5 \times 10^{-8}$
Suspended Matter (ppm)	53	720
Gross Alpha (pCi/g)	800	204
Gross Beta (pCi/g)	140	166

Figure 1.

Figure 2

CONCENTRATIONS RESULTING FROM THE INJECTION OF RAFFINATE OR ARBUCKLE FORMATION WATER INTO THE ILLINOIS AND ARKANSAS RIVERS

If one assumes the worst possible accident, it would consist of a leak of the entire effluent to one of the rivers. (Note this could be monitored by pressure drop in the well).

Rate of Waste Flow 19 gpm x 60 x 24 = 27,360 gal/day

= .0423 CPS

RA 226*
x 10^{-8} uCi/ml

	Flow (CPS)	Dilution Factor	Raffinate	Formation Water
Fresh Solutions			340	140
Illinois**				
Average	1,464	34,600	.01	.004
Min/Record (1 day only 9-16-59)	2	47.3	7.0	2.97
Min/Record/1971	17	402	.85	.35
Arkansas**				
Average 1970	19,520	462,000	.0007	.0003
Min/Record	66	1,560	.22	.09
Min/Record 1970	1,230	29,100	.012	.005

MPC (Soluble, Unrestricted Area) 3 x 10^{-8} uCi/ml

* Concentrations calculated by dividing fresh solution concentration by dilution factor.

1 CPS = 646,317 gal/day

** Water Resources Data for Oklahoma, Part I, Surface Water Records 1970 and 1971, Department of Interior, Geological Survey.

QUALIFICATIONS OF

CHARLES J. STERNHAGEN, M.D.

Home Address:

4139 Dietz Farm Circle N.W., Albuquerque, New Mexico 87107

Present Position:

Assistant Professor of Radiology and Radiation Oncologist
University of New Mexico Cancer Research and Treatment
Center, Albuquerque, New Mexico 87106

Place and Date of Birth:

Glasgow, Montana, October 15, 1933

Education:

Carroll College, Helena, Montana	B.A. Biology	1956
Loyola University Stritch School of Medicine, Chicago, Illinois	M.D.	1959
Graduate School, University of Idaho, 1964-1967, University of Oklahoma 8-70 to 1972		

Medical Career:

Intern, Saint Joseph's Hospital, South Bend, Indiana	1959 - 1960
Resident, National Institutes of Health Fellowship in Radiation Therapy, The University of Oklahoma Medical Center, Department of Radiological Sciences	1969 - 1972
General Practice, Smith Clinic, Glasgow, Montana	1960 - 1961
Solo General Practice, Challis, Idaho	1961 - 1963
Occupational Medicine:	
U.S. Atomic Energy Commission, Idaho Falls, Idaho	1963 - 1967
National Reactor Testing Station	
Assistant Chief, Medical Branch	1967
Kerr-McGee Corporation, Oklahoma City, Oklahoma	
Technical Director Radiological Sciences	1967
Corporate Director Environmental Health	1968
Corporate Medical Director	1969
Corporate Medical Consultant	1969 - Present

Licensure:

Montana, Idaho, Washington, Oklahoma, and New Mexico

Military:

Commanding Officer 744th Med. Det., New Mexico Army National Guard	1972 - Present

Appointments:

Consultant to the Federal Radiation Council, Washington, D.C.	1968
Faculty, University of Oklahoma, Instructor in Environmental Health	1968 - 1972

Associations:

Fellow American Public Health Association
Fellow Royal Society of Health
Health Physics Society
American Medical Association
American Society of Therapeutic Radiology
American College of Radiology
Charter Member, Oklahoma City Academy of Environmental Sciences
Board Director, Oklahoma City Council on Alcoholism
Vice-President, University of Oklahoma House Staff Association

Special Honors:

Elks National Scholarship Most Valuable Student Award	1952
Who's Who in American Universities	1955
Lederle Research Fellowship in Anatomy	1956