John B. Stanbury, M.D. 30 September, 1964

SUMMARY REPORT TO THE ATOMIC ENERGY COMMISSION ON THE UNITED NUCLEAR CORPORATION CRITICALITY ACCIDENT OF 24 JULY 1964

This is a summary of the criticality accident which occurred at the United Nuclear Plant in Charlestown, Rhode Island, on Friday, July 24. The information which is included has been derived from the hospital records of the Rhode Island Hospital, my own observations, and such other reports as have come to my attention since that time. The radiation data have been obtained in part through the generous cooperation of Dr. Gordon L. Brownell and Dr. Roger Rydin of the Physics Research Laboratory of the Massachusetts General Hospital.

The patient who died, was a -year-old, white, married father of 9 children, who was employed as a technician by United Nuclear Corporation. At approximately 6:07 P.M. on the evening of July 24, he was pouring approximately 7 liters of an enriched solution of U-235 from a tall, narrow cylinder into a shorter, thicker container holding sodium carbonate. His left hand was near the mouth of the cylinder. As he neared completion of this operation, there was an explosion, and flash which threw him backwards 6-7 feet and stunned him, but did not cause him to lose consciousness. He recovered immediately and ran from the building 100 yards or so to the emergency shack, removing his clothes while running. Two of his colleagues who were also in the building ran

OFFICIAL USE ONLY

RECEIVED
U.S. ATOMIC ENERGY COMM

1964 OCT 8 AM 11 30

DIVISION OF
BIOLOGY & MEDICINE

1006836 OFFICIAL USE ONLY

to this area as the radiation alarm sounded. Within 10 minutes of arriving in this shed, the patient complained of abdominal cramps, headache, and vomited. It is said that he was also incontinent. He was wrapped in blankets and taken to the Westerly Hospital, but was transferred directly without leaving the ambulance to the Rhode Island Hospital. En route to the Rhode Island Hospital, he vomited.

He arrived at the Rhode Island Hospital at 7:49 P.M. At that time his blood pressure was recorded as 160 systolic, 80 diastolic, his pulse 100, his respirations 20, and his temperature 101.4° F. He was well developed and well nourished, but was complaining of abdominal pain, cramps, thirst, and chilliness. He was perspiring profusely, was shaking, and was incontinent of brownish, diarrheal stool. Except for some dysarrthria, perhaps occasioned by his anxiety, general physical examination otherwise was normal. The abdomen was tense, with nonspecific guarding.

One hundred milligrams of benadryl was given intramuscularly, and 12 mg of morphine subcutaneously at 8 P.M. and the morphine was repeated 1 hour and 45 minutes later because of restlessness. A polyethylene catheter was introduced intravenously at the left ankle, and a unit of plasma was run in quickly. A Levin tube was placed in the stomach, and a Foley catheter in the bladder.

Hereafter, all times noted will be given as hours after the accident.

At 3 hours the blood pressure was 130 systolic, 60 diastolic, and the pulse 90. Diarrhea and vomiting had ceased. Admission hemoglobin was recorded at 15.5 grams, hematocrit at 43.5%, WBC 17,750, and 95% polys, 5% lymphs, and many band forms. Red blood

cell count was 4.46. The urine had a specific gravity of 1.012 and was free of acetone and sugar. There was a trace of protein, 8-10 red blood cells and 0-1 white blood cells and a rare granular and hyaline case. BUN was 18 milligrams %, sodium 140 MEQ/liter, potassium 3.7 MEQ/1, the chloride 104 MEQ, CO_2 21 MEQ/1, the total bilirubin 0.4 mg%, and the direct bilirubin, 0.1 mg per cent. A blood glucose was 100 mg%. At 2 hours a radiation exposure meter showed 18 MR/hr at 2 feet from the midportion of the body, 10 MR at 2 feet from the lower extremities, and 40 MR/hr at 2 feet from the face and upper chest.

At approximately 4 hours, the patient was washed down and scrubbed with physohex and warm water on a plastic sheeting. From this point forward, all linen, clothing, and other articles which came into contact with the patient were discarded in plastic bags after being labeled.

By 7 hours the blood pressure had dropped to 85 systolic and 40 diastolic, and the pulse was regular at 100. By this time 3 units of 250 ml each of plasma had been given, together with 40 mg of solumedrol, and 8 mg of levofed were added to an intravenous infusion, which was adjusted to maintain the blood pressure between 95 and 100 systolic. Neomycin, 1 gram every 4 hours, was given through the Levin tube, as well as 2 grams of chloromycetin /1000ml of the intravenous infusion. From this point forward it was necessary to use levofed to maintain the patient's blood pressure. At 26 hours the hemoglobin was 12.9, and the hematocrit 37%. The white cell count was 28,800, with 100% polys and no lymphs. BUN was 37, sodium 139 MEQ/liter, potassium 4.3 MEQ/1, chloride 121

PRIVACY ACT MATERIAL REMOVED

MEQ/l, CO_2 17 MEQ, urine specific gravity was 1.017, and there was a ++ protein, but no glucose. There were 0-2 red blood cells and 10-20 white blood cells in the urine, and occasional granular casts. The eosinophil count was 5, the serum transaminase was 40, the thymol turbidity 3+, the prothrombin time 50%, uric acid 16.9 mg%, total protein 5.8 mg%, and the albumin 4.2 mg%. The platelets were 155,000, the serum creatinine was 2 mg%, and the calcium 4.9 MEQ/l. The clotting time was 9 minutes, and the alkaline phosphatase was 5 King-Armstrong units.

I was called at my home in Chestnut Hill, Massachusetts, at 13 hours, and saw the patient first at 15 hours. Upon arrival at the Emergency Ward of the Rhode Island Hospital I was briefed by Dr. Forsyth and by of the AEC. The patient was in an anteroom off a larger room which was used for overflow and storage for the x-ray section of the Emergency Service. The larger room was set up as a nursing station and as a barrier approach to the patient. Attending the patient was Dr. Joseph Karus of the staff of the Rhode Island Hospital, two assistants from the hospital house staff, the hospital Radiation Officer, the staff hematologist, and the nurse. Access to the patient at this point was permitted by covering the feet with paper sacks and the hands with plastic gloves. These were discarded in the plastic bags on leaving the restricted area. The floor was being cleaned by swabbing.

The patient was lying at 45°, was alert, cheerful, and did not appear to be overly apprehensive, and seemed most concerned about his family. He was somewhat restless and was asking to be permitted

to get out of bed. He could read fine print. There was no evidence of motor incoordination. Respirations were 24-28. Pulse 100-120, and heart sounds were of good quality. The left side of the face was slightly red, and there was moderate conjunctival and minimal periorbital edema. The neck veins were not distended. The lungs were clear and the abdomen normal. The extremities were normal, except for the left hand and arm. The left hand was swollen about twice normal size, and was bright red. The fingers could be moved with difficulty. The left forearm was much swollen with brawny edema. He was receiving an intravenous drip of dextrose and levofed in order to maintain his blood pressure. By this time 5 units of plasma had already been given. A Foley catheter was in place, and urine was being collected.

A bone marrow aspiration done at approximately 14 hours was read by Dr. Maurice Albala and was said to show active hematopoiesis and possibly some toxic changes in a few of the cells. There was a slight shift toward erythropoiesis. The patient vomited again at approximately 14 hours.

Specimens of blood, urine, feces, vomitus, and hair were brought back to Boston for radioanalysis. By 20 hours the blood pressure was varying widely between 70 systolic and 40 diastolic, and 130 systolic and 90 diastolic, and vasopressors were required in increasing doses. The temperature had risen to 102°. A trial of manitol failed to increase noticeably the amount of urine produced. With the passage of time the heart sounds became somewhat more distant and tick-tack in quality. He complained increasingly of

pain over his lower extremities where the vasopressor agents were inducing venous spasm.

I saw the patient again at 38 hours. By this time sterile precautions had been instituted, and all persons entering the patient area changed into scrub suits, masks, caps, gowns, protective covering for the feet and gloves for the hands. The patient's condition had deteriorated remarkably since the previous day. He was apprehensive, restless, fatigued, and uncomfortable. He was somewhat more dyspneic. There had been considerable difficulty experienced in maintaining his blood pressure. The conjunctivitis and the blush over the left side of his face ~~was~~ were more apparent, and the left hand was much more swollen and had become livid. The forearm had increased in size, and there was now massive edema of the upper left arm. The chest was clear, and the heart sounds were fairly good. Vision had deteriorated to the point where the patient was unable to read 1 inch type, but he could still distinguish faces. He was nauseated, and vomited occasionally. Urine volume had decreased. An attempt to support the blood pressure with aramine failed, and levofed was reinstituted. At about this time his white blood count was 36,000, with 100% polys and no lymphocytes. Blood urea nitrogen was 45 mg%. Bilirubin was normal. Uric acid was 16.4 mg%. Platelets 220,000. Reticulocyte count 0.3%. During the remaining hours, the patient became increasingly disoriented, restless, and difficult to manage. The blood pressure became unobtainable approximately 4 hours prior to death. The patient died at 49 hours at 7:20 on the evening of Sunday,

Other laboratory data were obtained from the patient. An electrocardiogram on the evening of admission showed sinus tachycardia and slight prominence of the T waves but was otherwise unremarkable. Two electrocardiograms taken between the 36 and 48 hours showed increasing development of right axis deviation, flattening of the T waves, and lower voltage. An x-ray of the chest at approximately 14 hours showed mild congestive changes but was difficult to interpret, because it was a portable film. Bone marrow biopsy at 40 hours revealed a fluid specimen without marrow spicules. The smear showed 91% polys and 8.5% band forms, with marked depression of all precursor cells.

Autopsy was performed by a representative of the AEC approximately 8 hours post mortem. The records of this procedure presumably are available through another report.

It may be of some interest to note the total fluid balance as recorded. The total intake from the time of arrival at the Rhode Island Hospital at 2 hours to 38 hours was 4,575 ml. Of this 1750 was in the form of plasma. During this period the total output was 3,400 ml, including vomitus. Total intake from the 38th to the 47th hour was 2,500 cc, of which 500 was plasma. The total output during this period was 790 ml, including vomitus. These figures do not take into account fecal loss or insensible loss. Thus the total intake was 7,075 ml, and the total output, 4,190 ml. When one adds to the total output the presumed insensible loss, then it is apparent that the patient was not far from fluid balance.

PRIVACY ACT MATERIAL REMOVED

The surface radiation readings immediately after death were as follows: Hair, 7.5 mr/hr; face, 3.75; chest, 2.5; abdomen, 5.0; right arm, 2.5; left arm, 2.5; pubic hair, 4.0; thigh, 2.5; feet, 1.1.

Samples of blood were obtained from at 7 hours and at 16.5 hours and brought back to Boston on the afternoon following the accident for analysis in the laboratory of Dr. G.L. Brownell. The analyses were performed by Dr. Brownell and Dr. Roger A. Rydin. The findings appear in Appendix II. Both samples were extrapolated to zero time and indicated a sodium activity at that time of 2.64 x 10^{-2} microcuries per ml serum. The spectrum of the serum was consistent only with the presence of radiosodium.

Samples of vomitus and urine from were analyzed similarly to the blood samples, and disclosed only the presence of radiosodium. Copies of the spectra from the patient's serum, gold ring, and from his hair are appended.

Specimens of urine, feces, and vomitus were brought to the Massachusetts General Hospital and processed by beta counting. Small samples were dried on planchettes and counted repeatedly in a Nuclear-Chicago thin window counter of high sensitivity and low background. The machine sensitivity was corrected to authentic P^{32} standards counted at the same time, and the resulting values plotted and fitted by eye. The observed half life of the 4-hour urine sample of was 13.8 days, of the 13-hour urine sample, 15.6 days, and of the 34-hour sample, 17 days. The fecal specimen had an observed half life of 16 days. These values are thought to be within

the limits of error for measurement of P^{32}, but the possibility of contamination by other beta-emitting isotopes is not excluded. If it can be assumed that this was indeed P^{32}, then it can be estimated that the 4-hour urine contained about 0.0062 microcuries of radiophosphorus/ml.

PRIVACY ACT MATERIAL REMOVED

---

is a -year-old white married plant supervisor for the United Nuclear Corporation. He was in the building at the time of the criticality accident two floors removed vertically and approximately 50 feet horizontally. At the time of the accident he ran from the building to the emergency shack, and returned later with the plant director, , where he was engaged for a time in draining the tank in which the criticality accident had occurred. He remained in the area approximately 10 hours. He was seen in the accident room of the Rhode Island Hospital after the accident and was scrubbed down. Surface monitoring showed minimal activity, and he was released. The following day film badge monitoring indicated that he had received approximately 300 rads of whole body radiation. This was subsequently found to be an error, and a rough estimate was said to be approximately 50 rads. On this account, however, it seemed wise to hospitalize the patient, and he was admitted to the Rhode Island Hospital on the 26th of July and was discharged on July 31.

At the time of admission his blood pressure was 140 systolic

and 90 diastolic, pulse 96, respirations 20. Temperature was normal. The physical examination was entirely within normal limits. Initial hemoglobin was 16 grams; white cells, 4,900, with a normal differential; hematocrit 49%; platelets 270,000, and 1.1% reticulocytes. Urinalysis was normal except for a trace of acetone and slightly elevated urobilinogen at 0.4 mg% (normal: 0.05-0.2). Total bilirubin in the blood was 1.7 mg per cent, and direct bilirubin, 0.2. This is in excess of normal limits. Thymol turbidity was normal at three units. The total protein was 7.4 grams%; albumin, 6.4 grams %; total cholesterol 250 mg%, with 174 mg cholesterol esters; alkaline phosphatase, 7 King-Armstrong units; FBS, 87%, and BUN 13 mg%. The uric acid was elevated at 8.1%, the upper limit of normal being 5.5. Serum electrolytes were all normal. Benzedine test for blood in the stool was normal. A blood Hinton was negative. During hospitalization complete blood studies were done daily. Hemoglobin ranged from 15.4 to 16 grams. WBC were all within the 5-6,000 range, with normal differential counts. By July 30 the uric acid had dropped to 4.9, and the bilirubin had dropped to 0.6. Bone marrow aspiration done on July 27 showed active hematopoiesis. A repeat bone marrow on July 31 showed active hematopoiesis, and "increased stainable iron." An electrocardiogram on July 27 showed prolonged QRS complexes, measuring 0.12 secs, and having the configuration of a complete right bundle branch block. Examination on July 31 showed a disappearance of the right bundle branch block and QRS complexes which now measured 0.09 sec.

I examined the patient in Boston on 30 July. He seemed perfectly well, except that he was somewhat concerned about the

problem of subsequent sterility. Physical examination was entirely normal except for some straightening of the normal dorsal spinal curvature. Blood pressure was 110/70. Blood uric acid was 4.5 milligrams%, and the serum bilirubin, 0.8 mg%. Both these values are within normal limits by our methods. It was advised that the patient have serial blood counts and if possible, sperm counts. I have no information as to whether these have been done subsequently.

PRIVACY ACT MATERIAL REMOVED

This -year-old married, white, plant manager for United Nuclear entered the plant 32 minutes after the flash and remained approximately 12 hours. He determined the 100 MR line and emptied the container in which the accident had occurred. At the time of admission to the Rhode Island Hospital on the evening of the accident, he was found to have high contamination of his thumb and index finger of his right hand, but no other contamination. He was scrubbed down with soap and water, and discharged. However, the following day it became apparent from his film badge that he had received considerable whole body exposure. This was initially reported to be in the neighborhood of 300 R, but this was subsequently much reduced. On the basis of the initial report, the patient was hospitalized on the 26th of July, and discharged on the 31st.

At the time of admission his blood pressure was 130 systolic, 100 diastolic, pluse 82, respirations 20, and temperature normal. The general physical examination was entirely normal except for

bilateral iridectomy scars. The initial hemoglobin was 15.5 grams; hematocrit, 40%; WBC, 10,700, with 81% polys, 18% lymphs, and one monocyte, and platelest 220,000. Reticulocytes were 1.1%. Urinalysis was normal, except for a trace of acetone. Urobilinogen was 0.4; total bilirubin 1.1 mg% (slightly elevated; thymol turbidity ++; total protein 6.2 grams%; albumin, 4.9 mg%; total cholesterol 301 with esters of 270 mg%; alkaline phosphatase, 6 King-Armstrong units, and glucose 90 mg%. Blood urea nitrogen was 13 mg %, and uric acid 7.6 (elevated). Serum electrolytes were normal. Benzedine test for blood in the stool was negative. Blood Hinton was negative. Daily blood counts were done thereafter and showed no change in the normal findings. The uric acid rose from 7.6 to 9.2 mg%, and was 7.3 mg% on the day of discharge. Serum transaminase determinations were within normal limits. Electrocardiogram was normal. Bone marrow aspiration on July 27 showed active hematopoiesis, moderate erythroid hyperplasia, and some eosinophilia. A repeat aspiration on July 31 showed active hematopoiesis.

I saw the patient in Boston on 30 July. He gave a history of glaucoma with iridectomies in 1949. General physical examination was entirely normal. Uric acid determined at that time was 6.8 mg%, which is elevated for our laboratory. The bilirubin was 0.5 mg per cent, which is normal. He was advised to have repeated blood counts during subsequent months. I have no information on these.

PRIVACY ACT MATERIAL REMOVED

This -year-old chemical operator for United Nuclear was not admitted to the hospital. He was in the building at the time of the accident, and approximately 35-40 feet from the accident. He left the building immediately, and returned approximately 5 hours later. Apart from minor anxiety symptoms he felt perfectly well. At the time of examination on July 30, I found no physical abnormalities.

Additional observations on , , and were made in the whole body counter at MIT by Dr. Constantine Maletskos. His report indicates a minimal radiosodium load. In addition, the ring of showed minimal radio-gold. A copy of Dr. Maletskos' report is appended.

Ten ml samples of urine from and were dried on aluminum planchettes and counted serially for 25 days in a very thin window low background high efficiency Nuclear-Chicago automatic counter. The counting efficiency of the machine was corrected for machine variation to authentic samples of P^{32}. The values obtained on the two urine samples were in a low counting range, but when fitted by eye the decay curves were approximately 55 days for and 43 days for . These findings are interpreted to mean inhalation or ingestion of fission products. The order of magnitude of the contamination may be indicated by the fact that the counting rates were of the order of 200 counts in 10 minutes for 10 ml of urine in a machine which gave 1,500 counts per minute for 25 lambda

of an authentic sample of P^{32}, which contained 0.14 microcuries per ml.

PRIVACY ACT MATERIAL REMOVED

Critique of the Medical Problems of the Criticality Accident

It is apparent from all considerations, including dose calculations, that the radiation dosage received by was far in excess of the minimal lethal amount, and that nothing presently known could have saved him. The central clinical problem was maintenance of the blood pressure. There seems to be little information on the effects of heavy radiation on the blood pressure as such, and it seems evident that this is an important area for future investigation. None of the pressor agents which were tried were adequate. Levofed was helpful, but only in increasing doses, and it finally became ineffective. It occasioned considerable discomfort from local venospasm. There was no evidence of significant gastrointestinal hemorrhage, but frequent vomiting indicated damage to the GI tract. This was a factor as early as 10 minutes after the accident. Damage to the central nervous system was indicated by failing vision, but there was no other evidence of motor disturbance, except perhaps his restlessness. There was evidence of cardiac damage, but through his heart seemed to be able to tolerate the strain of a number of units of plasma without evidence of significant congestive failure. Electrocardiogram done on the day following admission showed some prominence of the T waves, but was otherwise unremarkable. Two cardiograms taken on the day

of death showed increasing development of right axis deviation, flattening of the T waves, and lowered voltage. Evidence of damage to the hematopoietic system was indicated by the rapid dropout of the lymphocytes. Evidence for general tissue damage was indicated by the very high blood uric acid and the elevation in the blood urea nitrogen. Radiation studies disclosed the presence of radiosodium in the blood and urine. There was also a component in urine, vomitus, and feces, which had a decay constant indistinguishable from that of P^{32}. The hair was heavily contaminated with a variety of gamma-emitting radioactive substances which were presumably fission products.

Insofar as I can see, everything was done for this patient which could possibly be done from the medical point of view. His medical care by Dr. Karus and his associates was wise, excellent, and devoted.

, , and seem to have presented no significant medical problem. had considerable contamination of his right hand, but this was easily removed by washing. The only evidence of radiation damage was the rise in the blood uric acid of both and and the slight rise in bilirubin in . Both and had evidence for a body load of radiosodium and of a nuclide or nuclides in the urine with a long half life. . gave evidence of radio-gold in his ring.

Critique of the Administrative Aspects of the Accident

An accident of this kind is so unusual and unexpected that inevitably there is some disorganization of administrative control. It seemed evident to me that of the AEC was doing a superb job under difficult circumstances. It seemed to me that his limits of authority were not sufficiently spelled out. It also seemed to me that medical authority was not sufficiently defined, and I was surprised that the Chief of Medicine of the Hospital did not take a more active role in the medical administration of this difficult problem. It seems to me that in a circumstance such as this, authority should be divided into three. In the first place, a single medical officer should be given absolute authority for all medical decisions. Secondly, a radiation safety officer should be given absolute authority over matters of radiation safety. Thirdly, an officer of the administration of the institution should set up a station at the entry to the area. His duties should be to control access to the area. He should be in charge of procurement, of handling telephone calls, and of attending to all administrative details. No one should be allowed in the area except for good and sufficient reasons, and everyone should leave the area as soon as his task has been accomplished.

My comments concerning administration derive from my impression that there was considerable confusion in the area where was hospitalized. Any number of members of the staff were wandering around without any particular function, or were remaining in the area when their specific duties had been discharged. This not only interfered with smooth handling of the operation, but tended

PRIVACY ACT MATERIAL REMOVED

to disturb the patient, whose principal complaint on the second day of his hospitalization was that there had been so much activity that he had been unable to get any sleep and was extremely fatigued. Some of this, of course, is inevitable, but some of it could have been avoided and might be of critical importance under other circumstances.

The interest and concern of the officials of the AEC at the time of an accident is, of course, entirely desirable and commendable. During the early hours after such an accident, however, too many telephone calls can be distracting. It was my impression that the function of was impaired by the number of telephone calls which he was receiving at a time when he was extremely busy.

John B. Stanbury, M.D.
Massachusetts General Hospital
Boston, Massachusetts

1006852

APPENDIX I

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF PHYSICS
CAMBRIDGE, MASSACHUSETTS 02139

12 August 1964

Dr. John B. Stanbury
Massachusetts General Hospital
32 Fruit Street
Boston, Mass. 02114

PRIVACY ACT MATERIAL REMOVED

Dear John:

In accordance with the request in your letter of 30 July 1964, we have made body burden measurements on 30 and 31 July 1964 on three persons from the United Nuclear Corp., Wood River Junction, Rhode Island. As noted in your request, these measurements have been carried out with the understanding that the results will be transmitted by you to the AEC.

At our request and through you, the subjects had been asked to shower and shampoo their hair well prior to coming to the laboratory and to wear clothes that had never been in the plant. Interrogation indicated that one subject ( ) had used his shirt, pants and shoes in the "clean" part of the plant.

The measurements on the γ-ray output of these subjects were carried out in our whole body counter which uses an 8" x 4" NaI(Tl) crystal and multichannel analyzer. The subjects wore our standard clean pajamas.

Measurements included the following:

1. Standard chair and crystal position.
2. Standard chair position with the 8" crystal face centered over the chest ~0.5" from the chest wall.
3. Subject standing, arms extended, and the palms of the hands held against the crystal face.

Na^{24} activity was found in and which appears to be generally distributed on and/or in their bodies. The measurements on the hands and chest showed no significant disproportionate excess activity in these regions. Assuming the Na^{24} to be distributed within their bodies the whole body activity is calculated to be 4.6 ± 0.5 nc (nanocuries) for and 2.2 ± 0.3 nc for both as of 1700, 30 July 1964.

The measurements on the third subject,

Dr. John Stanbury 12 August 1964

showed a spectrum consistent with that of a normal person, except for a small peak corresponding to Au^{198}. His Na^{24} activity is calculated to be 0.1 ± 0.2 nc as of 1500, 31 July 1964. The gold activity was confirmed by measuring his wedding ring separately (we had forgotten to ask him to remove it during his whole body measurement). The ring contained 3.8 ± 0.4 nc as of 1500, 31 July 1964 (ring weighed 4.818 g but composition is unknown) and accounts quantitatively for the activity seen on his body spectrum.

A specific search was made for I^{131} representing the fission products and for U^{235}. No significant quantities were detected for each of these isotopes indicating ≤ 2 nc I^{131} in the thyroid, ≤ 3 nc I^{131} in the body and ≤ 2 nc U^{235} in the chest, for both Holthaus and Smith.

If there are any further questions, please feel free to call me.

Sincerely yours,

C. J. Maletskos
Research Biophysicist
Room 2-034

CJM:ha

1006854

APPENDIX II

PRIVACY ACT MATERIAL REMOVED

CALCULATION OF . SAMPLES

Samples of serum, urine, hair, and portions of a gold ring were received from Dr. Stanbury on the afternoon of July 25, 1964. Gamma-ray spectra of these samples, measured by means of a standard sodium iodide well crystal connected to a Nuclear Data 512-Channel Analyzer, were obtained at intervals until July 27, 1964. The results of these measurements are summarized below.

Beta counts were obtained on various samples in an effort to detect fast neutron induced activity. The results of these measurements are discussed in the body of the report.

I. Plasma Samples

Two samples of plasma were obtained, S2 taken 7 hours after the accident, and S1 taken 16.5 hours after the accident. All the spectra from the serum samples were essentially identical and Figure 1 shows a typical spectrum together with the spectrum of an aliquot of a sodium-24 standard obtained from Oak Ridge. No other peaks were observed in the serum samples even at long times following the accident.

Standardization of sodium-24 in the serum samples was performed by integrating the total count in 120 channels which included both gamma peaks. Background was then subtracted and the number of counts in these channels compared with that of the standard. The total counts in each case was approximately 10,000 counts, giving counting statistics of 1%.

Two secondary standards were made from the Oak Ridge standard sodium-24, calibrated by Oak Ridge to ±3%. The calibration value was 3.0 millicuries per ml at 11:03 P.M. on August 3, 1964. Two standard sample dilutions were prepared. The first consisted of a dilution of 100 lambda in 10 ml. The calibration was referred to 11:00 A.M. on August 4, 1964, at which time the decay factor was .5755. The final activity as of 11:00 A.M., August 4, 1964, was:

$$\text{Standard} = (3.0 \text{ millicuries/ml}) \times (.5755) \times (10^{-2}) = 17.3 \ \mu c/ml$$

Aliquots were taken to give:

0.1 ml (diluted to 2 ml) = 1.73 μc

0.3 ml (diluted to 2 ml) = 5.18 μc

0.5 ml (diluted to 2 ml) = 8.65 μc

0.8 ml (diluted to 2 ml) = 13.85 μc

1.0 ml (diluted to 2 ml) = 17.3 μc

A second standard sample was prepared by diluting 10 lambda to 10 ml to give a total dilution of 10^3. An aliquot was then taken to give:

0.1 ml (diluted to 2 ml) = .173 μc.

Table I shows the results of the sodium-24 assay in serum samples. Both S1 and S2 were measured at various times and the results corrected to the time of the accident agreed adequately. The average value gave an assay of 5.28×10^{-2} μc/2 ml as assayed on 11:00 A.M., August 4, 1964, and corrected to the time of the accident. The serum activity at that time was, therefore, 2.64×10^{-2} μc/ml

of serum.

II. Urine Samples

Two samples of urine were obtained at 1:00A.M. on 7/25/64 and at 10:00 P.M. on 7/24/64. The samples were counted over a period of several days and the spectra obtained were essentially those of sodium-24. No attempt was made to standardize these samples, since the plasma samples would provide more suitable data for dose calculations.

PRIVACY ACT MATERIAL REMOVED

III. Hair Sample

0.3275 grams of hair was counted in a test tube in a standard well counter. The spectra obtained was quite complex, indicating a mixture of fission products. Figure 2 shows a series of spectra obtained between 7/25/64 and 8/27/64. At the latter time, some of the peaks stand out more clearly and possible isotopes are indicated. We were interested in the possibility of fast neutron activation of certain materials in hair, but it is obviously impossible to isolate such activity in the presence of large amounts of fission products. The data from the hair sample is of interest but of little value for dose calculations.

IV. Gold Ring Sample

A sample of 0.205 grams of a gold ring which was wearing at the time of the accident was analyzed over a number of days. A typical spectra is shown on Figure 3 and consists essentially of a pure gold spectrum. No lines could be detected

resulting from isotopes produced by fast neutron irradiation. We have not attempted to quantitate the Au^{198} activity from the ring measurements and the determination of flux from these readings would be quite complex because of self-shielding and other problems. Further, it is unlikely that the flux at the position of the gold ring would be typical of that over the body.

V. Subsequent Samples

Samples of vomitus, fecal matter, and blood cells were obtained. These showed only small amounts of the Na^{24} avtivity.

PRIVACY ACT MATERIAL REMOVED

VI. Estimation of Radiation Dose

Since no fast neutron induced activity was detected, the only measurement of direct application to the radiation dose received by was the sodium-24 level corrected to the time of the accident, 2.64×10^{-2} μc/ml serum. Since the sodium-23 level was 140 MEQ/liter, or 3.2 mg/ml, this corresponds to 8.20×10^{-3} μc/mg.

The conversion of this figure to neutron and gamma dose requires detailed knowledge of the neutron spectrum and irradiation geometry. A number of studies have been carried out in this relation, and the results are summarized in Table II. It is seen that the conversion factor for neutron dose (rad • $mg \cdot \mu c^{-1}$) differs considerably for the Godiva II studies, the ZPR accident studies, and the Y12 accident studies, as might be expected considering the widely differing neutron sources. The gamma/n ratio also varies considerably. If we assume that the present accident was analogous to the Y12

accident, we may take an approximately figure of 3.2×10^5 rad·mg·μc^{-1} and a gamma/n value of 3.0. An estimate of the average neutron dose to would then be 2200 rads and the gamma dose 6600 rads. The estimated total dose would, therefore, be 8800 rads.

PRIVACY ACT MATERIAL REMOVED

TABLE I

PRIVACY ACT MATERIAL REMOVED

SERUM DATA RESULTS

Sample	Back Corr. Counts	Count Time	Decay T (hrs.)	λT	$e^{-\lambda T}$	$e^{\lambda T}$	$R = \frac{\text{Count}}{\text{Time}}$	$(e^{\lambda T})$
S2 (1)	14,019	2.0	24.17	1.116	.3266	3.06	21	400
S2 (2)	8,868	10.0	69.42	3.21	.0403	24.8	22	000
S2 (3)	12,627	40.0	93.0	4.30	.0136	73.5	23	200
S1 (1)	8,784	10.0	68.92	3.18	.0413	24.2	21	200
S1 (2)	14,454	40.0	87.83	4.06	.0173	58.0	21	000
Na (1.73)	54,468	2.0	24.66	1.14	.3191	3.125	710	000
Na (0.173)	39,665	2.0	27.83	1.287	.276	3.62	71	800

S2 - Taken 7 hours after accident

S1 Taken 16.5 hours after accident

$$X = S \frac{Rx}{Rs} \quad (\mu c/2ml)$$

$$X = 1.73 \left(\frac{21800}{714000}\right) = 5.28 \times 10^{-2} \ \mu c/2ml$$

sodium activity at time of accident = 2.64×10^{-2} μc/ml serum

TABLE II

		rad . mg . μc^{-1}	γ/n	ref
Godiva II				
burro		4.85×10^5	0.1	1
phantom		4.33×10^5	0.1	
ZPR				
phantom	exp.	1.20×10^5	3.6	2
	Theor.	1.01×10^5		
Y12				
phantom	exp.	3.16×10^5	2.8	3
	Theor.	3.66×10^5	3.1	

1. Sanders, F.W. and Auxier, J.A., "Neutron Activation of Sodium in Anthropomorphous Phantoms." Health Physics, Pergamon Press, 1962, 8, pp. 371-379.

2. Hurst, G.S., Ritchie, R.H., Sanders, F.W., Reinhardt, P.W., Auxier, J.A., Wagner, E.B., Callihan, A.D., and Morgan, K.Z., "Dosimetric Investigation of the Yugoslav Radiation Accident." Health Physics, Pergamon Press, 1961, 5, pp. 179-202.

3. Hurst, G.S., Ritchie, R.H., and Emerson, L.C., "Accidental Radiation Excursion at the Oak Ridge Y-12 Plant-III." Health Physics, Pergamon Press, 1959, 2, pp. 121-133.