"CASE HISTORY OF A COMPLEX OCCUPATIONAL EXPOSURE TO TRITIUM AT A MEDICAL CENTER."

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Abstract--Assays for tritium of urine, breath water, and blood serum were made over a period of weeks on samples from a glassware washer in a laboratory where tritium and carbon-14 labeled biochemicals were employed. Bioassays were started following a report of a spill of an aqueous solution of these biochemicals on an open wound. Specific activities of samples fluctuated widely, with excursions as high as 4700 microcuries per litre.

The spill which initiated the bioassays did not involve sufficient activity to account for the levels seen. The subject was hospitalized to force fluids and for observation. Even while in the hospital bioassay levels rose and fell by a factor of 100.

No evidence of accidents which would account for the highest bioassay levels could be found; no metabolic explanation of the fluctuation could be found. It was established that there was a baseline specific activity of 20 to 50 microcuries per litre in body fluids with excursions above this in breath water and urine but not in blood serum. It was decided that "high" urine and breath samples had been adulterated and that baseline values were real. Distillation, ether extraction, and finally amino acid analysis of urine showed the activity in a "high" sample to be due to tritiated amino acids, proline and leucine, not metabolic byproducts.

This incident raises the problem of evaluation exposure history of an "accident", and reiterates the value of multiple bioassay data. Final conclusions in the absence of information supplied by the "victim" or other persons involved, must depend on bioassay data and other health physics techniques which furnish circumstantial evidence.

I. INTRODUCTION

This paper recounts the case history of a tritium exposure at a medical complex comprising a 200 bed hospital, clinics, medical and dental schools, and research labs, some eighty of which are engaged in research using radioactive materials. The individual involved was an eighteen-year-old girl who was simultaneously a full-time high school student and employee in three capacities: as a paid glassware washer in a lab using labeled biochemicals; as a volunteer technician in a similar lab; and as a volunteer clerk in the medical records office. The individual, hereafter referred to as Subject J, could be described as precocious and ambitious. She will enroll in college in the fall in a pre-med program.

Bioassays for tritium are not performed routinely for users of less than ten millicuries of organic tritium. In this case, the Radiation Safety Office was originally following up on a "spill" or "accident" which had been reported by Subject J's supervisor.

II. CHRONOLOGY

On May 7, 1975, Subject J injured her left hand with dry ice, causing second degree burns to the palm and fingers. The open burns were covered with gauze. On May 12, she reportedly spilled some liquid radioactive waste on this hand. The waste contained about 30,000 dpm per ml of organic tritium in a detergent solution, and perhaps 200 ml were involved in the "spill". The gauze bandage absorbed most of this, and the accident was not deemed to be serious at the time; however, bioassay procedures were instituted immediately.

Breath and urine levels following the "spill"were minimal (0.05 μCi/l). It was not discovered until some two weeks later that there had been instrumentation difficulties in the original analysis of the urine samples, and that these samples had averaged about 13 μCi/l, a significant level roughly equal to the specific activity of the aqueous waste involved in the accident.

A breath sample taken on the Thursday before Memorial Day showed a tenfold jump in specific activity. Another sample was not obtained until the following Tuesday, due to the intervening weekend. There was a four-thousand-fold jump in specific activity at this point, to nearly 2000 μCi/l. Subject J was not available until noon of the next day for another sample, as she was in school. At this point, we all believed that our assay was wrong.

The next breath sample was nearly 1700 μCi/l, and on May 28 Subject J was immediately hospitalized to force fluids. When all bioassays taken in the hospital were seen to be of a noncritical nature, Subject J was discharged on May 29 with instructions to

increase her fluid intake and to furnish regular bioassay samples. No cause for the body burden could be established.

Urine samples brought in the next morning showed levels of up to 1465 μCi/l, and Subject J was admitted to the hospital for the second time, on May 30, 1975. The patient was put on I.V. saline at 100 ml/hr. in order to force fluids, as output had been low during the last stay. Bioassay levels were low again, until Saturday night and Sunday, June 1, when another "excursion" occurred. It cannot be ruled out, however, that Subject J had access to tritium in personal effects during the hospital stay. Urine sample collection was done in private in the hospital room.

On Saturday, May 31, an inspector from N.R.C. visited and interviewed Subject J and also reviewed bioassay data. On Monday, June 2, a survey of Subject J's bedroom at home, done with parental permission, turned up two hypodermic needles containing upwards of 150,000 dpm of ^{3}H, and a drinking glass with more than 200,000 dpm dry activity on the bottom of the inside.

Subject J was discharged on Tuesday, June 3, when it was noticed that both urine "excursions" had occurred within hours of the administration of a diuretic. Another diuretic was administered on Wednesday, June 5, to test whether this was a causal relationship. No increase was seen for more than 24 hours, eliminating the causal nature of the diuretic.

On Friday, June 6, Subject J was readmitted for observation and bioassays in a controlled environment. Extensive interviews with physicians still failed to turn up a plausible cause for the body burden and the up-and-down nature of bioassays.

On Saturday, June 7, Subject J turned over two plastic liquid scintillation vials containing non-prescription pills (lecithin). Pills in one of the vials were very highly contaminated with tritium, in the tens of microcuries. The pills appeared to have had liquid dropped on them, which subsequently had dried. They were stuck together and to the vial, and cracked. It was indicated that these might be the source of the body burden. When urine, blood, and breath levels subsided again, Subject J was discharged from the hospital on June 10, 1975.

Subject J was repeatedly instructed not to continue working in laboratories where radioactive materials were used and to avoid future exposures. Subsequently however, Subject J was occasionally observed in labs where radioactive materials were used, even after instructions were repeated to supervisors and co-workers. Subject J was also provided with another job not involving work in a lab with

radioactivity, and compensated for lost time at the glassware washing job.

Since the discharge on June 10, breath, blood and urine specific activities decreased with a plausible effective half-life of about ten days.

Throughout the entire course of the incident, no evidence of spills or accidents could be found, except for the initial minor spill which alerted the Radiation Safety Office to the problem. No other individuals with whom Subject J worked or associated at work had any body burdens, nor did her parents with whom she lived. An inventory of all radioactive materials at the Health Center showed no major loss of tritium.

III. BIOASSAY DATA

At the outset, some difficulty was experienced in obtaining samples for urinalysis (1) so it was decided to try Steerman's breath water assay (2), in which a sample could be obtained immediately.

During the incident, three types of bioassays were routinely performed, in duplicate whenever possible. These were urinalysis and breath analysis as mentioned above, and blood serum analysis (3). Urinalysis findings were corroborated by the New England Nuclear Bioassay Laboratory. All samples were counted by liquid scintillation counting, using several different machines as checks. Internal standardization was used on all blood serum samples and on others as needed; external standardization was also checked. Commercially-prepared quenched and unquenched standards were run at frequent intervals, and after the first week, locally prepared standards and blanks were run with all samples.

There is strong evidence to indicate that some urine and breath samples were adulterated. Since blood samples could not be tampered with, they were used for dosimetry purposes.

As the Table I and Figure I indicate, there were four sudden rises in concentration by a factor of 100 or more in a matter of hours during the course of the incident. Following each of these rises, except that of May 31, which occurred in the hospital, the subject was hospitalized for observation and to force fluids. The equally precipitous decreases in specific activity of bioassay samples are not comprehensible in terms of metabolism, and prompted analysis of urine samples to see if they had been adulterated.

There is a report in the literature of analysis of water and organic components of urine (4), but it followed an accident involving a known

organic chemical. In our case, we did not know what chemical we were looking for.

Selected urine samples were distilled (5). In all eight samples tested, the specific activity of water was found to be roughly constant; however the nonvolatile residue varied in concentration from zero to the highest values seen in urine. Solvent extraction with ether showed these nonvolatile organic residues to be highly water soluble. Lastly, chromatography on an amino acid analyzer conclusively identified the dissolved organic compounds in urine sample 36.90 to be tritum-labeled proline and leucine, available in the lab where Subject J was a volunteer. These labeled acids cannot be found in urine as metabolic byproducts after ingestion (6). They must have been added to the urine externally.

The conclusion is that all bioassay samples showing levels above 50 μCi per liter were adulterated by the addition of tritium, probably in the form of tritium-labeled biochemicals.

IV. CONCLUSIONS

There are two types of conclusions which can be drawn from this incident. The first type specifically deal with this incident and are of passing interest. The second are long range conclusions which affect future handling of such incidents.

A. Specific Conclusions

1. The levels of radioactivity observed in blood serum and, since June 6, in breath and urine, may be understood in terms of the contaminated pills, needles and glass, although this evidence is circumstantial.

2. The high levels or "excursions" may be understood in terms of altered samples.

3. There has not been established any violation of the law in this case, either by the individual or the institution.

4. To prevent a recurrence of the incidents, Subject J was given a different job, away from radioactive materials. Since only one individual was involved, there is no evidence of a significant accident, and since levels of tritium in body fluids have decreased smoothly, this seems to be sufficient.

B. Long Range Conclusions

More interesting are the logistic questions which were answered and problems which were brought into focus by this incident. These fall into three categories, namely, Bioassay, Incident Handling, and Legal Aspects.

1. Bioassay

a) Urine and breath bioassays taken without strict supervision are unreliable in the sense that they can be tampered with by the individual giving the sample, or by someone else, prior to analysis.

b) Blood samples are unusual as a routine bioassay technique (7); however, in this case, they provided the only reliable assay technique. Blood was drawn by a laboratory technician and turned over to the Radiation Safety Office directly for analysis.

c) If multiple bioassay data (i.e., urinalysis, breath analysis, and serum analysis) had not been available, it would have taken longer or been impossible to make any sense out of the findings. Only by comparing the three levels throughout the course of the incident was a determination of a baseline concentration possible.

2. Incident Handling

a) This incident focuses on the fact that health physics depends to a large extent on the good will and cooperation of the radiation worker. In this case, we had good "cooperation" from the "victim" throughout the early stages of the incident, which caused us to believe that we were dealing with an accident.

b) Deciding whether this incident was an accident or a hoax was a dilemma. We could not conclude that there was no accident simply because none was found; however, after a thorough search, we began to actively investigate other possibilities. Subject J initially denied any knowledge of how the tritium got in her urine and postulated several plausible explanations.

At the beginning we had no reason to disbelieve her. If the incident had been treated as a hoax, then the individual involved would no longer feel trusted. In this event, further cooperation would be jeopardized, as the individual sensed the mistrust and became recalcitrant. Getting reliable bioassay samples would become difficult.

c) The bioassay data were unbelievable, but we had to treat them as valid until we could show them to be otherwise. We had to do everything possible to flush out the tritium from the "victim's" body. This resulted in three hospitalizations, and a sizeable medical bill. The assays themselves did prove to be correct; however, the samples were not representative of the body fluids.

3. Legal Aspects

At a medical institution where people are acutely aware of the malpractice nightmare, we had to consider the possibility of some sort of lawsuit.

a) For example, a psychiatric examination of Subject J would have been useful, but this was not done on the grounds that it might antagonize her, causing loss of cooperation, and might precipitate a lawsuit or unfavorable publicity.

b) There was debate on whether or not a hospital bill should be submitted. One side said that billing the victim of an occupational accident would antagonize the individual; the other, that the non-submission of a hospital bill could be construed by a court as an admission of guilt or responsibility, as has been done in malpractice cases. It was decided that the latter risk was more serious: a bill was submitted. It may be paid by insurance, the individual, or the institution; this can be settled later.

c) An alternate job had to be provided for Subject J, and compensation provided for time lost while in the hospital. Failure to do this could result in bad feelings, bad publicity, or a lawsuit.

d) We cannot prove what really happened in the absence of information supplied by the "victim" or other persons involved. The bioassay data and other observations made by Radiation Safety Personnel during the incident are circumstantial. At this point, one can only speculate about the motives behind the incident and the details of the intake.

V. ACKNOWLEDGEMENTS

The authors would like to thank Dr. Juris Ozols for his amino acid analysis, Roy Hodge and Fred Greenhalgh for their indefatigable efforts in performing bioassays and surveys during the incident, and countless others who supplied help and advice.

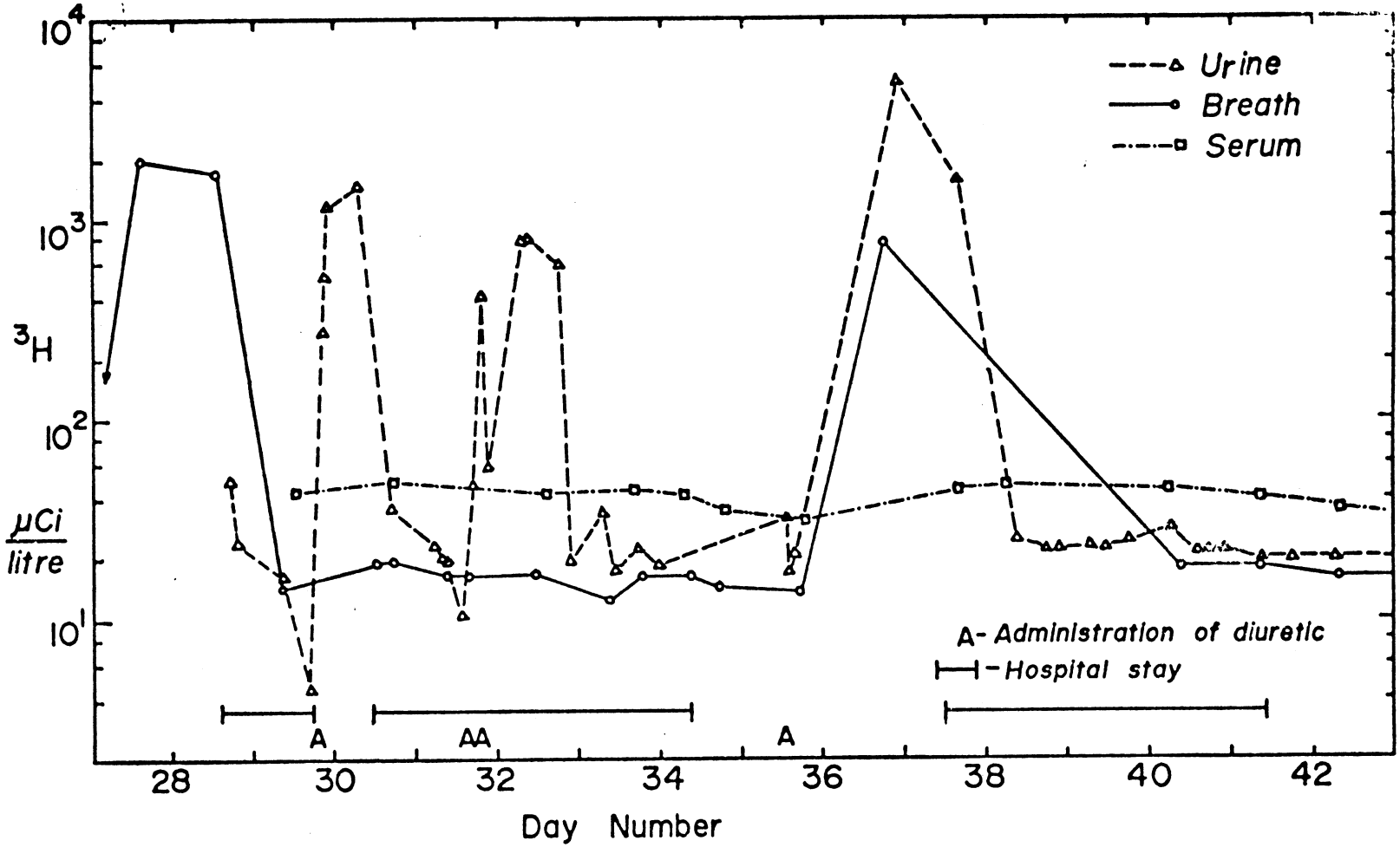

FIGURE I. Graph of bioassay data of Subject J. Days are numbered starting from 12:01 AM, May 1 = 1.00. All bioassay levels have decreased smoothly since day 39, indicating no further exposure.

Table I. BIOASSAY RESULTS SUBJECT J

EXPLANATION OF DATES: MAY 1, 12:01 AM = 01.00

	DATE	Specific Activity Urine µCi/l.	Specific Activity Breath µCi/l.	Specific Activity Serum µCi/l.
	12.70	13.9		
	13.26	12.0		
	14.58	16.5		
	14.58		.05	
	19.60		.06	
	22.60		.45	
	27.60		1940.	
	28.52		1686.	
Hospital Stay	28.70	49.4		
	28.79	23.9		
	29.35		14.2	
	29.50			43.2
	29.70	4.5		
	29.84	272.		
	29.88	512.		
	29.91	1121.		
	30.29	1465.		
Hospital Stay	30.50		19.1	
	30.69	35.4		
	30.71			47.5
	30.71		19.2	
	31.21	23.5		
	31.30	20.0		
	31.38		16.8	
	31.38	19.7		
	31.56	10.5		
	31.66		16.5	
	31.70	47.6		
	31.80	410.		
	31.88	57.4		
	32.39	775.		
	32.39	783.		
	32.46		16.9	
	32.60			42.2
	32.75	578.		
	32.88	19.1		
	33.29	37.6		
	33.37		12.6	
	33.42	17.5		
	33.47	19.2		
	33.68			44.0
	33.73	22.2		
	33.76		16.5	
	33.97	18.6		
	34.29			41.9
	34.37		16.6	
	34.69			34.5

	DATE	Specific Activity Urine µCi/l.	Specific Activity Breath µCi/l.	Specific Activity Serum µCi/l.
	34.71		14.4	
	35.58	31.4		
	35.60	16.8		
	35.66	21.2		
	35.69			31.2
	35.71		13.9	
	36.71		741.	
	36.90	4700.		
Hospital Stay	37.65	1494.		
	37.65			44.3
	38.28			42.0
	38.34	24.6		
	38.77	22.2		
	38.89	22.2		
	39.30	23.4		
	39.48	22.2		
	39.73	24.5		
	40.31	28.5		
	40.28			43.9
	40.39		18.7	
	40.58	21.6		
	40.70	21.4		
	40.94	21.3		
	41.42		18.16	
	41.42			41.3
	41.43	19.7		
	41.74	19.9		
	42.29	19.8		
	42.40			35.2
	42.41		16.4	
	45.48	17.3		
	46.33	15.4		
	47.34	13.9		
	48.31	13.3		
	49.29	13.2		
	49.44			12.5*
	49.46		11.8	
	50.35	12.2		
	51.29	11.8		
	52.45	10.2		
	53.34	10.7		
	54.29	10.2		
	55.27	9.2		
	56.26	8.5		
	56.41			26.1
	56.42		7.0	

*heparinized

Table 1. BIOASSAY RESULTS SUBJECT J

EXPLANATION OF DATES: MAY 1, 12:01 AM = 01.00

DATE	Specific Activity Urine µCi/l.	Specific Activity Breath µCi/l.	Specific Activity Serum µCi/l.
57.29	8.5		
58.29	8.3		
59.37	7.1		
59.26	7.4		
60.28	7.2		
61.27	7.1		
61.42			19.3
61.46		5.2	
63.40	5.7		
64.34	5.4		
65.39	5.2		
66.27	4.7		
67.29	5.4		
68.46			18.3
68.50		3.67	
75.29	3.45		
75.50			13.4*
82.46			15.0
82.46		2.08	
82.67	2.83		
89.42			11.3
98.57	1.76		

*heparinized

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1. New England Nuclear Technical Bulletin #4, "Tritium Urinalysis."

2. Steerman, Jerome J., and Sanders, Lorion J., "Simplified Breath Sampling for H-3 Bioassay," presented at HPS meeting, July, 1974. In our case, 19 ml of Aquasol or PCS was added to one ml of breath water in a liquid scintillation vial.

3. A non-heparinized blood sample, about 4 ml, is drawn and refrigerated until it can be centrifuged. Entire sample is centrifuged for 10 minutes at 1600 r.p.m. in a GLC-1 centrifuge. Serum (clear liquid) is carefully drawn fron the top of the sample and placed in a separate tube. 100 microliters of serum is placed in each of four liquid scintillation vials. To two of these vials is added 10 µl of deionized water, to the other two, 10 µl of tritiated water (18300 dpm). The four vials are then filled with 19 ml of Aquasol or PCS scintillation fluid. Counting yields were thus measured to range from 0.3 to 0.4, depending on the cocktail and counter used. Quenching of serum compared to that of an equal volume of water was measured to be closely the same, except when anticoagulent (heparin) had inadvertently been added to the blood sample prior to centrifugation.

4. Pagnotto, L.D., and Killian, C.B., "Measurement of Tritiated Organic Compounds in the Presence of Tritiated Water in Urine," Am. Ind. Hyg. Ass. J., 30, 407-412 (1964).

5. Single stage urine distillation was carried out in a petri dish on a hotplate, with a beaker of acetone/dry ice on top as a condenser. Urine was not boiled, but merely allowed to evaporate.

6. White,Handler, and Smith, Principles of Biochemistry, 5th ed., McGraw-Hill, NY, 1973, p.678 and 689.

7. NCRP Report No. 30, "Safe Handling of Radioactive Materials."

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