DP-1369

ENVIRONMENTAL EFFECTS OF A TRITIUM GAS RELEASE FROM THE SAVANNAH RIVER PLANT ON MAY 2, 1974

W. L. MARTER

E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, S. C. 29801

PREPARED FOR THE U. S. ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(07-2)-1

Printed in the United States of America

Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $4.00; Microfiche $2.25

DP-1369
UC-11

ENVIRONMENTAL EFFECTS OF A TRITIUM GAS RELEASE FROM THE SAVANNAH RIVER PLANT ON MAY 2, 1974

by

W. L. Marter

Approved by
B. C. Rusche, Director
Environmental Sciences Section

Publication Date: November 1974

E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, S. C. 29801

PREPARED FOR THE U. S. ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(07-2)-1

ABSTRACT

On May 2, 1974, 479,000 Ci of tritium gas was released from a Savannah River Plant exhaust stack to the atmosphere over a period of about four minutes. The release resulted from a metallurgical failure of a process valve in a tritium processing facility. Light winds of 4 to 6 mph carried the tritium in a northeasterly direction. Calculations indicate it passed out to sea from the southern half of the North Carolina coast about 36 hours after the release. Measurements of tritium offplant indicated that less than 1% of the tritium was in the oxide form. A maximum potential dose to a person (from inhalation and skin absorption) at the puff centerline on the plant boundary was calculated to be 0.14 mrem, less than 1% of the annual dose received from natural radioactivity.

The population dose was calculated to be .8 man-rem before the tritium passed out to sea. An extensive environmental sampling program was conducted after the release to verify the predicted trajectory of the tritium and to determine potential individual dose commitment. Approximately 1000 samples were collected and analyzed; these included air moisture, elemental tritium gas in the atmosphere, pine needles, grass, food crops, milk, surface water, soil, and human urine. Inhalation doses were < 0.05 mrem; that is, urine analyses were less than the sensitivity of analysis (< 0.005 μCi/ℓ). Potential individual doses from consumption of tritium-bearing food crops and milk were less than 1 mrem. The trajectory of the tritium puff was verified by analysis of vegetation at a distance of about 45 miles northeast from the plant boundary; beyond this point, tritium concentration in vegetation was generally less than 14 pCi/ml (free water) and variable (within the normal range of concentrations found in this area), making trajectory tracking impractical.

CONTENTS

ENVIRONMENTAL EFFECTS OF A TRITIUM GAS RELEASE FROM THE SAVANNAH RIVER PLANT ON MAY 2, 1974

INTRODUCTION

Tritium (T) is a radioactive isotope of hydrogen (H) with an atomic mass of 3 and a radiological half-life of 12.33 years. The maximum energy of the beta particle emitted during decay is 0.0186 MeV; the average energy is about 0.006 MeV. At the Savannah River Plant (SRP), some tritium is released during normal operations both as an elemental gas (T_2, HT, DT) and in combination with oxygen (tritium oxide - T_2O, HTO, DTO). Both forms are odorless, tasteless, colorless, and readily dispersed in air; they will enter into the same chemical (and biological) reactions as hydrogen or water vapor.

The low-energy beta particle emitted by tritium during decay will penetrate human tissue only 0.013 cm. As an elemental gas, tritium constitutes little hazard because the weak beta is completely attenuated (absorbed) in the inert external skin layer (epidermis). Investigations by W. Langham of LASL indicated that only 0.004% of the gas inspired is converted to the oxide and retained in the body.[1] The concentration guide for tritium oxide is several hundred times less than that of the elemental gas form because almost all of the oxide form (water vapor) that is inhaled is absorbed in the lungs and enters the body water pool, and all body tissues are exposed. In addition, almost as much tritium oxide is absorbed through the skin as is absorbed during inhalation.[2]

The average biological half-life of tritium in the body of SRP employees is 9.6 days.[3] Values as high as 19 days have been reported elsewhere.[4] The value used by the International Commission on Radiological Protection[2] for calculating concentration guides is 12 days and is the value used for dosimetry calculations in this report.

The concentration guides[5,6] for exposure of members of the off-site population to tritium in air and water are:

HTO or T_2O - 500-mrem whole body dose/year
inhalation and skin absorption (air) - 2×10^{-7} μCi/ml
ingestion (water) - 3×10^{-3} μCi/ml

HT or T_2 - 3-rem inert skin dose/year
submersion (air) - 4×10^{-5} μCi/ml

These concentration guides apply to individual members of the public exposed to the highest annual average concentration and should be reduced to one-third of the values shown when applied to a suitable sample of the population.

THE RELEASE INCIDENT

On May 2, 1974, 479,000 Ci of tritium gas (T_2) was released from a tritium processing facility at SRP when a process valve failed. Tritium monitors for the 200-ft (60 m) exhaust stack and for the enclosure cabinet exhaust system to the process room alarmed within a few seconds of each other at 8:01 AM Eastern Daylight Saving Time(EDST). Greater than 99% of the tritium was released over a period of four minutes as indicated by the exhaust stack tritium monitor (Figure 1). Approximately 50 g of tritium gas (~7 ft^3, STP) mixed with building ventilation exhaust air

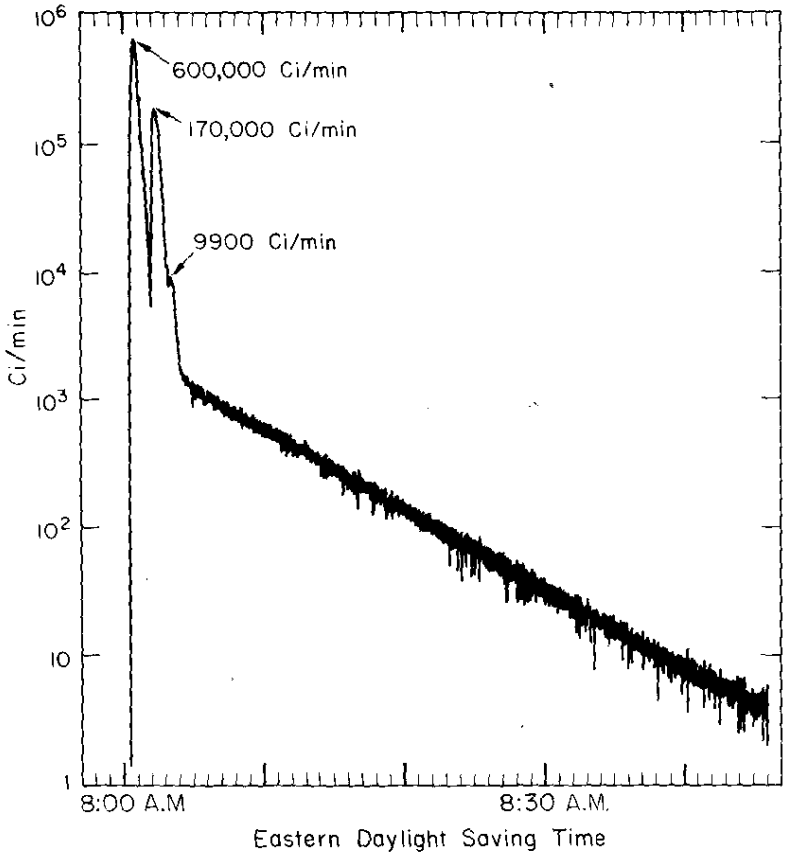


FIGURE 1. Tritium Rate of Release from Exhaust Stack Monitor (redrawn from original recording chart)

which was being discharged from the exhaust stack at a rate of 135,000 ft^3/min (a total volume of 540,000 ft^3 of air during the 4-min release) and exited the 8-ft-diameter opening of the stack top at a velocity of 2700 ft/min. The average tritium concentration in exhaust stack air over the 4-min release period was 13 ppm by volume. At this very dilute concentration, the discharge would be expected to behave as a gas with no appreciable buoyancy.

METEOROLOGICAL CONDITIONS AND PREDICTIONS

Local

Meteorological conditions at the time of the tritium release and for several hours thereafter were categorized as Pasquill Type D (neutral stability).[7] Wind direction was 210° to 225° at a speed of 4 to 6 mph. Figure 2 shows the predicted trajectory of the tritium plume (or puff) during the first 10 hr following the release.

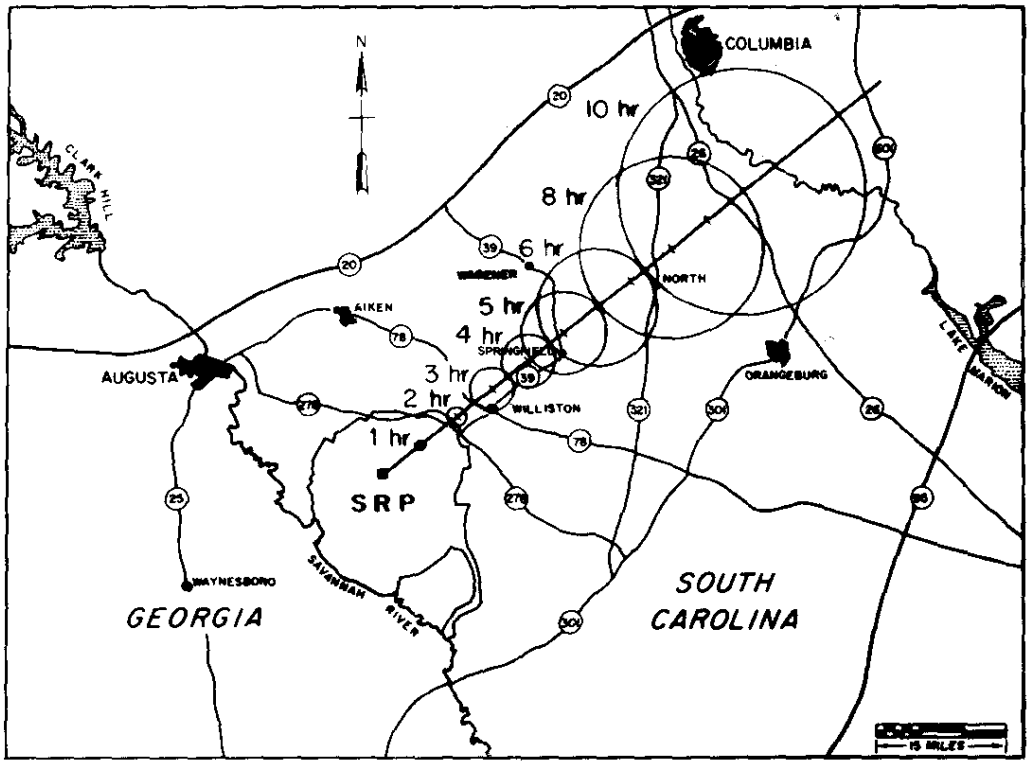


FIGURE 2. Predicted Puff Trajectory During First Ten Hours After Release

The circles in Figure 2 represent the calculated puff dimensions at varying times after the release; 91% of the released tritium was calculated to be within the circular boundaries. The integrated dilution factor at the plant boundary (15 km from release point), as calculated by standard methods[7] for an instantaneous or "puff" type of release, was 1×10^{-6} sec/m^3. The calculated dose to a person exposed to the plume centerline at the plant boundary during a 1-hr estimated passage time of the tritium-bearing puff was:

$$\text{Dose} = (479{,}000)\ (1 \times 10^{-6})\ (0.143)\ (0.002)$$
$$= 1.4 \times 10^{-4} \text{ rem or } 0.14 \text{ mrem}$$

where

479,000 = curies of tritium released

1×10^{-6} = dilution factor, sec/m^3

0.143 = rem/[(Ci-sec)/m^3] (dose factor for inhalation and skin absorption of HTO by an active man)

0.002 = fraction of tritium in oxide form

Figure 3 shows the calculated maximum instantaneous concentration of total tritium under the puff centerline at ground level as a function of time after release. The calculated results in Figure 3 are shown as a band to indicate the effect of assumed "deposition velocities." The upper limit of the band was calculated assuming no depletion of tritium in the puff from surface deposition, i.e., $V_g = 0$. The lower limit was calculated with an assumed deposition velocity of 1 cm/sec and would apply to tritium in the oxide form. However, because less than 1% of the tritium was probably in the oxide form, the upper limit is probably more representative of expected maximum concentration of total tritium in air under the puff centerline at ground level.

The tritium concentration was measured with a tritium forms* sampler at Springfield, S. C., approximately 5 hr after the release (Figure 3); the concentration is shown as a bar to represent the average for a 30-min sampling period. Even though the measured average concentration is about one-tenth the predicted maximum concentration, the agreement between measured and calculated concentrations is reasonable considering the precision of the dispersion calculations, the location of the sampler several miles south of the predicted trajectory centerline, and the 30-min sampling period. (Complete passage of the puff near Springfield was estimated to require 1 to 2 hr.)

*See Appendix A.

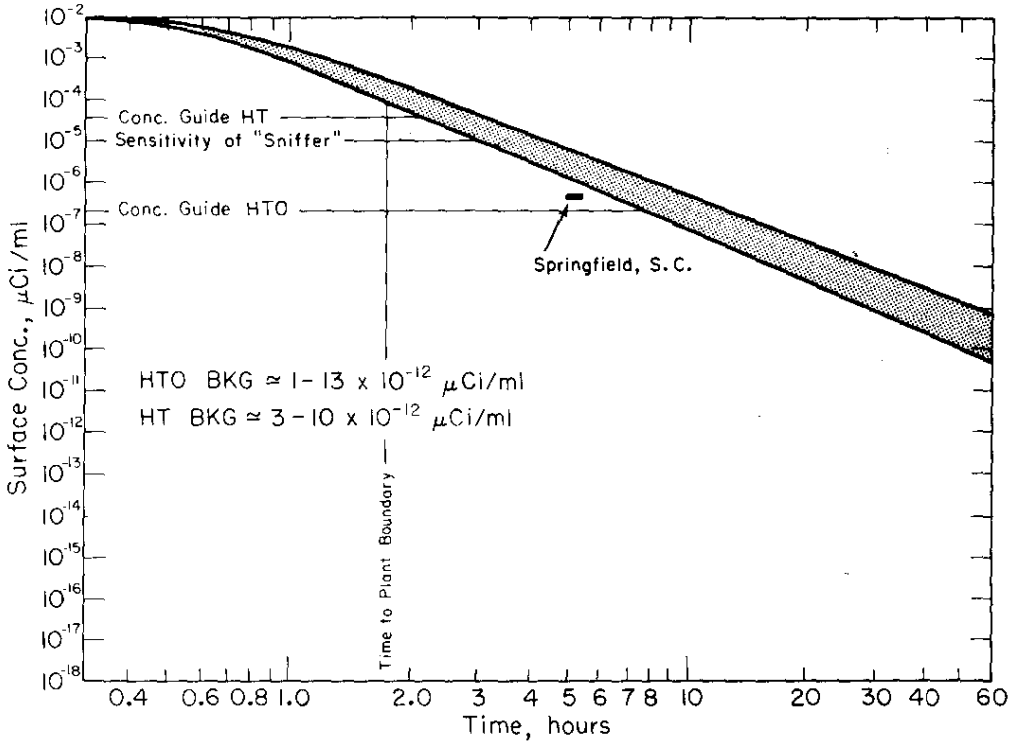


FIGURE 3. Calculated Maximum Instantaneous Tritium Concentration Under Puff Trajectory Centerline at Ground Level

Regional

At the time of the release, a polar front was located approximately 50 miles north of SRP extending in a east-west direction (Figure 4). This front formed a dividing line between two different wind regimes that existed in the Carolinas during and after the release. To the south of the front (in the tropical air mass), the winds were from the southwest, and to the north of the front (in the polar air mass), the winds were from the northeast. In the vicinity of the front, a very complicated wind pattern existed, caused by the interaction of the opposing air flow in the two air masses. In general, the sky conditions were overcast over the Carolinas with most precipitation restricted to the area north of the front.

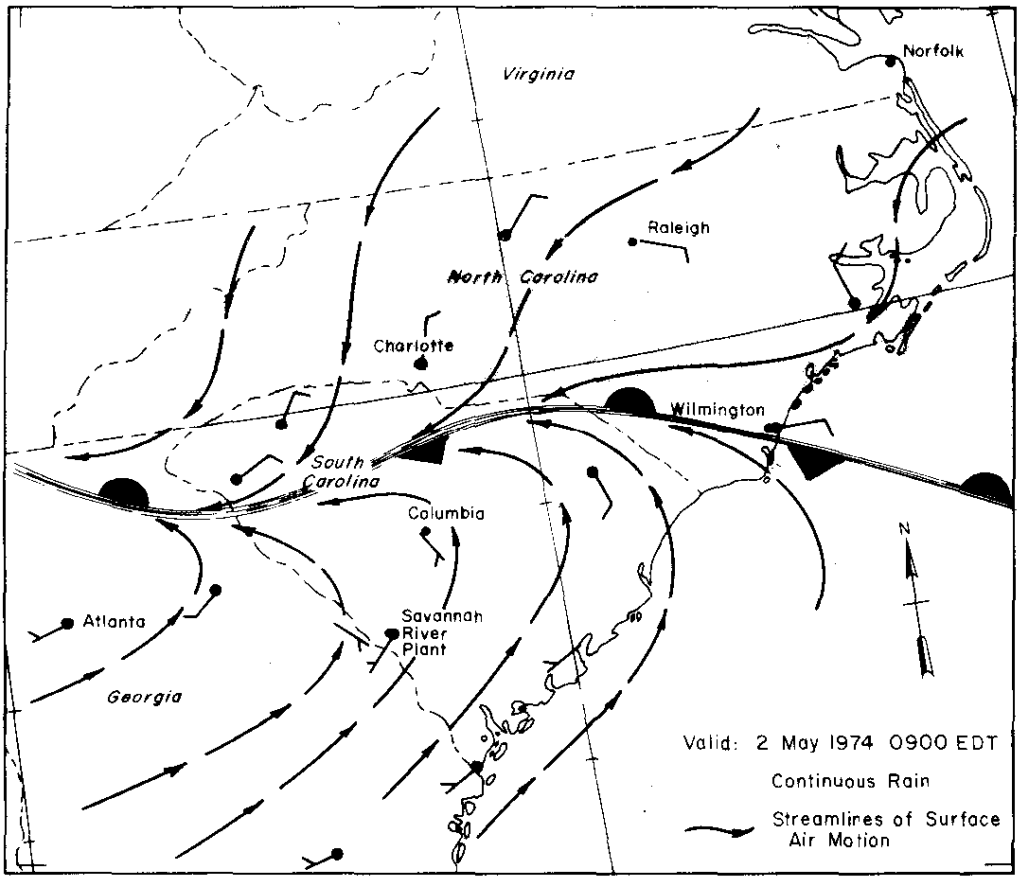


FIGURE 4. Surface Weather Map

The overcast skies and generally steady winds over SRP produced atmospheric diffusion corresponding to a Pasquill Type D. Measurements obtained with an acoustic sounder operating at SRP indicated that the maximum height through which the release could be mixed was about 2000 ft. Thus, the puff was transported by winds below 2000 ft.

Figure 5 shows two 36-hr paths of the tritium obtained from wind data representing the top and the bottom of the well-mixed layer. The lower curve (solid line) shows the path of the portion of the puff remaining in the lowest few hundred feet. The tritium traveled toward the northeast almost in a straight line for the first 12 hr and then curved toward the east for the remaining 24 hr. The upper curve (dashed line) represents the path of the portion of the tritium located near 1500 ft. The primary difference between the two paths occurs due to the higher wind speeds at the 1500-ft level. The tritium located at this level would overtake the front and come under the influence of the flow to the north of the front. As the front moved northward, the puff was influenced by the southwesterly flow and moved toward the northeast.

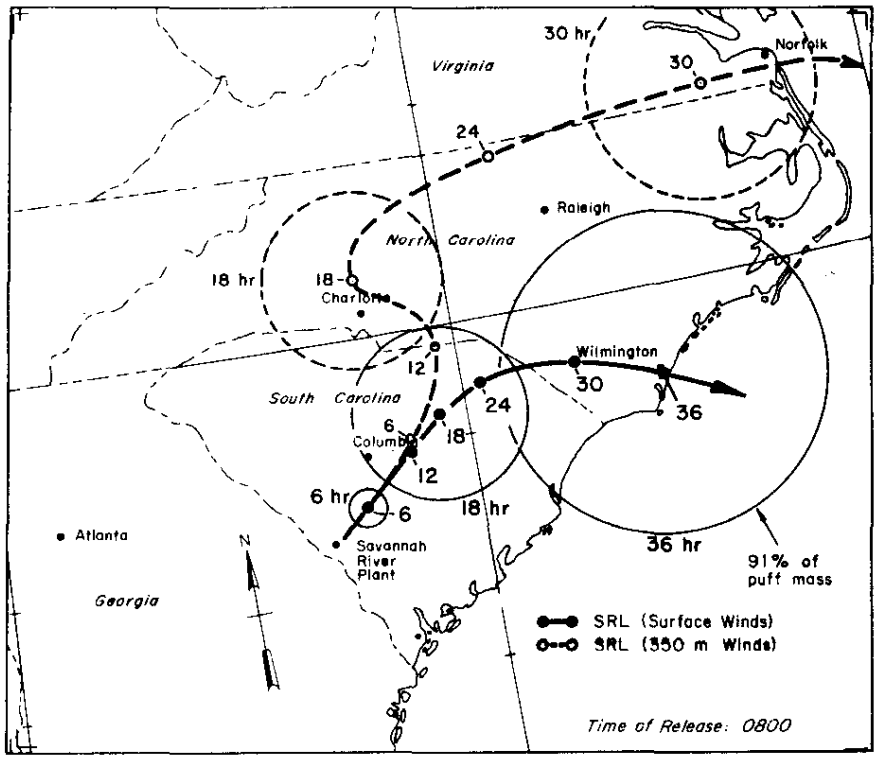


FIGURE 5. Predicted Puff Trajectories

The trajectory of the puff north of Columbia, S. C., cannot be predicted with assurance because of the vacillating nature of the polar front; thus, the two trajectories shown in Figure 5 represent the possible paths of the tritium during its passage out to sea.

The calculated population dose from inhalation-absorption during passage of the tritium to the coastline is 8 man-rem, assuming population density to be uniform and 1% of the tritium to be in the oxide form. A description of the method used to calculate population dose is given in Appendix B.

FORM OF TRITIUM RELEASED

The tritium was released in the form of the elemental gas, T_2. In this form, it can undergo oxidation in the atmosphere to form water ($2T_2 + O_2 \rightleftarrows 2T_2O$), and it can exchange with normal hydrogen present in atmospheric moisture ($T_2 + H_2O \rightleftarrows HTO + HT$). In the absence of a catalyst, both of these reactions should occur at a very slow rate, less than 1% per day.[4] Following a similar release incident[8] at the Lawrence Radiation Laboratory in Livermore, California, in 1970 (289,000 Ci released), air moisture, vegetation, and milk sampling indicated tritium concentrations only slightly above normal values. Because the values were marginally above normal, only a small fraction of the tritium, probably less than 1%, was in the oxide form, the form which is most readily assimilated by biological systems. Off-site air sampling near SRP with a tritium forms sampler following the SRP release indicated that less than 1% of the tritium in the atmosphere near the centerline of the puff trajectory was in the oxide form (see "Tritium Forms Sampling," page 10).

AIR MONITORING IMMEDIATELY FOLLOWING THE RELEASE

The tritium monitor (Kanne chamber) for the process cabinet ventilation system where the tritium release occurred alarmed within seven seconds of the process valve failure. The building exhaust stack monitor alarmed within 20 seconds. Tritium monitors in other buildings in the same process area showed no readings above normal following the release. Surveys were made outside of buildings with portable sniffers, tritium survey instruments with a lower limit of sensitivity of 1×10^{-5} μCi/ml. No tritium was detected.

During the estimated two hours that elapsed before the airborne tritium passed the plant boundary, survey teams equipped with sniffers surveyed in the northeast quadrant of the plant and along the northeastern plant boundary, approximately 9 to 10 miles

(15 km) from the point of release. At these distances, the predicted maximum surface concentration under the centerline of the puff was 1×10^{-4} to 8×10^{-4} μCi/ml, concentrations that are within the range of sensitivity of the sniffer survey instruments. Tritium was not detected during this survey. The fact that tritium was not detected onplant was later attributed to the finding that the tritium from this release did not reach ground level until nearly at the plant boundary (as determined from vegetation sampling).

Based on early projections, the survey team was at the plant boundary a few miles west of the path of the puff. The precision of the prediction of the pathway and its time history was affected by the short duration of the release, the existence of meteorological conditions that made precise prediction of the trajectory impossible, and the short residence time of the puff in any one location.

ENVIRONMENTAL SAMPLING

Shortly after the release, an extensive environmental sampling program was initiated to determine the trajectory of the tritium and to assess the biological effects (radiation dose commitment) in the path of the puff. Approximately 1000 samples were obtained and analyzed following the release, including repetitive sampling over a period of three weeks of some milk and vegetation samples to characterize the residence half-time of tritium. A large portion of the samples were obtained in South Carolina northeast of SRP; however, sampling also extended to the eastern sections of North Carolina, Georgia, and Virginia to determine if there were detectable amounts of tritium in those locations lying in the most-probable long-range trajectories of the tritium.

Types of samples taken included air moisture, tritium forms in air, bioassay (urine) samples from potentially exposed people, pine needles, grass and other vegetation, food crops, milk, surface water, and soil.

Air Moisture

Permanently installed air sampling buildings at the plant boundary and on a 25-mile radius around the plant are equipped with silica gel samplers to collect air moisture for measurement of tritium oxide concentration in air. Tritium oxide concentrations at four plant boundary locations were 130 to 190 pCi/m^3 during the period May 1 through May 6 (Figure 6). Concentrations at the plant perimeter averaged 140 pCi/m^3 during 1973, with a

maximum concentration at one station of 520 pCi/m^3. An elevated concentration of tritium oxide in air of 620 pCi/m^3 was measured near Williston, S. C., during the period May 1 through May 3. This measurement indicates that some portion of the puff probably passed over the sampler and helps confirm the predicted near-in trajectory.

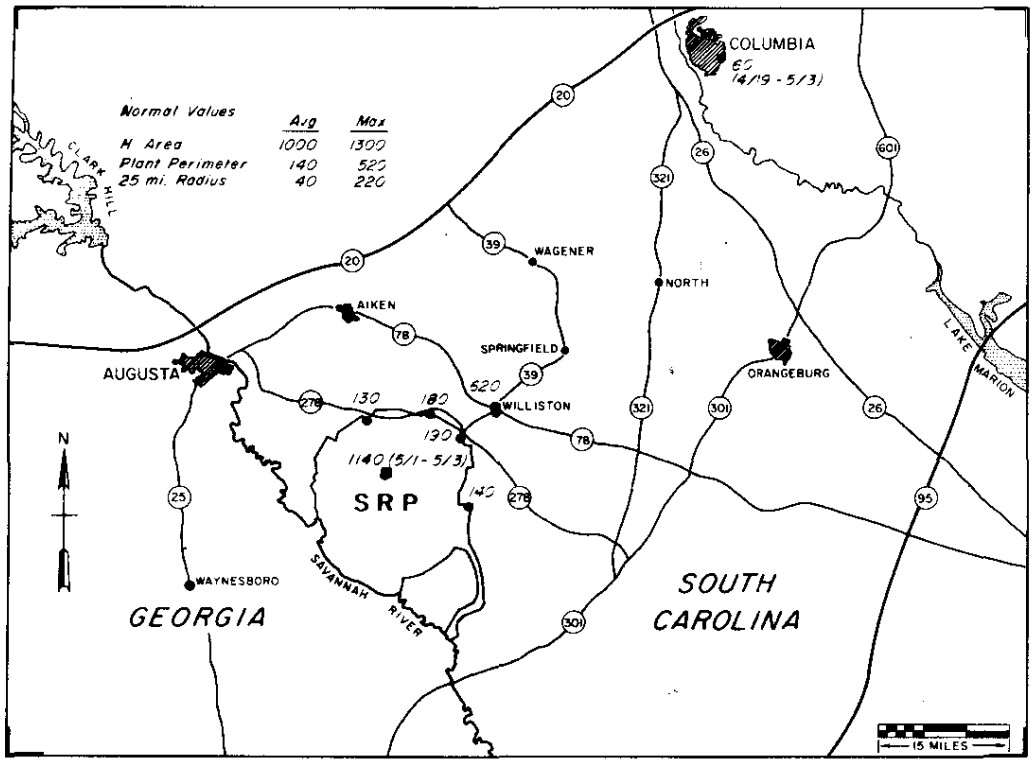


FIGURE 6. Concentration of Tritium Oxide in Air (pCi/m^3) on May 1-6, 1974

Tritium Forms

A tritium forms sampler was deployed to eight locations northeast of the point of release. This sampler is capable of collecting samples of elemental tritium gas and tritium oxide. Figure 7 shows the location, concentration of HTO and HT, ratio of oxide to elemental gas at the eight sampling locations, and time of sampling. Samples were collected for 30 min starting at the times shown. Also shown are the results of two tritium forms

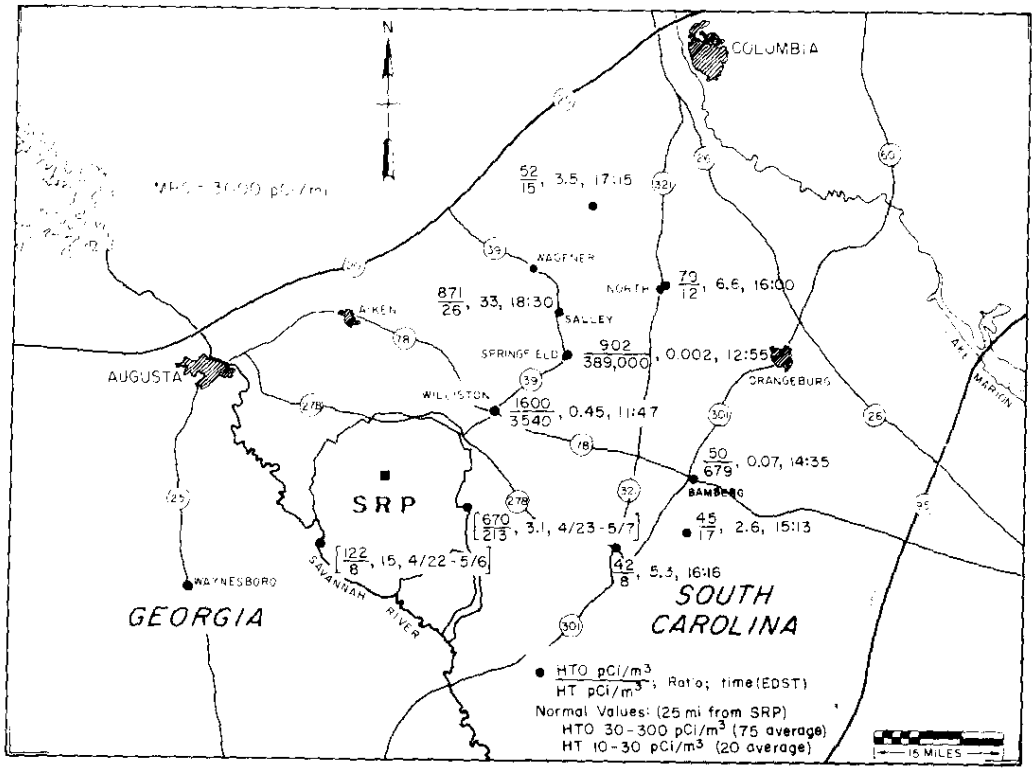


FIGURE 7. HTO and HT in Atmosphere on May 2, 1974

samplers that were in operation before and after the release at the Barnwell barricade on the east side of SRP and near the Heavy Water Area powerhouse on the southwest side of SRP.

Of the eight samples, the one taken at 12:55 PM (approximately five hours after the release) at Springfield, S. C., appears to have been near the centerline of the puff during the time of passage. The concentration of total tritium, averaged over 30 min, was ~390,000 pCi/m^3 (3.9×10^{-7} μCi/ml), of which only about 0.2% was in the oxide form. Samples taken at Williston, S. C., Bamberg, S. C., and Salley, S. C., appear to have been influenced by the tritium release but are not representative of the puff centerline during time of passage.

Bioassay

More than 300 urine samples were measured for tritium content. The samples were obtained from:

- Workers in the tritium processing facility
- Workers in the process area where the release occurred

- Timber cutters and fence post repair crews onplant
- Puff tracking survey team personnel
- Families of SRP-SRL personnel
- Members of the public in 20 counties of eastern South Carolina and five locations in North Carolina

In all cases, the tritium content of the urine samples was less than 1 μCi/l (the lower limit of detection for the method used), indicating no significant uptake of tritium. Selected samples from those people offplant expected to have the highest tritium uptake were analyzed by a more sensitive method, and all had concentrations of tritium of less than 0.005 μCi/l. Analytical data for urine samples are given in Appendix C.

Vegetation

Approximately 350 vegetation samples were collected northeast of the plant following the release (Figure 8). A variety of vegetation was sampled, but mostly Bermuda grass and pine needles.

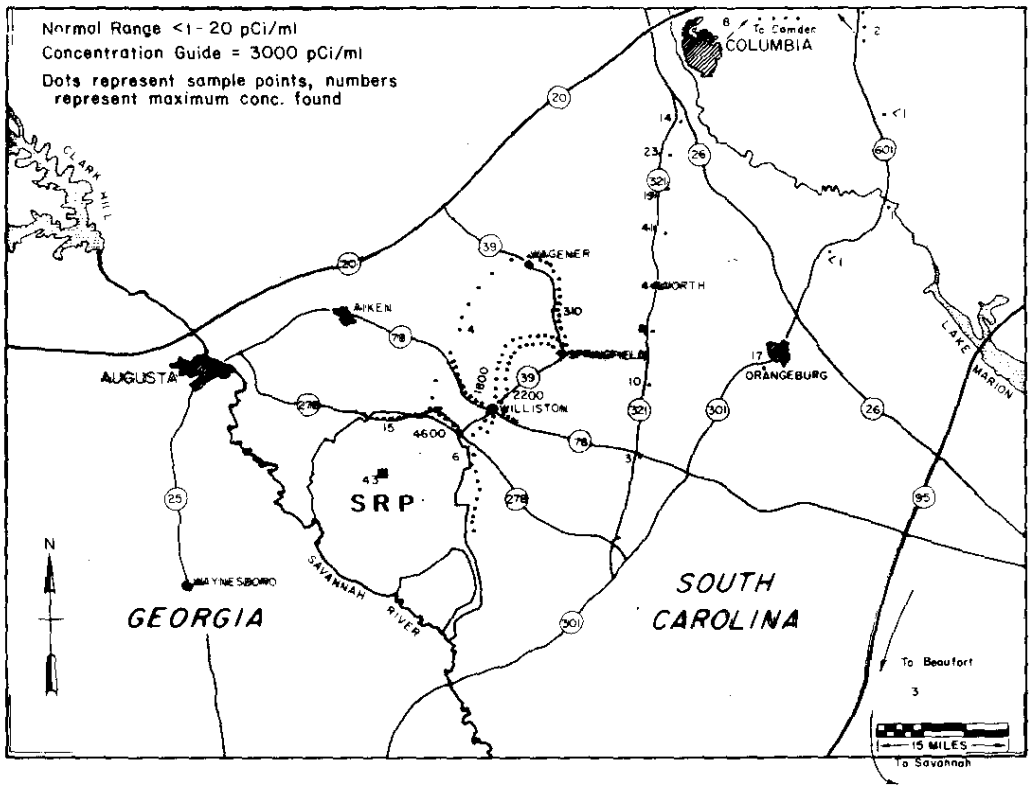


FIGURE 8. Maximum Tritium Oxide Concentration in Vegetation and Food (pCi/Mℓ) on May 2-7, 1974

Elevated concentrations of tritium oxide were measured in grass northeast of the plant perimeter. The maximum concentration was 4600 pCi/ml in a sample collected on May 3 along the plant perimeter at a point about two and one-half miles east of the junction of Highways 781 and 278. This had decreased to 11 pCi/ml by May 23. The greatest distance that plant-released tritium was detected in vegetation was along Highway 321 near the junction of Highways 26 and 321, approximately 45 miles from the plant perimeter; low concentrations (14 to 23 pCi/ml) were found on May 3. At greater distances, tritium concentration in vegetation was generally less than 14 pCi/ml (free water) and variable, making trajectory tracking impossible. Several locations where the highest concentration of tritium in vegetation was detected were sampled repetitively over a period of three weeks. The tritium exhibited an apparent half-time of about one day in grass.

The highest tritium concentration detected in pine needles (1000 pCi/ml) was on the plant boundary at approximately the same location as the maximum concentration in grass; this sample was collected on May 10. Concentration of tritium in free water in pine needles decreased with two apparent half-times: a short-lived component with a half-time of 4 days and a longer-lived component with a half-time of about 100 days. The infinite time integral concentration of the shorter-lived component was about 4 to 5 times the longer-lived component.

Food Crops

Approximately 100 samples of vegetables from the area of the puff trajectory and surrounding areas were analyzed during the weeks following the release. Most samples from the trajectory contained tritium concentrations in free water of 20 to 300 pCi/ml at distances up to six miles from the plant perimeter. The maximum concentration found in a single sample was 1825 pCi/ml in a cabbage from a location adjacent to the plant boundary along the puff centerline. Although no tritium half-time studies were made in vegetables, their growth pattern and transpiration rates lead us to assume that tritium half-times would be intermediate between grass and pine needles, i.e., between one and four days.

Milk

Approximately 45 milk samples were collected from farms and dairies during the week following the release. The highest concentration of tritium detected in milk used for human consumption was 23 pCi/ml from a farm cow near Williston, S. C. The maximum concentration detected in milk from a dairy was 7 pCi/ml.

The maximum concentration detected in any milk sample was 375 pCi/ml from a beef breeder cow (milk not consumed by humans) near Williston, S. C. Repetitive measurements (over a period of three weeks) of the concentration in the milk of this cow indicated an apparent effective half-time of tritium in the cow of five and one-half days. This reflects the combined effect of half-time of tritium in the cow's diet and half-time of body water in the cow.

Surface Water

Surface water was collected from about 100 locations northeast of SRP. These samples included rainwater puddles, rain gages, surface streams, and ponds. With the exception of three rainwater puddles near Williston, S. C. (range: 30 to 138 pCi/ml), all surface water samples were in the range of >1 to 8 pCi/ml (Figure 9). Water samples from 37 U. S. Forest Service rain gages all contained <3 pCi/ml of tritium (Figure 10).

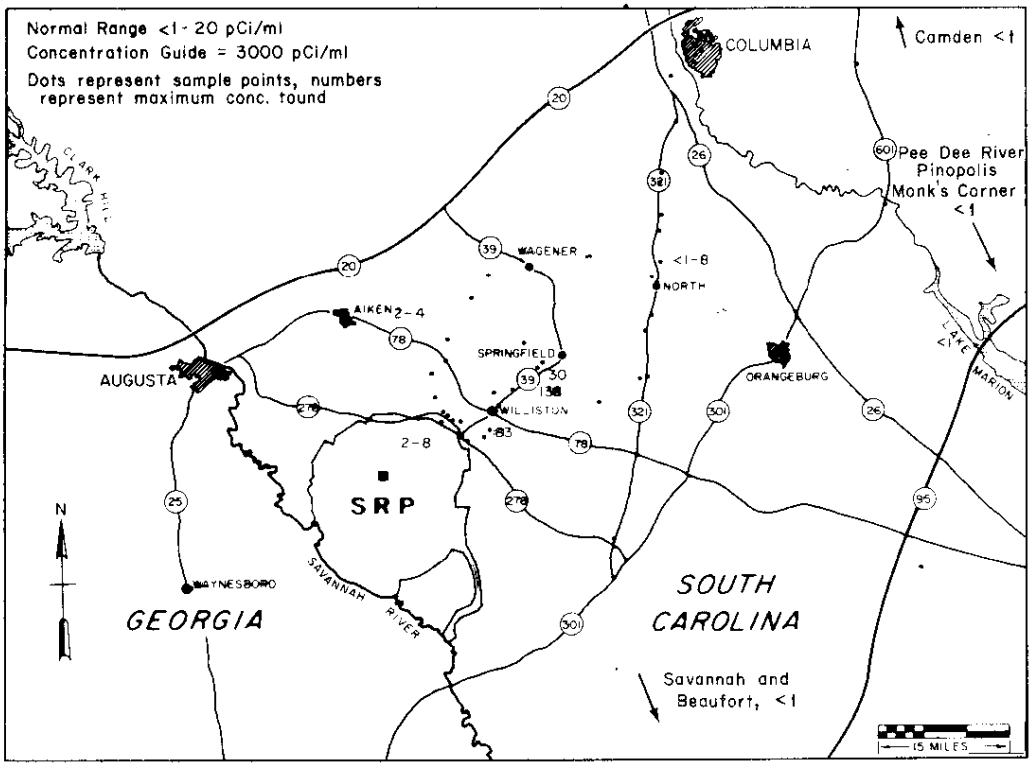


FIGURE 9. Tritium Oxide Concentration in Surface Water (pCi/mℓ)

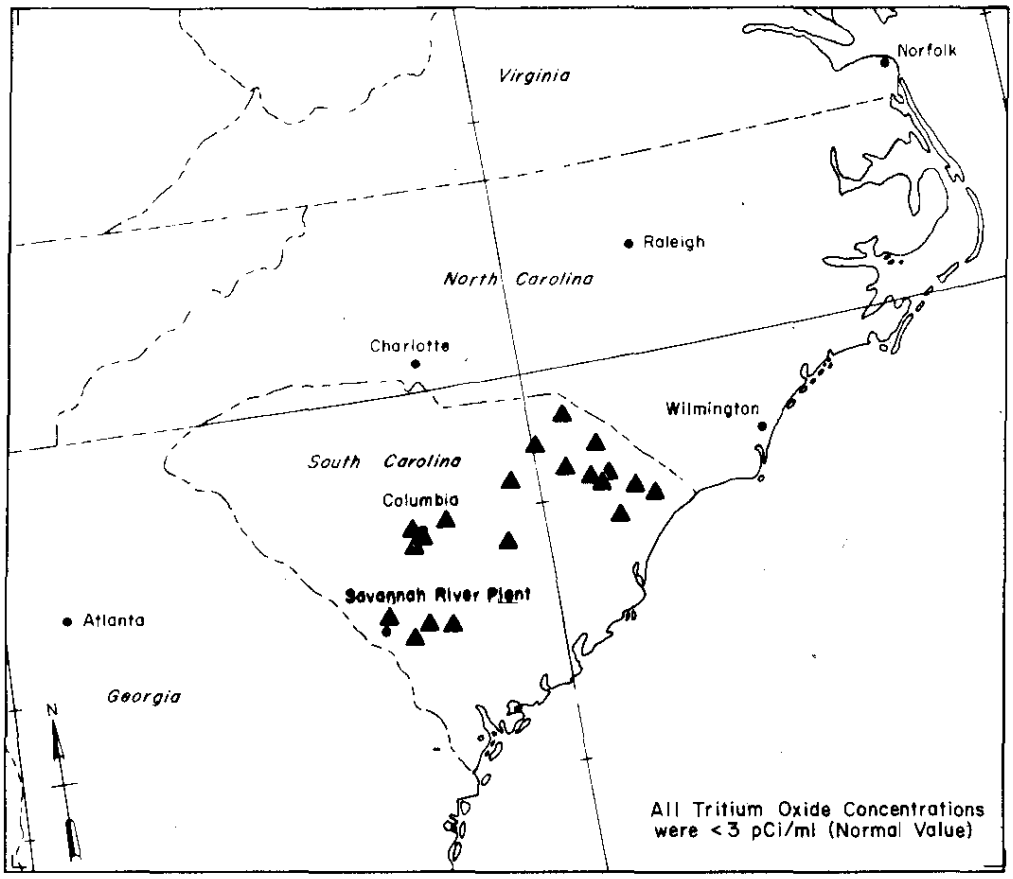


FIGURE 10. Location of Rainwater Samples Collected by the U. S. Forest Service

Tri-State Sampling

Sampling of milk, water, soil, vegetation, and food crops was extended on May 9-11 over a three-state region (South Carolina, North Carolina, and Virginia) to measure tritium concentrations in the regions that represented the two most-probable long-range trajectories (Figure 5) of the tritium release. About 130 samples were obtained from locations shown on Figure 11. All of these samples contained less than 3 pCi/ml of tritium, a level considered normal for this region.

POPULATION DOSE CALCULATION

The maximum integral concentration of tritium at ground level in the centerline of the puff at the plant boundary was calculated

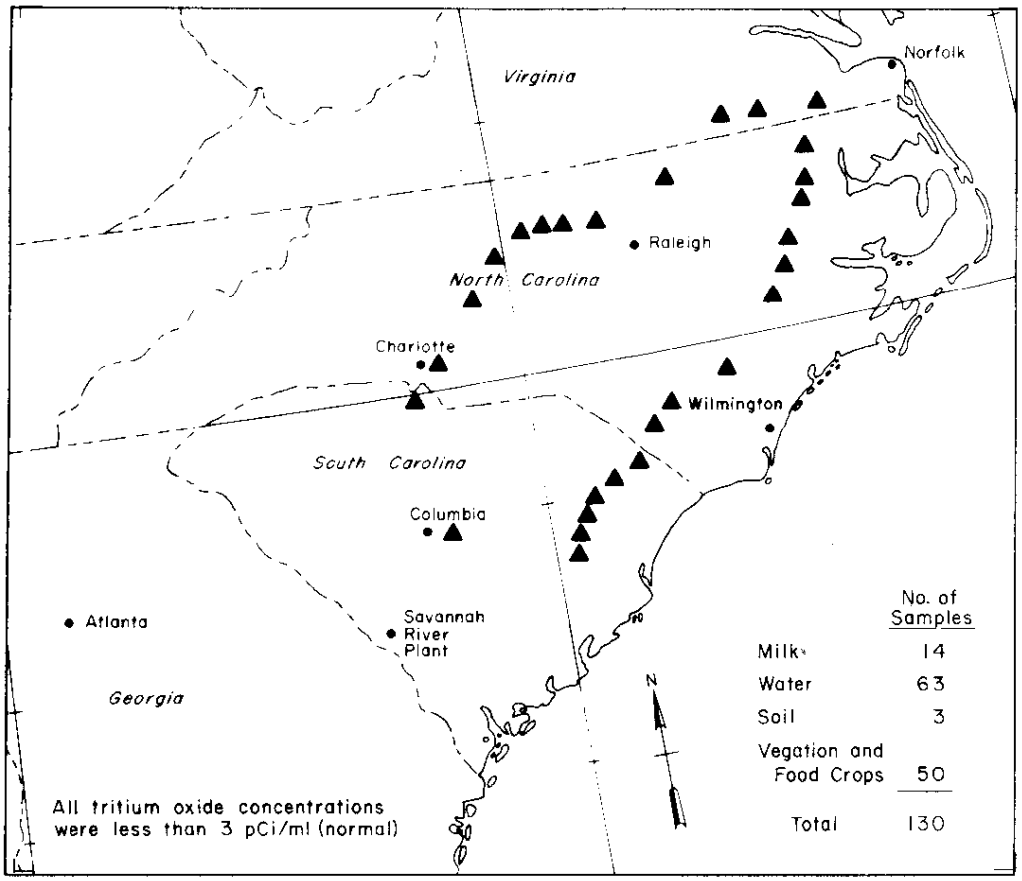


FIGURE 11. Tri-State Sampling Locations

to be 0.48 (Ci-sec)/m^3. A person exposed to this integral concentration would receive an inhalation-skin absorption dose of 70 mrem if 100% of the tritium was in the oxide form. Offplant monitoring with a tritium forms sampler indicated that 0.2% of the tritium was in the oxide form; thus, the maximum dose was calculated to be 0.14 mrem. Early bioassay samples of persons in suspected locations of highest exposure contained less than 0.005 μCi/l of tritium, indicating that offplant doses to the population were generally less than 0.05 mrem. A dose of 0.05 mrem is only 0.04% of the 120-mrem natural radiation dose received by members of the population in one year, i.e., it corresponds to the amount of natural radiation dose received in about four hours.

The population dose received before the tritium moved off the coast was calculated to be 8 man-rem (see Appendix B). The dose to an infant from consumption of milk initially containing 23 pCi/l and declining in concentration with a half-time of five and one-half days (assuming a consumption rate of 1 liter of milk per day) would be 0.3 mrem. The dose to an adult from consumption of one-half pound of freshly picked uncooked cabbage each day containing an initial concentration of 1825 pCi/ml and declining in concentration with a half-time of four days would be 0.5 mrem.

ACKNOWLEDGMENTS

The analysis of the effects of the May 2, 1974 tritium release was made possible by meteorological data and extensive sampling, analysis, and interpretation of data by a number of groups. The names of all individuals contributing to these efforts is too extensive to list here. However, the author wishes to acknowledge the major contributions of the following groups:

Savannah River Plant
- Health Physics Area Survey Groups
- Health Physics Environmental Monitoring Group
- Health Physics Bioassay Group

Savannah River Laboratory
- Environmental Transport Division
- Environmental Effects Division
- Environmental Analysis and Planning

Lawrence Livermore Laboratory
- Atmospheric and Geophysical Sciences Division

Also contributing by obtaining rainwater and urine samples were:

- SRP-SRL employees and families
- North Carolina Department of Human Resources
- U. S. Forest Service
- South Carolina Department of Health and Environmental Control
- North Carolina Forest Service
- South Carolina Commission of Forestry

REFERENCES

1. E. A. Pinson and W. H. Langham. "Physiology and Toxicology of Tritium in Man." *Appl. Phys. 10,* 108 (1957).

2. *Report of ICRP Committee II on Permissible Dose for Internal Radiation (1959).* ICRP Publication No. 2, International Commission on Radiological Protection, Pergamon Press, New York (1959).

3. H. L. Butler. "Observation of Biological Half-Life of Tritium." *Health Physics 11,* 1 (1965).

4. D. G. Jacobs. *Sources of Tritium and its Behavior Upon Release to the Environment.* AEC Critical Review Series, USAEC Report TID-24635, Oak Ridge National Laboratory, Oak Ridge, Tenn. (1968).

5. "Standards for Radiation Protection," AEC Manual Chapter 0524.

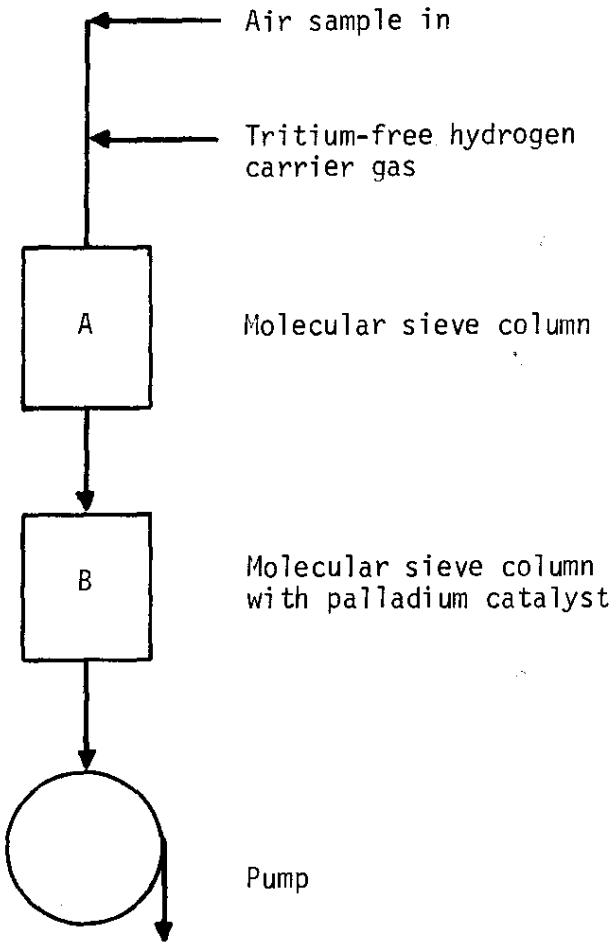
6. *U. S. Code of Federal Regulations,* Title 10, Part 20.

7. D. H. Slade. *Meteorology and Atomic Energy.* USAEC Report TID-24190, Oak Ridge National Laboratory, Oak Ridge, Tenn. (1968).

8. D. S. Myers, J. F. Tinney, and P. H. Gudiksen. "Health Physics Aspects of a Large Accidental Tritium Release." *Tritium,* Proceedings of a Symposium in Las Vegas, Nevada, 1971, A. A. Moghissi and M. W. Carter (Ed), USAEC Report CONF-710809 USAEC Technical Information Center, Oak Ridge, Tenn. (1973).

APPENDIX A

TRITIUM FORMS SAMPLER



METHOD OF OPERATION

1. Air moisture (H_2O and HTO) is collected on molecular sieve in Column A.

2. Elemental tritium gas (HT and T_2) mixes with tritium-free hydrogen carrier gas and passes through Column A.

3. Hydrogen gas enters Column B and is converted to oxide form by a palladium catalyst. The water so formed is collected on molecular sieve in Column B.

4. Moisture is distilled from Columns A and B and collected separately.

5. Moisture samples A and B are analyzed for tritium content separately. Sample A represents tritium that was in the form of oxide in air, and Sample B represents tritium that was in the form of elemental gas in air.

6. Tritium content of water samples A and B are related to tritium concentration in air by measurements of the following, taken at the time of sampling:

   - Absolute humidity
   - Air sampler flow rate
   - Length of sampling time
   - Flow rate of tritium-free hydrogen carrier gas

APPENDIX B

METHOD OF ESTIMATING MAN-REM POPULATION DOSE FROM ACCIDENTAL TRITIUM RELEASE

Population dose resulting from an accidental tritium release from SRP depends on the prevailing meteorological conditions during and following the release. Exact population dose depends on a precise knowledge of integrated concentrations that each individual is exposed to during passage of the tritium. Since this is not practical, other means were applied to obtain an estimate of population dose. The following assumptions were made:

1. Homogeneous population distribution.

   The average population density was taken to be the average in the areas of the predicted puff trajectories (Figure 5); this average is 41 people/km^2.

2. Confinement within a mixing layer of .45 km (about 1500 ft) with a homogeneous vertical distribution.

With these two assumptions, the only variable affecting total dose is the total time the cloud is over a populated area. It is adequate to assume the material is confined in a square column with sides 1 km in length and with a height of 0.45 km corresponding to the mixing layer. The concentration within this volume is:

$$\chi = Q/0.45 \qquad (1)$$

where χ = concentration, Ci/km^3

Q = Total source term, Ci

Population dose is then determined by:

$$E_p = \chi\gamma PTW \qquad (2)$$

where E_p = population dose, man-rem

γ = dose conversion factor, $rem/[(Ci\text{-}sec)/km^3]$

P = population per km^2

T = total time of exposure, sec

W = fraction of tritium in the oxide form

As shown in Figure 5, due to meteorological uncertainties, two possible paths are given that the tritium may have taken before reaching the coast. However, the time taken to traverse each of these paths is about the same. Therefore, the result of applying Equation 2 to either of these paths is the same. Taking values appropriate for the release incident:

$Q = 4.79 \times 10^5$ Ci

$\gamma = 1.43 \times 10^{-10}$ rem/[(Ci-sec)/km^3]

P = 41 persons per km^2

T = 36 hours = 1.3×10^5 sec

W = the fraction of tritium in oxide form*

which yields an estimated population dose of 8 man-rem. This is the dose to the exposed population from inhalation and skin absorption during the initial passage of the tritium out to sea past the Atlantic coastline. Subsequent dose to this population from global recirculation of tritium in the atmosphere will be many orders of magnitude less because of dilution of the tritium with the global atmosphere, entry of tritium oxide into the hydrosphere where much of it becomes unavailable for exposure to humans, and depletion through radioactive decay.

---

*Air samples indicated this fraction to be 0.002 at Springfield, S. C., approximately 25 miles (40 km) from the point of release. To allow for possible additional formation of the oxide form before the puff passed out to sea, a value of 0.01 was used in the population dose calculations.

APPENDIX C

HTO IN URINE

Location and Group	Samples	1974 Date	µCi/l
On-plant			
Inside tritium facility	122	5/2	<1
Outside tritium facility	10	5/2	<1
U. S. Forest Service	3	5/2	<1
Barnwell Lumber Company	9	5/2	<1
International Paper Company	4	5/2	<1
Savannah River Ecology Laboratory	1	5/2	<1
Dorris Construction	7	5/2	<1
Survey Teams	3	5/2	<0.005
Off-plant Families			
Williston, S. C. (5 Individuals)	3	5/2	<0.005
Williston, S. C. (5 Individuals)	4	5/3	<0.005
Williston, S. C. (5 Individuals)	1	5/9	<0.005
Williston, S. C. (5 Individuals)	1	5/10	<0.005
North, S. C. (2 Individuals)	2	5/3	<0.005
North, S. C. (2 Individuals)	1	5/10	<0.005
North, S. C. (2 Individuals)	2	5/17	<0.005

Location and Group	Samples	1974 Date	μCi/l
South Carolina Counties			
Berkley	5	5/8	<0.005
Calhoun	5	5/8	<0.005
Chesterfield	5	5/8	<0.005
Clarendon	5	5/8	<0.005
Darlington	5	5/8	<0.005
Dillon	5	5/8	<0.005
Fairfield	3	5/8	<0.005
Florence	5	5/8	<0.005
Georgetown	5	5/8	<1
Horry	5	5/8	<1
Kershaw	5	5/8	<1
Lancaster	5	5/8	<0.005
Lee	3	5/8	<1
Lexington	5	5/8	<1
Marlboro	5	5/8	<1
Marion	5	5/8	<1
Orangeburg	5	5/8	<1
Richland	15	5/8	<1
Sumter	5	5/8	<1
Williamsburg	4	5/8	<1
North Carolina			
Cape Fear, Wilmington	10	5/13	<0.005
Forsyth	9	5/15	<0.005
Halifax	5	5/15	<0.005
Iredell	5	5/24	<0.005
Person	5	5/28	<0.005
Pasquotank	5	5/22	<0.005
Rockingham	5	5/20	<0.005