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C. E. Linderoth

REVISED HAZARDS STUDY -- UNDERGROUND STORAGE OF
RADIOACTIVE LIQUID WASTES

By

W.A. Janey
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Process Demonstration & Analysis
Chemical Effluents Technology
CHEMICAL RESEARCH & DEVELOPMENT OPERATION

January 20, 1959

Hanford Laboratories Operation

GENERAL ELECTRIC COMPANY

Richland, Washington

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REVISED HAZARDS STUDY -- UNDERGROUND STORAGE OF
RADIOACTIVE LIQUID WASTES

Reference⁽¹⁾ presents data on the hazards which might arise from the hypothetical release of 50,000 pounds per hour of uncondensed vapors and 3,000,000 gallons of high activity liquid waste from the Purex underground storage tanks. Chemical Effluents Technology requested the opportunity to review and to update these data prior to insertion in documented literature⁽²⁾. This request was made in consideration of the more accurate meteorological and dose rate information, and more realistic tank farm operating data that have been made available during the past eighteen months. Radiological Development Operation concurred on the advisability of a hazards reappraisal⁽³⁾, and presented more recent tank farm operating information on which to base the current hazards study. It is the purpose of this communication to re-evaluate the possible hazards that may result from the accidental

(1) Letter, "Hazards Study -- Underground Storage of Liquid Radioactive Wastes", L.C. Schwendiman to E. Doud, January 30, 1957.

(2) Letter, "Purex Tank Farm Hazard Appraisal", C. E. Linderoth to E. Doud, July 11, 1958.

(3) Letter (Conf-Undoc), "Review of Radiological Hazards", E. Doud to C. E. Linderoth, August 5, 1958.

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release of contaminated vapors at a rate of 25,000 pounds per hour from the 241-A tank farm stack, and the loss of 100,000 gallons of high level waste to the soil beneath a leaking storage tank.

This is not a comprehensive study since it is understood that the use to which this information will be put does not warrant such a complete evaluation at this time. One should recognize that actual dose rates and other conditions may differ considerably from those reported. Misinterpretation may result if these data are included in externally distributed literature without qualifications. For this reason it is recommended that prior to releasing this information externally (if such is contemplated) a more comprehensive study should be made.

UNCONDENSED VAPOR RELEASE

A condensate sample was obtained from the cyclone separator in the 241-A tank farm in August, 1958. Isotopic analyses of the sample showed the major contributors to be Cs^{137} ($0.2 \mu\text{c/ml}$), Ru^{106} ($6.3 \times 10^{-2} \mu\text{c/ml}$), and Ru^{103} ($7.9 \times 10^{-3} \mu\text{c/ml}$). In addition to these three radioisotopes, the short-lived Rh^{103} and Rh^{106} , daughters of Ru^{103} and Ru^{106} respectively, were considered to be present in the vapors in equilibrium and therefore at the same concentrations as the parents. Other radioisotopes detected in lower concentrations would not contribute significantly to any hazard resulting from the vapor release. The boil-off rate at the time that the sample was collected was 7,000 pounds per hour, or about 30% of the rate considered in making this evaluation. No attempt has been made to predict the concentrations of radioisotopes in the vapors as a result of an increase in the boil-off rate to 25,000 pounds per hour. Variability in the age of the waste and cyclone efficiency would make this a difficult and probably an inaccurate extrapolation.

The release of radioactive vapors to the atmosphere, via the 24" emergency relief header and stack, at a rate of 25,000 pounds per hour and a concentration

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of 0.34 $\mu\text{c}/\text{ml}$ (summation of Cs, $\text{Ru}^{106}\text{-Rh}^{106}$ and $\text{Ru}^{103}\text{-Rh}^{103}$) will result in an emission rate of 1000 $\mu\text{c}/\text{second}$. Table I shows maximum radioisotope concentrations in the air near ground level that would probably be encountered at various distances downwind of the stack under stable, neutral, and unstable atmospheric conditions. For comparison purposes the concentrations have been expressed as the ratio of the expected concentrations to the maximum permissible concentrations for occupational exposure of this mixture of radioisotopes in air ($6.5 \times 10^{-8} \mu\text{c}/\text{cc}$).

TABLE I

ESTIMATED MAXIMUM CONCENTRATIONS OF RADIOISOTOPES IN AIR
RELATED TO THE MPC_(air) FOR CONTINUOUS OCCUPATIONAL EXPOSURE

Downwind Distance From Base Of Stack (meters)	Ratio: $\frac{\text{Expected Concentration}}{\text{MPC}_{(air)}}$		
	Stable Atmosphere	Neutral Atmosphere	Unstable Atmosphere
10	450	73	18
30	165	27	7.2
50	105	17	4.7
100	54	10	2.7
300	15	3.5	1.1
500	8	2.5	0.7
1000	3	1.3	0.4
2000	1.3	0.7	0.2

Concentrations greater than MPC_(air) would be encountered out to distances greater than 2,000, 1,000, and 300 meters from the stack for stable, neutral and unstable atmospheric conditions respectively during the vapor emission period.

Tables II and III show maximum gamma and beta dose rates at one meter above ground level resulting from deposition of entrained activity downwind of the stack. Dose rates have been calculated for an emission period of one hour. No correction was made for plume meander during the emission period. Extension of these dose

* Meteorological and dose rate evaluations were performed by J.J. Fuquay of Atmospheric Physics Operation.

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rates to longer emission periods would probably not be valid because of wind direction variability and other changes in meteorological conditions which would result in appreciable alteration in the plume and deposition patterns.

TABLE II

ESTIMATED MAXIMUM GAMMA DOSE RATES FROM DEPOSITION
OF ENTRAINED ACTIVITY FOR A ONE HOUR EMISSION PERIOD

Downwind Distance From Base Of Stack (meters)	Gamma Dose Rates At One Meter Above Ground Level (mr/hr)		
	Stable Atmosphere	Neutral Atmosphere	Unstable Atmosphere
10	1.8	0.4	0.1
30	1.3	0.3	0.1
50	1.0	0.2	0.1
100	0.7	0.1	0.1
300	0.3	0.1	0.1
500	0.2	0.1	0.1
1000	0.1	0.1	0.1
2000	0.1	0.1	0.1

TABLE III

ESTIMATED MAXIMUM BETA DOSE RATES FROM DEPOSITION OF
ENTRAINED ACTIVITY FOR A ONE HOUR EMISSION PERIOD

Downwind Distance From Base Of Stack (meters)	Beta Dose Rates At One Meter Above Ground Level (mrad/hr)		
	Stable Atmosphere	Neutral Atmosphere	Unstable Atmosphere
10	400	70	20
30	150	25	7
50	100	20	4
100	50	9	2
300	10	4	1
500	7	2	0.6
1000	3	1	0.3
2000	1	0.7	0.2

High beta dose rates are attributable to the Rh^{106} daughter which emits high energy beta particles. Although it constitutes only 18% of the activity in the mixture, it contributes 93% of the beta dose at one meter above ground level. Beta and gamma dose rates were also calculated for a person passing through the

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cloud (immersion dose); however, these were an insignificant fraction of the dose from deposited activity and are therefore not reported.

LEAK TO GROUND

Since reference (1) has been written there have been a few developments which necessitate reconsideration of the consequences of a tank leak. Essentially the original analysis is still sound. However, certain complications have developed which could conceivably effect the use of the Columbia River for diluting radioactive wastes.

Increased production in IPD has raised the radioisotope concentration in the river close to the control limit during the winter months of the year. Further production increases are probable which could further tax the dilution capacity of the river. In addition the construction of the Ben-Franklin Dam above the 300 Area, in the general location where ground water from the 200 Areas may discharge, is still being considered. Also being considered is opening the river to navigation. All of these factors represent problems, whether they are of radiological, financial, moral or political significance. For these reasons it seems only reasonable, in considering the radiological consequences of a 100,000 gallon leak, to be conservative in interpreting the limited amount of available information.

To properly evaluate the hazardous nature of a leak it is first necessary to establish a reference plane. The most frequently used and probably the best basis (or reference plane) at the present time is the maximum permissible concentration (MPC) of radioisotopes in drinking water. Continuous consumption over a period of years of water containing concentrations of radioisotopes significantly greater than MPC may result in biological damage to humans. In considering a solution containing a mixture of radioisotopes, such as stored Purex waste, the additive nature of the radiation from each must be taken into account. That is, the concentrations of individual radioisotopes in a mixture may be well below their respective

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MPC's but the sum of the individual contributions could result in irradiation of body organs in excess of the recommended limit.

Data do not exist which will permit a complete evaluation of the possible consequences which may result from a 100,000 gallon leak. However, it is possible to approximate what leak rate could be tolerated. This can be done by assuming that the waste will enter the river at the same rate it leaks from a tank.

The total radioisotopic concentration of supernatant liquid waste in the Purex tanks is somewhat less than would be predicted. This is because either during neutralization or self concentration precipitates are formed which carry down much of the strontium and cerium isotopes. A decontamination factor of approximately 1000 is achieved by this mechanism. If a leak occurs whereby the sludge escapes from the tank, the soil will act as a filter and retain the particulates. Supernatant liquid should not dissolve these solids or leach the radioisotopes to any appreciable extent since it is the parent liquid.

Approximately 50,000 gallons of supernatant liquid will be detained by the soil. This is based on the assumption that the wastes will flow downward in a conical pattern and on the specific retention properties of the soil. This retention of waste has been used to advantage in the past where wastes were disposed to trenches. It is not certain how long these wastes will be detained by specific retention; however, any drainage into the ground water would be very slow, spreading out over 100 or maybe 1000 or more years.

Based on a river flow rate of 500,000 gallons per second and assuming complete dilution, the table below has been calculated to indicate the additional potential internal radiation exposure (relative to MPC's) to people in the environs which may result from specific leak rates.

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TABLE IV

POTENTIAL INTERNAL RADIATION EXPOSURE⁽²⁾ RELATIVE TO MPC's

Age Of Waste, Years (1)	Leak Rate (gallons/day)			Critical Organ
	MPC	1/10 MPC	1/20 MPC	
0	10	1	0.5	GI Tract
1	100	10	5	GI Tract
2	220	22	11	GI Tract
3	400	40	20	GI Tract
4	820	82	41	GI Tract
5	1,280	128	64	GI Tract
8	1,880	188	94	Bone
10	2,040	204	102	Bone
15	2,420	242	121	Bone
20	2,880	288	144	Bone

(1) Zero time is assumed to be 90 days following reactor discharge.

(2) Exclusive of reactors' effluents contributions.

The extremely small permissible leak rates should not be viewed with excessive alarm, for if the leak is small the 50,000 gallons in the soil would provide a huge reservoir for aging the waste. For example, if one year old waste started leaking at a rate of 5 gallons per day and continued at that rate it would take 27 years to use up the soil retention capacity. This age waste (28 years) entering the river at the rate of 5 gpd would be diluted to well below 1/20 MPC. However, if the initial and sustained leak rate were 50 gpd only 2.5 to 3 years would be required to exhaust the specific retention reservoir. The above table shows that 4 year old waste entering the river at a rate of 50 gpd would be diluted to approximately 1/20 MPC.

However, if the sustained leak rate was 500 gpd the reservoir capacity would be exhausted in 100 days. The discharge of 1.3 year old waste into the river at a rate of 500 gpd would result in radioisotope concentrations in the river exceeding MPC by a factor of 4.

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As can be seen the problems which may result from a 100,000 gallon leak are dependent upon the leak rate as well as the total volume lost. A low leak rate (500 gpd or less) is the most probable but is also the most difficult to detect. High leak rates, while not so likely to occur during the initial stages of a tank failure, could create major problems but should be somewhat easier to detect.

In the foregoing analysis certain factors have not been included. Soil adsorption of radioisotopes and travel time to the river are two important factors which have been omitted. These were not included because data are not in existence which will permit approximating their decontamination effect with any assurance of accuracy. However, this conservatism is fairly well balanced by the optimistic assumption that complete river dilution will be obtained before the water reaches a point of use. In actual practice ground water contaminated by 300 Area waste is diluted by the river to 1/500th of its original concentration in moving one-half mile. If the Ben Franklin dam is constructed or if a channel is dredged for navigation purposes the effectiveness of the river for dilution purposes would probably change. Spillways of a dam could increase the mixing; however, a channel may hinder it. In both cases more slack or stagnant water would probably be created near the river shore. These areas could become contaminated to a degree that would cause concern. There is little or no way of realistically weighing in these considerations until the proposed river developments are activated.

In summary, the consequences of a 100,000 gallon leak are dependent upon the age of the waste and the rate of leak and cannot be evaluated exclusive of these considerations. In the case of Purex, in which all the waste is relatively young, a leak rate of 50 gallons per day or greater should be considered very serious, since contamination of the Columbia River equal to or greater than the Hanford control limit for prolonged periods of time can conceivably result.

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It is emphasized that any leak of high level waste to the ground should be regarded as a serious situation and action should be taken immediately to transfer the contents to another tank.

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