ENVIRONMENTAL DOSE PATHWAY STUDY

QUAD CITIES STATION

Spring 1979 through Summer 1980

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SUMMARY

In 1979-1980, the Commonwealth Edison Company continued their Environmental Dose Pathway Studies at Quad Cities Station. This study was designed to add knowledge in the following areas:

(1) The exposure from airborne noble gases at levels below 10mR/yr;

(2) The concentration of I-131 in milk relative to the predictive model of Regulatory Guide 1.109;

(3) The concentration of certain radionuclides in fish relative to the RG 1.109 predictive model; and

(4) The source term of the lesser radionuclides such as the transuranics.

The results of studies 1 and 2 are believed to provide useful information and indicate that the RG 1.109 models for noble gas exposure and I-131 in milk are accurate within a factor of two or better.

The validity of the RG 1.109 models for radionuclides in fish (study area 3) remain unproven because the concentrations of plant released radioactivity in fish are too small to be detected, even with the sensitive techniques used herein. It is doubtful that this particular model will ever be confirmed at a nuclear power station because so little radioactivity is released from there to the aquatic environment. The Quad Cities study of the lesser radionuclides (Study 4) was not conducted due to scheduling difficulties.

Section I

QUAD CITIES EDPS - EXTERNAL DOSE STUDY
(1979-1980)

I. Introduction

The Quad Cities Nuclear Power Station is located on the east bank the Mississippi River, four miles of Cordova, Illinois. Units 1 and 2, each an 800-MWe boiling water reactor release airborne effluents such as noble gases and radioiodine to the atmosphere from two locations: a 94-meter chimney located just west of the building complex and a 50-meter vent stack near the center of the comples. The height of the reactor building is 44 m; the combined cross-sectional area of the reactor and turbine buildings is 2840 m^2.

The main source of population exposure near nuclear power stations has been gamma radiation from radioactive noble gases. The doses, which are calculated from effluent measurements on the basis of dispersion models (RG 1.109), decrease rapidly as a function of distance from the point of release. Doses have been measured at several installations in the course of special studies, but routine environmental monitoring programs usually report "less than" values because the doses are exceeded by the natural background radiation. Even fluctuations in the natural radiation background can be of the same magnitude as the dose from airborne effluents.

The purpose of the study was to test a procedure for determining external radiation exposure from airborne effluent throughout the area around the station with reasonable effort and cost at levels of 10 mR/year and less. The system consisted of TLD's placed at 16 locations near the station perimeter for measuring the total exposure for 3-month periods, two pressurized argon ionization chambers (PIC's) for distinguishing between the natural radiation background and radiation exposure from airborne effluent, and periodic survey meter readings with a detector sensitive at the μR/hr level at the 16 locations to determine radiation background differences among them. Comparison of measured with computed exposures from airborne effluent at these locations can then be used to calibrate the computational model for predicting exposures at more distant locations.

II. Study Plan

In the 1979-1980 period, Quad Cities Station was ringed by 16 dosimetric measurement locations at or near the site boundary in the directions used for dispersion calculations (Figure 1 and Table 1). Two of the locations (H and E), in approximately opposite directions, had Pressurized Ionization Chambers (PIC's) for continuously reading (by 10-second integrations) the gamma-ray exposure rate. Thermoluminescent dosimeters (5 per station) were placed at all stations for 3-month exposure integrations. A field technician measured the instantaneous background radiation exposure with a scintillation survey meter calibrated relative to the PICs, at each location, at 2-week intervals, and serviced the PICs. Thus the natural radiation background was recorded continuously (except when the noble gas plume was nearby) by the PICs at two locations, and fortnightly at the other 14 locations. Interpolations based on these two sets of measurements will yield the background exposure of the TLDs.

A. PIC Program

Pressurized Ionization Chambers manufactured by Reuter-Stokes, model RSS-111, were used in this program. The RSS-111 Environmental Radiation Monitor is a complete ultra-sensitive gamma exposure monitoring system designed to measure and record the low level exposure rates such as those due to fallout and natural background radiation. The RSS-111 is housed in two cable-connected weatherproof enclosures (Figure 2). The sensor housing contains a high pressure spherical ionization chamber with direct mounting to a solid state electrometer. The control housing contains the readout device. The spherical ionization chamber is filled to a pressure of 25 atmospheres (absolute) with ultra-purity argon. When radiation is incident upon the chamber, the ion pairs produced in the active volume are swept to the electrodes by a collecting potential. The resulting current is measured by an electrometer and can be related directly to the free air exposure rate.

The PICs provide numerous data points to record the exposure rate, so that precise distinctions can be made between the natural background continuum and periodic increases due to station effluents. The background varies gradually at a given location because of the changing accumulation of radon daughters in the ground near the surface and in the ground level air, and because of changes in shielding by snow, rain, and vegetation against radiation emitted by radionuclides in the soil and rock. Changes in the background value observed with the PICs provides adjustments for the background values determined fortnightly with the survey instrument. The survey meter consists of a 2" x 2" NaI (Tl) crystal shielded with cadmium to minimize response to energies below about 80 KeV. The system yields a count rate of about 4000 counts per minute when the pressurized ion chamber indicates a dose rate of about 8 μR/hr. The gamma readings, with adequate intercalibration with the PIC, will provide additional information on the natural background dose rate at the TLD stations and may therefore enable measurement of doses due to station releases at these locations to be calculated.

The computer-processed PIC data consisted of, on an hour-by-hour basis, the average total exposure rate (μR/hr), the standard deviation of the average, the measured (or assumed) background, and the estimated plume contributions to the total exposure rate (the difference between the total and background). (An "assumed" background rate is the last total exposure rate measured without a plume present. A plume was considered present if the total exposure rate exceeded by 3σ of the background. The hourly plume contributions were summed to give the monthly measured total. This total was then compared to calculated exposure rates computed with accepted sector-averaged dispersion models (RG 1·109) and station reported gross radioactivity levels.

II. Study Plan (continued)

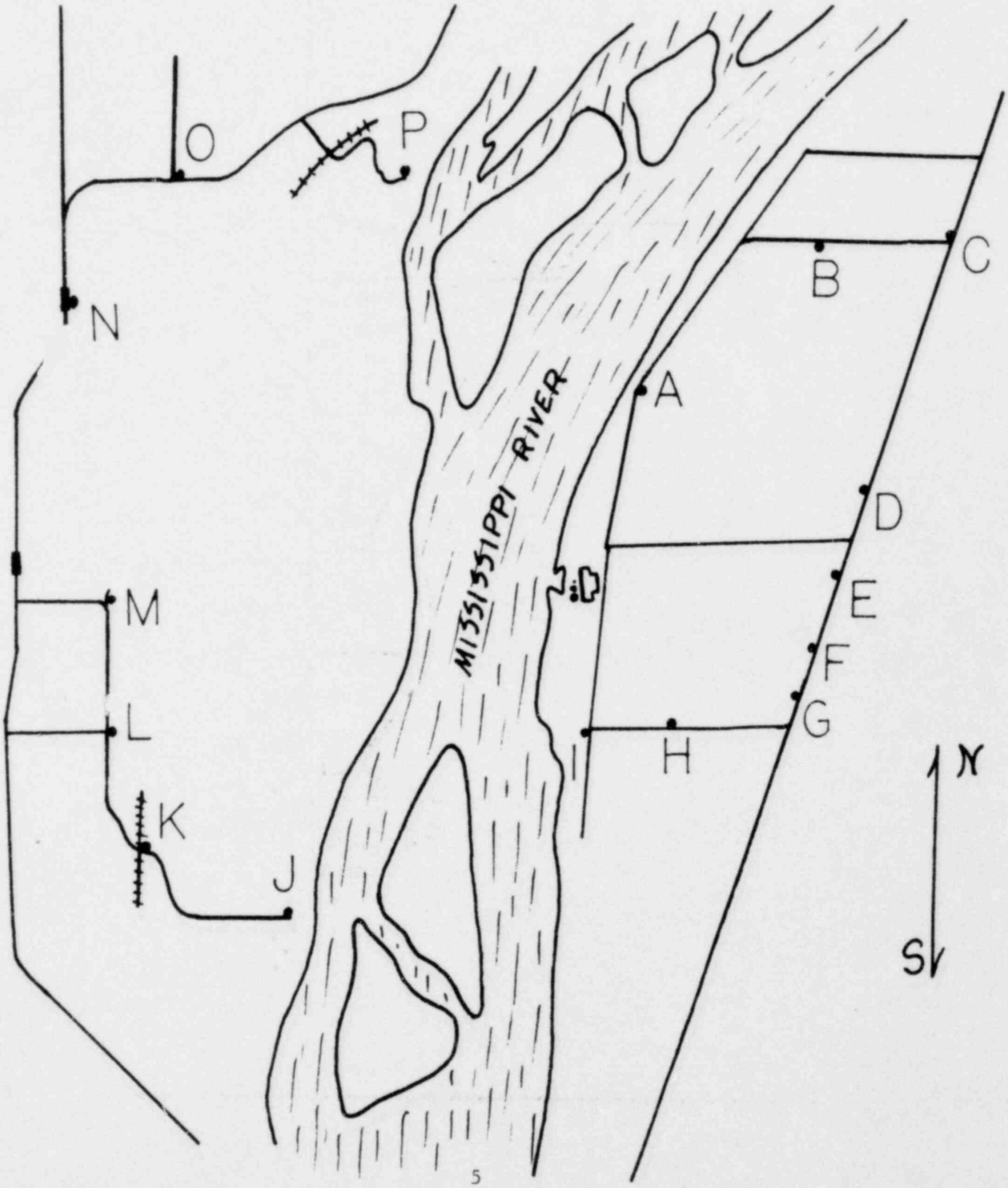
The PIC readings are based on calibration by the manufacturer. The calibration is in terms of Ra-226. The radiation exposure response is energy dependent: it is within 3 percent of the Ra-226 value from 0.5 to 2.5 MeV, but the response factor is higher above 2.5 and below 0.5 MeV, especially at 0.1 MeV. The PIC does not detect external alpha and beta particles or gamma rays below 0.06 MeV.

TABLE 1

QUAD CITIES E.D.P.S. MONITORING LOCATIONS

Site	Sector	Direction	Range (miles)	Location
A	N	5.5°	0.7	On the section line post behind the post box with two wheels on it, in the bushes.
B	NNE	25°	1.3	After the curve right side of the road on the warning sign telephone post.
C	NE	44.5°	1.7	On the fence at Nitrin air sampler.
D	ENE	68°	1.0	On the #3 yellow warning sign post between the road (84) and RR track.
E	E	85.5°	0.8	On the fourth pole after the road to the station, on right side of Ill 84 going south (a PIC location).
F	ESE	113°	0.7	On the tenth pole after the road to the station on right side of Ill 84 going south.
G	SE	137°	0.8	On the eighteenth pole after the road to the station on right side of Ill 84 going south.
H	SSE	160°	0.8	On the pole with meter on the bottom right side of the road (a PIC location).
I	S	174°	0.8	On the fence by the pole and telephone post.
J	SSW	212°	2.5	In the area shown in the map.
K	SW	226°	2.6	On on of the signs by R.R. track.
L	WSW	248°	2.1	On the sign post ⟷
M	W	265°	2.0	On the "shot gun shells only" sign post.
N	WNW	294°	2.5	Area shown on the map around the bridge.
O	NW	317°	2.5	Along the side route 67 at road to Shaffton Cemetery.
P	NNW	334°	1.9	On the fence at Hanson's boat landing air sampler.

FIGURE 1 - MONITORING LOCATIONS



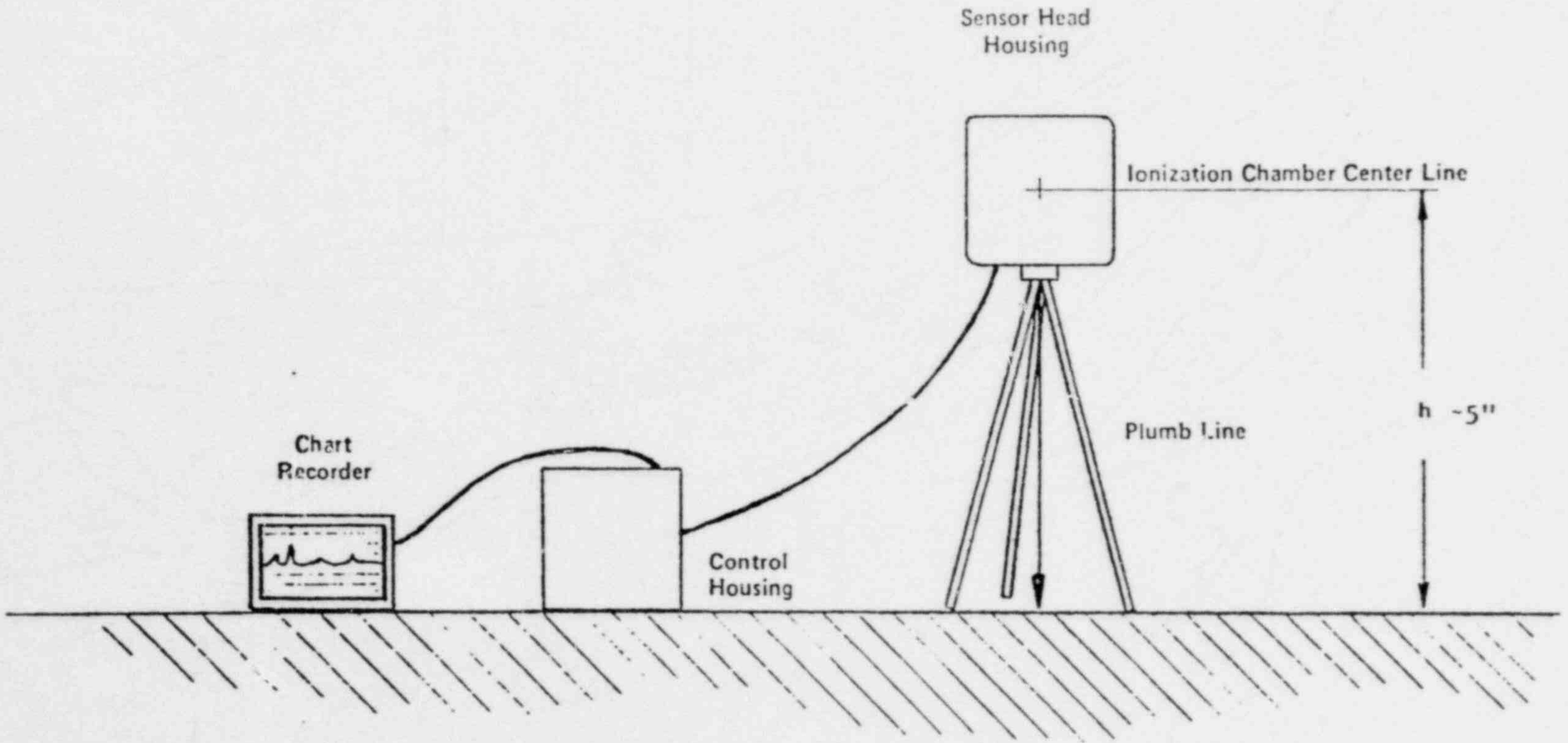


Figure 2 - DETECTOR AND READ-OUT SET UP

II. Study Plan (continued)

B. Thermoluminiscent Dosimeter Readings

Lithium Fluoride thermoluminiscent dosimeters (TLDs) were emplaced at 16 locations surrounding the plant, approximately one location per sector used for dose calculations. Locations are given in Table 1 and Figure 1. TLD badges remained on station for three months. Exposure rates were measured and compared with those calculated from release and meteorological data, gamma survey data (see Section C), and where possible, from PIC data (see Section A).

The Polyethylene Shield in Polyethylene Vial (~56 mg/cm^2) and PVC sphere isotropic holders (~1 gm/cm^2) were chosen for the period of September 23, 1979, through November 15, 1980.

The TLDs are calibrated at frequent intervals and are found to be accurate within a standard deviation of ±10%.

C. Survey (gamma) Meter Readings

Gamma survey readings were made at each of the TLD stations on alternate weeks using a survey meter with a 2" x 2" NaI (Tl) crystal and a discriminator set to eliminate detection of gamma radiation below 80 KeV. The results are summarized in Section III-C. The table shows the conversion factor used to relate counts per minute (survey meter) to μR/hr for each location

III. Results

A. PIC Data*

Because of the operational difficulties with the PICs, useful data were not collected until October 1979. Data collection continued until June 1980.

The following table shows the measured vs. estimated cumulated gamma dose (estimated cumulative gamma dose provided by Murray and Trettel Inc., based on the actual noble gas release information, actual site meteorology and RG 1.109 atmospheric dispersion and dose calculation model.) for the 4th Quarter 1979, 1st Quarter 1980 and 2nd Quarter 1980.

	(Dose μR)			
	Site E		Site H	
	Measured	Estimated	Measured	Estimated
4th Quarter 1979	451	180	150	150
1st Quarter 1980	185	60	37	60
2nd Quarter 1980	NA	100	NA	90

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*The PICs were calibrated by the manufacturer and as discussed later in the text, may measure high by a factor of 1.2 when compared to LiF TLDs encapsulated in PVC Isotropic spherical holders (~1 gm/cm^2).

Table 2

Gross Radioactivity Release Rates (mCi/sec)*

4th Quarter 1979	1.05
1st Quarter 1980	0.46
2nd Quarter 1980	0.74

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* An assumed average gamma energy of 0.8 MeV and no radiological decay were used in the calculation.

III-A. PIC Data (continued)

Table 2 shows the gross radioactivity release rates for the period October 1979 - June 1980. Tables 3-A and 3-B summarize the PIC data on a weekly basis for the period October 1979 - August 1980. Table 4 summarizes the PIC background data for the same period of time.

B. Thermoluminiscent Dosimeter and Gamma Survey Data

Table 5 summarizes the data, on comparison of dose with TLDs in various packing materials from Dresden EDPS Report (1979). At Dresden five different packing materials were tested for the effect on the TLD response to natural and noble gas radiation. At Quad Cities only two types of packaging materials were tested--one used by CECo for environmental monitoring and the isotropic sphere developed by Eberline Instrument Corporation.

The TLD packings Polyethylene Shield in polyethylene vial (~56 mg/cm^2 thickness), and Isotropic PVC holder (~1 g/cm^2 thickness) were chosen for the study.

Tables 6 and 7 summarize the Gamma Dose Rates measured using TLDs from September 23, 1979, to November 15, 1980.

Comparison of TLD data with PIC data is presented in Table 9 From this the correction factors are obtained to correlate TLD and PIC data.

Table 10 presents the background data obtained from PIC and γ-survey measurements. The γ-survey readings were converted to μR/hr, using a calibration curve between γ cpm and PIC μR/hr (Table 8).

Table 11 presents the average background from γ-survey readings for all locations.

III-A. PIC Data (continued)

Table 3-A

Summary of PIC Data from September 1979 - June 1980

ON-SITE #2 LOCATION - E
(weekly average)

		ΣμR		Ave. μR/hr		
Dates	Hours	Gross	Bkgd	Total	Bkgd	Net
09/09/79-09/22/79*	322	2294	2274	7.12	7.06	0.06
10/06/79-10/13/79	171	1249	1218	7.30	7.12	0.18
10/13/79-10/20/79	162	1211	1167	7.48	7.20	0.28
10/20/79-10/27/79	172	1244	1194	7.25	6.96	0.29
10/27/79-11/03/79	171	1283	1229	7.50	7.19	0.31
11/04/79-11/10/79*	147	1033	1007	7.03	6.85	0.18
11/17/79-11/23/79*	144	1178	1031	8.18	7.16	1.02
11/30/79-12/01/79	214	1668	1543	7.79	7.21	0.58
12/01/79-12/08/79*	165	1186	1160	7.19	7.03	0.16
12/29/79-01/05/80	164	1291	1139	7.87	6.95	0.92
01/05/80-01/12/80*	168	1226	1193	7.30	7.10	0.20
01/26/80-02/03/80*	188	1278	1277	6.80	6.79	0.01
02/23/80-03/02/80	251	1279	1270	5.09	5.06	0.03
03/02/80-03/08/80*	135	820	832	6.07	6.16	-0.09
04/12/80-04/19/80*	218	1158	1153	5.31	5.29	0.02
04/28/80-05/06/80*	252	1391	1383	5.52	5.49	0.03
06/06/80-06/10/80*	103	736	700	7.17	6.82	0.35
06/23/80-06/27/80	130	749	726	5.76	5.58	0.18

*Data were not available in between periods.

III-A. PIC Data (continued)

Table 3-B

Summary of PIC Data from September 1979 - August 1980

ON-SITE #1 LOCATION - H

(weekly Average)

Dates	Hours	ΣμR		μ		
		Gross	Bkgd	Total	Bkgd	Net
09/09/79-09/23/79	317	2338	2221	7.38	7.01	0.27
09/23/79-10/06/79	311	2285	2197	7.35	7.06	0.29
10/06/79-10/13/79	167	1163	1155	6.96	6.92	0.04
10/13/79-10/20/79	159	1134	1104	7.13	6.94	0.19
10/20/79-10/27/79*	174	1192	1153	6.85	6.63	0.22
11/04/79-11/10/79*	144	996	965	6.92	6.70	0.22
11/17/79-11/23/79	143	1029	979	7.20	6.85	0.35
11/23/79-12/01/79*	192	1307	1297	6.81	6.76	0.05
12/08/79-12/15/79*	172	1155	1151	6.72	6.69	0.03
12/29/79-01/05/80	165	1108	1103	6.72	6.68	0.04
01/05/80-01/12/80*	169	1184	1147	7.01	6.79	0.22
03/29/80-04/05/80*	170	1054	1075	6.21	6.34	-0.13
04/28/80-05/06/80*	196	1203	1308	6.14	6.67	-0.53
06/06/80-06/14/80*	184	1230	1201	6.68	6.53	0.15
07/18/80-07/25/80*	175	1073	1136	6.13	6.49	-0.36
08/16/80-08/23/80	161	1099	1060	6.83	6.58	0.25
08/23/80-08/30/80	204	1132	1131	5.55	5.54	0.01
08/30/80-09/06/80	204	1106	1052	5.02	5.16	0.26

*Data were not available in between periods.

III-A. PIC Data (continued)

Table 4

Summary of PIC Background Date µR/hr
(integrated over 4-week intervals)

	Site E	Site H
1979		
October	7.38	6.98
November	7.61	6.98
December	7.49	6.72
1980		
January	7.32	6.87
February	5.49	6.18
March		
April		
May	6.15	
June		

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Table 5*

Dose Rates in µR/hr (April 26 - May 19, 1978)

Packaging Material	Locations (±1σ)			
	A	B	F	H
Al Shield, PVC holder	8.40±0.43	7.27±0.24	7.37±0.34	7.84±0.17
Al Shield, Polyethylene holder	8.67±0.35	7.00±0.44	7.39±0.26	8.19±0.67
Polyethylene Shield, PVC holder	9.88±0.17	9.36±0.35	-	9.40±0.29
Polyethylene Shield, Polyethylene Vial holder	-	-	-	9.45±0.75
Isotropic PVC Sphere	7.69±0.26	6.24±0.29	6.27±0.22	6.67±0.61

*Previously reported Dresden Station data (1979).

III-B. Thermoluminiscent Dosimeter and Gamma Survey Data (continued)

Table 6

Average Environmental Gamma Dose Rates using TLD's in μR/hr (±1σ)* (Polyethylene shield in Polyethylene vial holder - 56 mg/cm^2 thickness).

Station	23 Sept 79--3 Feb 80	3 Feb 80--11 June 80	11 June 80--15 Nov 80
A	8.5±0.5	6.6±0.6	8.3±0.1
B	7.5±0.3	6.4±0.4	6.7±0.2
C	6.6±0.3	6.5±0.3	6.4±0.4
D	7.2±0.5	6.5±0.7	8.1±0.4
E	6.9±0.5	5.7±0.4	6.4±0.2
F	7.2±0.8	5.8±0.6	6.6±0.6
G	7.2±0.5	6.0±0.3	6.8±1.4
H	7.5±0.8	6.4±0.2	8.4±0.3
I	6.3±0.3	5.7±0.5	8.5±0.3
J	7.2±0.3	Missing	Missing
K	6.6±0.5	6.1±0.5	8.5±0.3
L	6.9±0.3	5.8±0.7	8.0±0.6
M	7.5±0.3	Missing	7.5±0.6
N	7.2±0.5	6.8±0.8	7.9±0.2
O	8.5±0.6	7.0±0.2	8.0±0.2
P	7.8±0.5	Missing	8.6±0.3

*Standard deviation 1σ is usually based on five replicate LiF TLD chip readings.

III-B. Thermoluminiscent Dosimeter and Gamma Survey Data (continued)

Table 7

Average Environmental Gamma Dose Rates using TLD's in μR/hr (±1σ)*
(Isotropic PVC Sphere holder ~1 g/cm^2 thickness)

Station	23 Sept 79--3 Feb 80	3 Feb 80--11 June 80	11 June 80--15 Nov 80
A	6.3±0.3	5.4±0.4	6.6±0.6
B	6.6±0.6	5.7±0.2	6.4±0.2
C	6.0±0.3	5.1±0.4	6.2±0.8
D	6.3±0.5	5.3±0.2	6.0±0.1
E	6.0±0.3	4.9±0.1	5.7±0.2
F	6.3±0.3	5.3±0.2	5.9±0.2
G	5.6±0.3	4.7±0.3	5.7±0.3
H	6.0±0.3	5.3±0.5	6.4±0.2
I	5.6±0.3	5.2±0.4	5.5±0.1
J	6.3±0.3	Missing	Missing
K	6.0±0.8	5.1±0.5	6.6±0.6
L	6.3±0.3	5.6±0.6	6.5±0.2
M	6.6±0.3	5.8±0.4	Missing
N	6.3±0.6	5.5±0.3	7.2±0.2
O	7.2±0.3	6.4±0.2	7.1±0.6
P	6.9±0.6	6.4±0.4	7.1±0.2

The comparison of TLD and PIC data (Table 9) is in good agreement with previously reported results from the 1979 Dresden EDPS program.

The PIC and NaI Gamma Survey data (Table 10) are in good agreement. It also indicates that the two systems (PIC and NaI) are well cross-calibrated.

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*Standard deviation 1σ is usually based on five replicate LiF TLD chip readings.

Table 8

Conversion Factor to Calculate µR/hr from Counts per Minute (Survey Meter Reading) at Sites A through B

Site	*µR/hr =
A	1.11×10^{-4} (cpm) + 6.37
B	1.14×10^{-4} (cpm) + 6.36
C	1.12×10^{-4} (cpm) + 6.16
D	1.09×10^{-4} (cpm) + 7.27
E	1.11×10^{-4} (cpm) + 6.98
F	1.07×10^{-4} (cpm) + 6.66
G	1.08×10^{-4} (cpm) + 6.25
H	1.05×10^{-4} (cpm) + 6.99
I	1.09×10^{-4} (cpm) + 6.88
J	1.09×10^{-4} (cpm) + 5.89
K	1.07×10^{-4} (cpm) + 6.73
L	1.05×10^{-4} (cpm) + 7.84
M	1.08×10^{-4} (cpm) + 6.81
N	1.07×10^{-4} (cpm) + 7.74
O	1.09×10^{-4} (cpm) + 7.32
P	1.09×10^{-4} (cpm) + 7.36

*Calibration was done using linear regression on the readings obtained with the survey meter and the PIC for background (~10µR/hr), Source A (~ 85 µR/hr) and Source B (~100 µR/hr) at each site.

III-B. Thermoluminiscent Dosimeter and Gamma Survey Data (continued)

Table 9

Comparison of TLD and PIC Data (μR/hr)

Date	Site	(±1σ) TLD Data 56 mg/cm²	(±1σ) TLD Data 1 g/cm²	PIC Data	Correction Factors* (Compared to PIC) 56 mg/cm²	Correction Factors* (Compared to PIC) 1 g/cm²
09/23/79-02/03/80	H	7.5±0.8	6.0±0.3	6.9	0.92	1.15
09/23/79-02/03/80	E	6.9±0.5	6.0±0.3	7.4	1.07	1.23

*PIC Data divided by TLD data.

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Table 10

Comparisons of Data Obtained (instantaneous readings) from PICs and NaI (Tl) γ Survey

Date	μR/hr Site H γ	μR/hr Site H PIC	μR/hr Site E γ	μR/hr Site E PIC
09/23/79	7.4	6.5	7.3	7.2
10/06/79	7.5	7.0	7.4	6.8
10/20/79	7.4	6.8	7.4	7.2
11/17/79	7.4	7.3	7.4	7.5
12/01/79	7.5	7.1	7.4	6.9
12/15/79	7.4	7.9	7.4	6.7
12/29/80	7.5	6.9	7.4	7.0
01/12/80	7.4	7.0	7.3	6.0
03/08/80	7.4	6.7	7.4	7.1
04/19/80	7.3	6.7	7.3	7.9
05/31/80	7.3	6.5	7.4	7.0
06/28/80	7.4	9.0	7.3	*
07/12/80	7.3	6.8	7.3	*
07/25/80	7.4	7.2	7.4	*
Average	7.4±0.1	7.1±0.7	7.4±0.1	7.0±0.5

* Unit out of service.

Table 11

Average Background Dose from γ-Survey

Date	Wind Direction	µR/hr															
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
06/16/79	N	6.8	6.8	6.6	7.6	7.3	7.0	6.6	NA	7.2	6.3	7.1	8.2	7.2	8.1	7.8	7.7
06/23/79	S	-	-	-	-	-	-	-	-	-	6.2	7.1	8.2	7.2	8.1	7.7	7.8
06/29/79	N	6.8	6.7	6.5	7.6	7.4	7.0	6.6	NA	7.2							
07/06/79	S										6.3	7.1	8.1	7.1	8.1	7.7	7.8
07/14/79	No wind	6.9	6.9	6.6	7.7	7.6	7.1	6.7	7.4	7.3							
07/21/79	NE										6.3	7.1	8.1	7.1	8.1	7.7	7.8
07/28/79	N	6.8	6.8	6.6	7.7	7.4	7.0	6.6	7.4	7.3							
09/22/79	S											7.1	8.2	7.1	8.1	7.8	7.8
09/23/79	E	6.9	6.8	6.6	7.7	7.3	7.0	6.7	7.4	7.3							
09/29/79	No wind										6.4	7.2	8.3	7.3	8.2	7.9	8.0
10/06/79	NW	6.8	6.7	6.6	7.7	7.4	7.1	6.7	7.5	7.3							
10/13/79	NE										6.2	7.1	8.2	7.2	8.1	7.8	7.9
10/20/79	SE	7.0	6.8	6.7	7.7	7.4	7.0	6.6	7.4	7.4							
10/27/79	NE										6.3	7.1	8.2	7.2	8.1	7.8	7.9
11/04/79	S	7.0	6.9	6.8	7.9	7.6	7.2	6.8	7.6	7.5							
11/10/79	E										6.3	7.1	8.1	7.1	8.1	7.8	7.9
11/17/79	SW	6.9	6.9	6.8	7.7	7.4	7.1	6.6	7.4	7.3							
11/23/79	NE										6.3	7.1	8.2	7.2	8.1	7.7	7.7
12/01/79	NW	6.8	6.8	6.6	7.7	7.4	7.1	6.7	7.5	7.4							
12/08/79	NE										6.3	7.1	8.2	7.2	8.1	7.6	7.8
12/15/79	S	6.8	6.8	6.6	7.7	7.4	7.1	6.7	7.4	7.3							
12/22/79	No wind										6.3	7.1	8.2	7.2	8.1	7.9	7.9
12/29/79	No wind	7.0	7.0	6.7	7.7	7.4	7.0	6.7	7.5	7.4							
01/05/80	No wind										6.3	7.1	8.2	7.2	8.1	7.7	7.8
01/12/80	S	6.9	6.8	6.7	7.7	7.3	7.0	6.7	7.4	7.3							
01/19/80	NW										6.3	7.1	8.2	7.2	8.2	7.8	7.8
01/26/80	N	6.7	6.8	6.5	7.6	7.3	7.0	6.7	7.3	7.3							
02/03/80	No wind										6.4	7.2	8.3	7.2	8.2	7.8	7.8
02/09/80	N	6.8	6.7	6.5	7.6	7.3	7.0	6.6	7.4	7.3							
02/16/80	W										6.2	7.1	8.2	7.1	8.1	7.6	7.7
02/23/80	N	6.8	6.8	6.6	7.7	7.3	7.1	6.7	7.4	7.3							
03/02/80	NE										6.2	7.1	8.2	7.2	8.1	7.7	7.7

Table 12

Radiation Exposure from Airborne Effluent

Location	Sept. 23, 79 - Feb. 3, 80 Net mR	Feb. 3, 80 - June 11, 80 Net mR
A	0.6	0.4
B	0.9	0.7
C	0.3	0.1
D	0.6	0.3
E	0.3	-0.1
F	0.6	0.3
G	0.3	-0.3
H	0.3	0.3
I	-0.1	0.2
J	0.6	not available
K	0.3	0.1
L	0.6	0.6
M	0.9	0.8
N	0.6	0.5
O	1.5	1.4
P	1.2	1.4
Average	0.6±0.4(1σ)	0.4±0.5 (1σ)

Note: Net μR/hr is TLD average exposure rate (in g/cm² shield) without background. This value was calculated by subtracting from the values in Table 7, 5.7 μR/hr and 5.0 μR/hr during the September 23, 1979 - February 3, 1980 and February 3, 1980 - June 11, 1980. These values are the PIC average background exposure rates of 6.9 and 6.1 μR/hr, respectively, divided by 1.2 (see Table 9) to convert to TLD values.

III. Thermoluminiscent Dosimeter and Gamma Survey Data (continued)

The measured exposure rates due to airborne effluents in the period September 23, 1979 - February 3, 1980, average 0.6 ± 0.4 mR (1σ) and in the period February 3, 1980 - June 11, 1980, average 0.4 ± 0.5 mR (1σ). The average value is consistent with the estimated cumulative gamma dose values of 0 - 0.2 mR at these locations. This yields a 3σ minimum detectable level of about 1.5 mR per quarter. The uncertainty of the total measurement averages about 0.4 mR per quarter (Table 7) and of the background value subtracted from it, which appears to have a similar average standard deviation. The minimum detectable annual exposure by this procedure for four quarterly TLD measurements is $3(4)^{0.5}$ = 6mR/year.

IV. Conclusion

LiF TLDs could accurately measure the station-contributed dose when the current period background was subtracted; the current period background being determined by a survey meter standardized against a PIC-measured exposure rate.

The procedure utilizing two PICs and sets of 16 TLDs yields exposure results that permit measurements as low as 6 mR per year, based on a standard deviation of 0.5 µR/hr when the exposure rate from airborne effluent is near 0.1 µR/hr. Determination of differences in the background values at the 14 non-PIC locations should be improved by performing more precise measurements with survey meters and also making PIC measurements at each location, possibly twice each year.

The results obtained from the Dresden EDPS program (1979) suggested that the off-axis finite plume model most accurately reflected the measured exposure at a near-the-boundary site. This model provides realistic and useful estimates of the measured exposures so long as appropriate corrections are made for periods of extremely unstable atmospheric conditions with the monitor bearing close to the down-wind wind direction.

The releases from Quad Cities Station during the period of this study were very small and it is reflected in the measured data.

Section II

OUAD EDPS - IODINE-131 in MILK

I. Introduction

The thyroid dose rate of 15 mrem/yr per reactor given in POCFR50 Appendix I as the numerical guide for design objectives and limiting conditions for operation to meet the criterion "as low as is reasonably achievable" for radioactive effluents indicates that airborne I-131 may be among the radionuclides that cause the highest organ dose near nuclear power stations. The critical pathway is usually airborne effluent-to-air-to-pasture grass-to-cows' milk-to-infants. Regulatory Guide 1.109 (Revision 1, October 1977) gives a dose/ingestion factor of 0.0139 mrem to the infant thyroid per pCi ingested. At the consumption rate of 330 liters/yr given in the same guide, an average concentration of 1 pCi/liter milk leads to an annual dose to the infants thyroid of 4.6 mrem due to I-131. Hence to reach the 15 mrem/yr per reactor design objective, an annual average concentration of 3 pCi/l is required.

Because of the critical role played by I-131 in the siting and operation of nuclear reactors this study was designed to evaluate the accuracy of the calculational model used to demonstrate compliance with the design of objectives.

In this study, the levels of I-131 in milk from two farms near Dresden Station were measured and compared to concentrations predicted by the mathematical model of NRC Regulatory Guide 1.109 (Revision 1, October 1977). However, only the direct transfer of I-131 onto plant foliage was considered after an evaluation of the model showed that the root uptake and stored feed pathways contributed little to the iodine intake of the dairy animals relative to that from foliage. It was further assumed that only one-half of the iodine was in the elemental form, the form most likely to deposit onto vegetation.

II. Study Plan

A. Calculation Model

As previously stated, the environmental transfer model of Regulatory Guides 1.109 and 1.111 was used weekly to predict I-131 concentrations in milk. Station I-131 effluents measured daily and site meteorology measured hourly were used in the predictions. The principal parameters of the model are given in Table 13.

B. Sampling Program - Description

Samples of about 1.5 liters of milk were obtained from the morning and evening milkings of two farms, one located five miles N , the other

II-B. Sampling Program - Description (continued)

2.5 miles SW, until the weekly collection was made. The milk collected on each day was kept frozen and sent to the laboratory at the end of each week for stable iodide and I-131 analyses.

C. Analytical Procedure - Methodology

Stable iodide concentrations of the samples were measured using a specific ion electrode. Concentrations of stable iodide in milk have been shown in this and other studies to be quite variable and often quite high, making knowledge of the total iodide present, not only carrier, important to chemical yield determinations.

Radioiodine-131 is isolated from milk with stable iodine carrier (corrective also for the presence of stable iodide content) and anion exchange resin. The iodine is eluted from the resin with NaOCl which also oxidizes it to the iodate. The iodate is reduced to iodine with hydroxylamine in ~3N nitric acid solution. The iodine is extracted into carbon tetrachloride, then reduced to iodide with sodium bisulfite, extracted into water and precipitated as AgI from an acidified solution, filtered and washed with NH_4OH to remove any AgCl. Sample is dried, weighed to determine the gravimetric yield of iodide and counted in low level beta counters for about 1000 minutes and the measured I-131 concentrations were decay corrected to the mid-time of sample collection.

III. Results

Analytical results are summarized in Table 14 for Hanson Farm (5 miles N) and Table 15 for Turner Farm (2.5 miles SW).

Tables 14 and 15 summarize the result from each week.

IV. Conclusion

Since the Iodine-131 releases from the Quad Cities Station were very small, the cows were permitted to graze only for an unknown limited periods by the farmers and the measured I-131 levels in milk were near or below the detection limit of 0.01 pCi/l, a fruitful comparison of measured vs. calculated I-131 concentrations in milk is not possible. Considering these limitations the findings of the Dresden EDPS (1979) program are the only information gathered by EDPS. At Dresden the comparisons of measured and computed I-131 concentrations indicate agreement by better than a factor of two over a period of half a year.

TABLE 13

Principal Constants Used in I-131 Milk Pathway Model

Parameter	Description	Value
F_m	Fraction of daily intake which appears in milk	$6x10^{-3}$ d/l
Q_f	Amount of seed (grass + stored seed) consumed per day	50 kg/d
λ	Radiological decay constant of I-131	$3.61x10^{-3}$ hr^{-1}
f_p	Fraction of time animals are in pasture	1.0
f_s	Fraction of daily seed that is pasture grass	1/2
λ_E	Effective decay constant = $\lambda w + \lambda$	$5.67x10^{-3}$ hr^{-1}
λ_w	Environmental weathering removal constant	$2.1x10^{-3}$ hr^{-1}
r	Fraction of released activity retained on pasture grass	0.5
te	Period of pasture grass exposure	720 hr
Yv	Agricultural productivity percent area	0.7 kg/m²
T_E	Release period	720 hr
Q_o	Release rate	Δ Ci/wk
Dr	Relative Deposition	ΔΔ m^{-1}
R	Range: Station to dairy farm	N 8000m SW 4000m

Δ as reported by the station.

ΔΔ From USNRC Regulatory Guide 1.111 (Revision, July 1977)

TABLE 14

		Q-17		Hanson Farm		5 miles N
Collection Date	e-λt	Vol(l)	I-127 mg/l	Grav. Yield	Net cpm ± 1σ	I-131 pCi/l ± 1σ
06/14/79	0.48	21.0	1.00	0.61	0.09±0.04	0.02±0.01
06/21/79	0.55	18.0	1.02	0.52	0.09±0.05	0.02±0.01
06/28/79	0.33	17.5	0.32	0.43	0.00±0.08	0.00±0.03
07/05/79	0.35	19.5	0.78	0.45	0.12±0.05	0.05±0.02
07/11/79	0.36	16.1	0.67	0.43	0.03±0.07	0.02±0.04
07/18/79	0.46	18.0	0.91	0.43	-0.09±0.05	-0.03±0.02
07/26/79	0.50	12.0	1.80	0.37	0.00±0.047	0.00±0.03
08/02/79			Sample destroyed during shipment.			
08/09/79	0.30	16.0	0.69	0.41	0.04±0.05	0.03±0.03
08/16/79	0.55	16.6	0.72	0.49	0.04±0.09	0.01±0.02
08/23/79	0.50	16.8	1.00	0.35	-0.08±0.05	-0.03±0.02
08/30/79	0.42	18.9	0.84	0.19	0.20±0.05	0.08±0.02
09/06/79	0.50	13.0	1.10	0.32	-0.02±0.05	-0.01±0.03
09/13/79	0.55	15.3	0.52	0.63	0.12±0.07	0.03±0.02
09/20/79	0.46	21.0	2.36	0.47	0.28±0.08	0.09±0.03
09/27/79	0.39	19.6	1.47	0.58	0.00±0.07	0.00±0.02
10/04/79	0.46	20.3	1.54	0.34	0.30±0.07	0.12±0.03
10/11/79	0.48	18.9	1.59	0.35	0.07±0.07	0.03±0.03
10/18/79	0.28	16.8	1.87	0.32	-0.10±0.07	-0.09±0.06
10/25/79	0.55	18.2	1.41	0.48	-0.12±0.07	-0.03±0.02
11/01/79	0.50	14.7	1.45	0.51	0.06±0.07	0.02±0.02
11/08/79	0.46	14.7	1.38	0.55	-0.01±0.07	0.00±0.01
11/15/79	0.36	14.0	1.07	0.73	0.09±0.07	0.04±0.03
11/22/79	0.36	17.5	0.93	0.63	0.17±0.08	0.06±0.03
11/29/79	0.50	13.0	1.34	0.73	0.04±0.07	0.01±0.02
12/06/79	0.50	14.5	1.44	0.58	0.02±0.07	0.01±0.02
12/13/79	0.50	18.0	0.24	0.65	0.01±0.07	0.00±0.02
12/20/79	0.16	12.0	0.69	0.96	0.03±0.07	0.02±0.07
12/27/79	0.33	15.5	0.73	0.59	-0.02±0.07	-0.01±0.03
01/02/80	0.46	16.5	0.87	0.65	0.10±0.07	0.03±0.02
01/10/80	0.23	15.0	0.65	0.62	-0.15±0.06	-0.09±0.04
01/17/80	0.36	16.0	0.72	0.55	-0.07±0.07	-0.03±0.03
01/24/80	0.33	15.0	0.60	0.59	-0.06±0.07	-0.02±0.02
02/01/80	0.57	16.0	0.54	0.76	-0.13±0.06	-0.03±0.01
02/07/80	0.34	15.5	0.51	0.64	0.06±0.08	0.02±0.03
02/13/80	0.50	19.0	0.60	0.57	-0.05±0.07	-0.01±0.02

TABLE 15

Collection Date	e-λt	Q-34		Turner Farm		2.5 miles SW
		Vol(l)	I-127 mg/l	Grav. Yield	Net cpm ± 1σ	I-131 pCi/l ± 1σ
06/20/79	0.31	15.0	0.86	0.65	0.00±0.05	0.00±0.02
06/26/79	0.26	11.8	1.60	0.42	0.07±0.07	0.07±0.07
07/02/79	0.27	15.9	0.56	0.33	0.08±0.06	0.06±0.05
07/10/79	0.31	16.8	0.99	0.45	0.26±0.07	0.14±0.02
07/17/79	0.23	14.4	0.61	0.53	-0.00±0.05	0.00±0.03
07/24/79	0.28	14.4	0.93	0.56	0.02±0.07	0.01±0.04
07/31/79	0.42	15.0	0.71	0.38	0.07±0.05	0.04±0.03
08/07/79	0.28	16.5	0.39	0.16	0.25±0.07	0.40±0.11
08/14/79	0.28	16.8	0.41	0.16	0.00±0.07	0.00±0.11
08/21/79	0.28	19.2	0.78	0.47	0.42±0.05	0.21±0.02
08/29/79	0.30	16.2	0.45	0.47	0.04±0.07	0.02±0.04
09/04/79	0.30	14.0	0.41	0.25	0.09±0.06	0.10±0.07
09/12/79	0.23	21.0	0.73	0.52	0.41±0.07	0.13±0.02
09/20/79	0.44	14.6	0.91	0.56	0.34±0.08	0.14±0.03
09/26/79	0.46	21.0	0.48	0.51	0.16±0.07	0.04±0.02
10/03/79	0.42	16.2	1.31	0.43	0.17±0.07	0.07±0.03
10/10/79	0.46	17.5	1.90	0.34	0.15±0.07	0.07±0.03
10/17/79	0.46	16.8	2.24	0.45	0.12±0.07	0.05±0.03
10/24/79	0.46	21.0	1.40	0.38	-0.05±0.07	-0.02±0.02
11/01/79	0.48	18.4	1.32	0.38	0.04±0.07	0.02±0.02
11/08/79	0.55	21.0	0.82	0.61	0.02±0.07	0.00±0.01
11/15/79	0.33	16.9	0.33	0.72	0.03±0.07	0.01±0.02
11/22/79	0.46	20.0	0.81	0.50	-0.06±0.07	-0.01±0.01
11/29/79	0.50	20.0	0.74	0.75	-0.12±0.07	-0.02±0.01
12/05/79	0.50	20.0	0.84	0.65	0.04±0.07	0.01±0.01
12/14/79	0.37	21.5	0.93	0.99	0.04±0.07	0.01±0.02
12/20/79	0.26	16.4	0.72	0.84	0.10±0.07	0.04±0.03
12/27/79	0.30	24.0	0.43	0.62	0.07±0.07	0.02±0.02
01/02/80	0.37	15.9	1.06	0.68	0.09±0.07	0.03±0.02
01/10/80	0.25	15.5	0.69	0.66	0.01±0.06	0.01±0.03
01/17/80	0.46	17.0	0.71	0.51	0.03±0.07	0.01±0.02
01/24/80	0.55	10.0	0.54	0.67	-0.05±0.07	-0.02±0.02
02/01/80	0.34	15.0	0.67	0.51	-0.11±0.07	-0.05±0.03
02/07/80			Sample lost in processing			
02/13/80	0.39	18.5	0.50	0.52	-0.07±0.07	-0.02±0.02

Section III

QUAD EDPS - AQUATIC PATHWAY STUDY
(1979-1980)

I. Introduction

The aquatic pathway study at Quad Station consists of measurements of radioactivity in edible fish tissue. The major nuclides examined were I-131, Cs-134, Cs-137, and P-32.

The area where the fish were collected is not a commercial fishing area. Some sport fishermen frequent the area during the seasons. Nearly fifty species of fish have been identified in the bay, although many are not eaten by man. In this report, the fish collected have been classified according to feeding habits and human consumption, both being important in consideration of the food chain.

II. Study Plan

Seven (7) species of fish were collected and are listed in Table 16 which indicates particulars about those species. Samples were frozen immediately after collection, and returned to the laboratory on dry ice. For analysis, the fish were thawed and weighed, and those of sufficient size were dissected to separate the edible portion. Small fish were analyzed whole. Measured concentrations were then to be compared to calculated concentrations using the model of Regulatory Guide 1.109.

III. Results

Table 17 summarizes the data on the radionuclide concentrations in fish collected during the period 06/79 - 08/79. Small amounts of Cs-137 (0.005 - 0.028 pCi/g wet) were detected in ten fish samples that were attributable to atmospheric fallout. No Cs-134, I-131 or P-32 was detected in the fish samples. The absence of plant attributable activity in the fish prevented accurate comparison with the calculated concentrations.

IV. Conclusion

During this study period the releases from Quad Cities Station were very small and the measured concentration of plant released radioactivity in fish were below the detection limits. Based on the results from Dresden EDPS program (1979) the impact of station discharges to the aquatic environment as represented by fish are too small to be detected even with the sensitive techniques herein. The model indicates that the dose via the aquatic pathway is very small, very much less than 1 mrem.

Table 16

Fish Collected at Quad Station

Fish Name	Food	Habitat**	Human Consumption
Carp	Bottom feeder - opportunist*	Resident - Most abundant	Yes
Sunfish	Opportunist*	Resident - Abundant	Yes
Crappie	Fish, animal foods	Resident - Abundant	Yes
Large Mouth Bass	Fish, animal foods	Resident - Not very abundant	Yes
Gizzard Shad	Plankton	Resident - Abundant	No
Blue Gill	Opportunist*	Resident - Abundant	Yes
Carp	Bottom feeder	Both - abundant	Yes

* Consumes any food available to him.

** Migrant - fish that enters the area during certain seasons of the year.
Resident - fish continuously present in the area.

Table 17

Gamma Emitters (I-131, Cs-134, and Cs-137) and P-32 in Fish

Collection			pCi/g wet			
Date	Location	Species	I-131	Cs-134	Cs-137	P-32
06/28/79	Upstream	Bluegill	<0.08	<0.01	<0.01	<2.0
06/07/79	Upstream-5	Carp	<0.10	<0.01	0.02±0.010	<2.0
06/14/79	Downstream-8	Carp	<0.05	<0.01	0.01±0.010	<2.0
06/29/79	Below Station	Crappie	<0.02	<0.01	<0.01	<2.0
07/31/79	Upstream	Carp	<0.04	<0.005	0.008±0.002	<0.9
07/24/79	Downstream	Crappie	<0.20	<0.005	0.007±0.002	<4.0
NA	Downstream	Carp	<0.30	<0.005	0.015±0.001	<0.3
07/24/79	Upstream	Bluegill	<0.03	<0.003	<0.003	<2.0
07/24/79	Upstream	Crappie	<0.04	<0.003	0.006±0.001	<1.0
08/31/79	Upstream-1	Large Mouth Bass	<0.80	<0.040	<0.040	<0.2
08/29/79	Upstream-34	Sunfish	<0.60	<0.010	0.028±0.003	<1.0
08/31/79	Downstream-110	Gizzard Shad	<0.06	<0.004	<0.004	<0.05
08/14/79	Upstream-66	Gizzard Shad	<0.07	<0.005	<0.005	<1.0
03/14/79	Downstream-11	Crappie	<0.80	<0.005	<0.005	<2.0
08/08/79	Upstream-60	Gizzard Shad	<0.90	<0.005	0.005±0.001	<1.0
08/08/79	Upstream-2	Carp	<0.40	<0.006	<0.009	<0.3
08/09/79	Downstream-4	Carp	<0.30	<0.003	0.007±0.001	<0.2
08/14/79	Upstream-1	Carp	<0.70	<0.005	0.005±0.002	<0.3

Section IV

QUAD CITIES EDPS - SOURCE TERM STUDY
(1979-1980)

Due to scheduling difficulties this portion of the study was not conducted.

ENVIRONMENTAL DOSE PATHWAY STUDY

QUAD CITIES STATION

- APPENDIX -

ANALYTICAL PROCEDURES

subject: Radiodine in Milk or Water
page: 2-24

☐ title: Radiochemical Determination of I-131 in Milk or Water with Low Beta Counting
date: 1-16-75
Revised 10/15/79

approved:

REAGENTS

70% HNO_3 ($\sim$16M), 4M HNO_3, 0.2M HNO_3

36% HCl ($\sim$12M)

30% NH_4OH ($\sim$15M)

0.085 M KI (10 mgI/ml)

0.045 M $AgNO_3$

5% NaOCl (or Clorox)

2M Hydroxylamine Hydrochloride Solution

Carbon Tetrachloride

2.4 cm diameter Glass Fiber Filter

Anion Exchange Resin, 20-50 mesh, chloride form (Dowex 2 x 8 or equivalent)

10% Sodium Bisulfite

EQUIPMENT

A glass tube ($\sim$2.5 cm. ID) is plugged with a small piece of aquarium fiber floss. A suspension of $\sim$30 g. of Dowex 1x8 (20-50 mesh) anion exchange resin in the chloride form is poured into the tube to make a resin column about 10 cm. in height. The column is then connected to a 4 liter plastic reservoir by latex tubing. The flow rate to be adjusted using a screw clamp.

Hot Plate

15 ml, 125 ml Millipore Filter Apparatus

250 ml, 500 ml Beakers

Weighing Balance, 0.0001g

Low Background Beta Counter

Funnel Rack

10 ml, 25 ml Graduated Cylinders

500 ml Separatory Funnel

125 ml Separatory Funnel

subject: Environmental Monitoring page: 2-25

☐ title: Radiochemical Determination of I-131 in Milk or Water with Low Beta Counting date: 04/27/78
Revised: 10/15/79

approved: 7/20/80

METHODOLOGY

Radioiodine-131 is isolated from milk with stable iodine carrier and anion exchange resin. The iodine is eluted from the resin with NaOCl which also oxidizes it to the iodate. The iodate is reduced to iodine with hydroxylamine in ∿3N nitric acid solution. The iodine is extracted into carbon tetrachloride, reduced to iodide with sodium bisulfite, extracted into water and precipitated as AgI from an acidified solution, filtered and washed with NH_4OH to remove any AgCl. Sample is dried, weighed to determine gravimetric yield of iodide and beta counted. ^{131}I content is determined from chemical recovery of iodine, decay, analysis volume and instrument efficiency. Recovery is 70% and MDA is 0.1 pCi ^{131}I/1.

PROCEDURE

1. Pour a known volumn (∿20 1) of milk into the plastic reservoir (Note 1). Adjust the pH of the milk to approximately 8 using 6N NaOH (pH paper is ok).

2. Add a known amount of iodide carrier (∿20 mg. as AgI). Stir thoroughly using a glass rod.

3. Open the screw clamp and adjust the flow rate to be ∿100 ml/min.

4. Transfer the effluent milk to its original container.

5. Transfer the resin from the column to a 250 ml beaker. Wash three times (or more if needed) with ∿50 ml of hot DI water to remove adhering butterfat.

6. Add 50 ml of 5% NaOCl (chlorox) and stir for ∿20 minutes. Decant as much of the liquid as possible into a clean 600 ml beaker, or filter through a Whatman No. 541 filter paper to separate the resin from the liquid if more convenient.

7. Repeat step 6 with 50 ml portion of 5% NaOCl (chlorox) combining all the liquids in the beaker. Filter the last extraction to remove all the solution, wash the resin with ∿20 ml of chlorox, and filter.

8. Make the solution approximately 3M in HNO_3 by adding ∿35 ml concentrated nitric acid. Heat to boil and stir in a fume hood. Cool and transfer the solution into a 500 ml separatory funnel.

9. Add 15 ml of carbon tetrachloride and shake the contents (use the fume hood).

10. Add 45 ml freshly prepared 2M hydroxylamine solution. Mix, stopper to avoid loss of I_2, shake vigorously, and allow a few minutes for reaction to go to completion. If the solution does not have a definite amber color, add more hydroxylamine.

11. Allow the liquid phases to separate, and drain the organic layer into a clean 125 ml separatory funnel containing 25 ml of DI water. Note: Organic layer will turn lavender if the above steps were performed correctly.

PROCEDURES (Cont'd)

12. Repeat the extractions with a second portion (15 ml) of carbon tetrachloride, until no I_2 color is apparent in the organic layer. This should require no more than 2 extractions or until there is no additional color change of the organic layer. Combine all the organic fractions in the separatory funnel.

13. Add a few drops of sodium bisulfite solution (100 grams/liter) and shake. Both layers should now be colorless. Discard the organic phase and work with the 25 ml of water.

14. Transfer the water layer containing iodide to a clean 100 ml beaker. Heat to boling to expel SO_2 (avoid prolonged heating) which would interfere with precipitation of AgI, and add 5 ml of 4 N HNO_3.

15. Add 4 ml of 0.045M $AgNO_3$ slowly while stirring the hot solution. Keep warm until precipitate has coagulated to permit good filtering.

16. Decant supernatant through a tared Whatman No. 42 filter paper.

17. Add ~2 ml of conc. NH_4OH to the precipitate remaining in the beaker and stir (use the fume hood).

18. Filter. Wash with warm water, followed by 0.2N HNO_3 and with 10 ml hot DI water.

19. Dry to constant weight (use the oven at ~100°, for ~20 minutes).

20. Weigh precipitate and record weight.

21. Transfer the filter paper to a SS planchet, and count with the Low Beta system. Counting time should be adjusted to achieve sensitivity specified by client.

(See HASL-300, Section D-08)

Note 1 (a) If the milk has fat globules, filter the milk through a small piece of fiber floss using a large funnel.

(b) If the milk is sour, then avoid using the column method and use a plastic bucket and stir using a stirring apparatus (batch method) as follows: A known volume (4-8 l) of milk is placed in a plastic bucket. Adjust the pH to 8 and add a known amount of iodide carrier. A submersible pump is placed in the solution to mix the contents. Add ~30g of resin and the milk is stirred for ~1 hour. The pump is then removed and the resin is allowed to settle. Decant the milk into its original container and transfer the resin to a beaker and start with step 5 of the procedure.

subject: Procedure for Determination of Stable Iodide in Liquids   page: 2-30

☐ title: date: 05/02/77

approved: [illegible] 2/20/80

REAGENTS

Iodide Standard Stock Solution (e.g. 100 ppm)

5M $NaNO_3$ (Ionic Strength Adjustor)

EQUIPMENT

150 ml beakers
1" magnetic stirring bars and stirrer
thermometer
10 ml or 25 ml burette
2 ml pipet
Ionalyzer Unit (with iodide and reference electrodes)

CHECKING ELECTRODE OPERATION

(to be done before each use)

1. Put 100 ml distilled water and 2 ml ISA into a 150 ml beaker. Turn the function switch to the F^- position. Place electrodes in the solution to a depth of about 3 cm (1 inch).
2. Pipet 1 ml of 100 ppm standard into the solution. Stir thoroughly. Adjust the calibration control until the meter needle (red scale) points to 100 at the center of the scale.
3. Add 10 ml of 100 ppm standard. Stir thoroughly. Adjust the temperature compensator until the meter needle points to 1000 at the extreme right of the red scale. Turn the clear slope indicator dial until the white arrow on the temperature compensator points to the temperature of the solution. Read the percent electrode slope on the lower scale of the dial. Correct electrode operation as indicated by a percent slope between 97 and 100. If this is not obtained, see your supervisor.

DIRECT MEASUREMENT PROCEDURE

1. Prepare standards in the range of 1 ppm to 100 ppm from the stock solution.
2. Add 2 ml of ISA to every 100 ml of the standard solutions. Stir thoroughly.
3. Place electrodes in the 1 ppm standard. Stir thoroughly. Adjust the meter needle to 100 on the red scale (center scale).
4. Rinse electrodes, blot dry and place in the 10 ppm standard. Stir thoroughly. Turn the temperature compensator knob until the meter needle reads 1000 (full scale) on the red scale.

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DIRECT MEASUREMENT PROCEDURE cont'd

5. Transfer 100 ml of sample to a 150 ml beaker. Add 2 ml ISA and stir thoroughly (larger volume of sample may be used if required and add 2 ml ISA per 100 ml of sample).

6. Rinse electrodes, blot dry and place in sample. Stir thoroughly. Read the meter value on red scale and determine the sample concentration in ppm or mg/l from the calibration curve. Or multiply the meter reading on the red scale by 0.01 to determine the sample concentration in ppm or mg/l.

OFF-SCALE READINGS IN SAMPLE

If the needle goes off scale right, rinse electrodes, blot dry and place in the 10 ppm standard. Adjust the calibration control until the needle points to 100 (center scale) on the red scale. Rinse the electrodes, blot dry and replace in sample. Multiply the meter reading on the red scale by 0.1 to determine the sample concentration in ppm or mg/l.

If the needle goes off scale left, rinse the electrodes, blot dry and place them in the 1 ppm standard. Adjust the calibration control until the needle points to 1000 (full scale right) on the red scale. Rinse the electrodes, blot dry and replace in sample. The meter reading on the red scale multiplied by 10^{-3} is equal to sample concentration in ppm or mg/l.

KNOWN ADDITION METHOD
(sample concentration must be known to within a factor of three)

1. Prepare a standard solution about 100 times as concentrated as the sample concentration.

2. To measure an unknown sample, place electrodes in 100 ml of sample and add 2 ml ISA.

3. Turn the function switch to X^-, set the slope indicator dial to the percent slope determined in the daily checkout, and turn the temperature compensator knob to the sample temperature. Set the needle to ∞ on the green scale by turning the calibration control.

4. Pipet 1 ml of 100 ppm standard solution into 100 ml sample. Stir thoroughly. Record the reading 'R' from the green scale.

5. To determine the original sample concentration, use the following equation:

$$Co = \left(\frac{R}{100}\right)Cs$$

where:
Co = sample concentration
R = reading from green scale
Cs = concentration of added standard

The following procedures were used in the analyses of fish:

I. Iodine-131, Cesium-134, and Cs-137

Edible portions of fish were separated and digested carefully with 2.5 M NaOH containing ~10 mg I^- Carrier on a hotplate to dryness. The sample was then ashed in a muffle furnace at 600°c. and the ash was transferred to a suitable container for gamma isotopic analyses using a Ge(Li) detector.

II. Phosphorus-32

(a) Weigh out ~200g of fish fillet. Record the wet weight.

(b) Dry the sample at ~110°c. and record the dry weight.

(c) Place the dry sample in a crucible and ash at ~700°c., till it is completely ashed.

(d) Pulverize the ash and record the ash weight. Transfer the ash to a 250 ml beaker. Add ~50 ml of 8N HNO_3 to the crucible and transfer to the beaker. Heat to boiling with stirring for ~30 minutes and allow it to cool.

(e) Filter though a 5.5 cm glass filter and rinse the filter with DI water.

(f) Refilter the filtrate through a 47 mm Millipore filter.

(g) Add 6N KOH until a precipitate is formed. Add 8N HNO_3 dropwise until precipitate is dissolved. Adjust the pH to 2 with a pH paper.

(h) Transfer to a 100 ml volumetric flask and dilute to the mark with DI water.

(i) Determine the stable phosphorus content by using the procedure on page 8-5.

(j) Proceed to separation of phosphorus by using the procedure on page 8-7.

subject: Colorimetric Determination of Stable Phosphorus page: 8-5

☐ title: Stable Phosphorus Determination date: 10/20/78

approved:

REAGENTS:

1. Standard Phosphorus Solutions:

   (a) Standard 1: (5g P/1) 21.32g $(NH_4)\ HPO_4$, dried at ~100°C is dissolved in 1 liter of DI water in a volumetric flask.

   (b) Standard 2: (50 μg/ml) 10 ml of Std. #1 is diluted to 1 liter with DI water in a volumetric flask.

2. Vanadate-Molybdate Solutions:

   (a) Solution A: Dissolve 25g of ammonium molybdate tetrahydrate in 400ml of DI water.

   (b) Solution B: Dissolve 1.25g ammonium meta vanadate in 300 ml of DI water. Heat to boil, cool, and add 300ml concentrated HCl.

   (c) Mix solutions A and B to give one liter of Vanadate-Molybdate reagent. (This needs to be made fresh each month.)

EQUIPMENT

1. Chemtrix 20 Colorimeter
2. Cuvettes for Colorimeter

PROCEDURE

1. For each sample take 70 ml of DI water in a 30 dram plastic vial.

2. Known aliquots V_1 (eg. 1 ml from phosphate solutions prepared from fish and 4 ml from solutions prepared from urine samples) is transferred to the plastic vial.

3. A series of standard phosphate solutions (blank, 5, 10, 15, 20, 25, 30, and 35 μg P/ml) are prepared as follows. Measure in separate plastic vials 70, 60, 50, 40, 30, 20, 10, and 0 ml of DI water and add 0, 10, 20, 30, 40, 50, 60, and 70 ml of phosphorus Std. #2 (50 μg/ml) respectively.

4. Add 20 ml of Vanadate-Molybdate reagent to each of the vials and dilute to 100 ml, or a known volume. This can be done by volume or weight. (V_2)

5. Allow the solutions to stand for ∿10 minutes before reading their absorbances.

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6. Set the wavelengths dial of the colorimeter to 420 mμ and turn the power switch on. Allow the instrument to stay on for ~30 minutes before use.

7. Place the blank cuvette in the holder and adjust the reading to 100% transmission (zero absorbancy) with the zero adjust dial.

8. Rinse the cuvette with the solution to be read and fill to the mark. Wipe the outside of the tube with a tissue paper. Place the cuvette in the holder with the etch mark facing the operator.

9. Unknowns and standards are read on the linear scale (% transmission). Zero is reset between readings with the blank tube. The % transmission readings of the unknowns should fall within the range of the standard values. If the samples read higher or lower than the standards, their approximate concentration can be estimated. Based on this estimation, the sample or the standard can be diluted appropriately.

10. Absorbance (A) of the solution is calculated from the % transmission (%T) readings using the equation:

$$A=2-\log(\%T)$$

11. Concentration of phosphorus (μg P/ml) is determined from the calibration curve. The concentration of phosphorus P_c in the solution made in Step 4 is thus determined.

12. The concentration of phosphorus (mg/ml) in the original solution is calculated from the equation:

$$\text{Pi mg/ml (Or Px in general)} = \frac{P_c \times V_2}{1000 \times V_1}$$

where V_1 = ml sample aliquot used in Step 2
V_2 = total volume from Step 4
P_c = colorimetric value of phosphorus in μg/ml
Pi = initial or original concentration of the sample.
(to determine V_2 by weight: specific gravity of colorimetric solution (Step 4) is 1.016.)

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subject: Radiophosphorus in Fish page: 8-7

☐ title: Radiochemical Separation of P-32 in Fish date: 10/20/78

approved:

REAGENTS:

1. Cobalt Carrier: 1.010g $CoCl_2 \cdot 6H_2O$ in 50 ml of DI water (5mg Co^{2+}/ml).
2. Zirconium Carrier: 2.3550g $Zr(NO_3)_4 \cdot 5H_2O$ in 50 ml of DI water. (10 mg Zr^{+4}/mℓ)
3. Silver Carrier: 1.575g Ag NO_3 in 50 ml of DI water (20 mg Ag^+/ml). Store in dark or brown bottle.
4. Manganese Carrier: 0.525g $MnCO_3$ in 50 ml of DI water containing 6N HCl just sufficient to dissolve any precipitate upon heating. (5 mg Mn^{2+}/ml)
5. Magnesia Mixture: Dissolve 200 g NH_4Cl and 230 g $MgCl_2 \cdot 6H_2O$ in DI water and dilute to 1 liter.

PROCEDURE:

1. Transfer an aliquot (V, ml)) of the solution to be tested into a 250 ml beaker (solution from Step 8 of sample preparation for fish on page 8-4 and step 4 from urine samples on page). The size of the aliquot is calculated so that

$$V = \frac{33.8}{P_i}$$

where P_i is the amount of phosphorus in mg/ml determined from colorimetric determination on page 8-5

2. Record the aliquot volume used. Dilute to 50 ml with DI water.
3. Add 1 ml of 8N HNO_3 and 0.5 ml each of Cobalt, Zirconium, Silver, and Manganese carriers.
4. Add two drops of 30% H_2O_2 and slowly add 6N KOH until the hydroxides have completely precipitated (pH ∿9.0). Heat to coagulate the precipitate and filter through two #41 filter papers in a buchner funnel. Refilter through a #42 filter paper.
5. Transfer the filtrate to a beaker and add two drops of H_2O_2 and two drops each of Cobalt and Zirconium carriers. Heat to coagulate. Refilter through two #41 filter papers. If the filtrate is turbid, refilter through #42 filter paper followed by using a 47 mm millipore membrane filter, if necessary.
6. Acidify the clear filtrate with concentrated HCl and boil for ∿5 minutes to remove H_2O_2. Cool in ice.

subject: Radiophosphorus in Fish page: 8-8

☐ title: Radiochemical Separation of P-32 in Fish date: 10/20/78

approved:

7. Add 20 ml of magnesia mixture and neutralize to methyl red end point with concetrated NH_4OH. Allow it to stand for 2 minutes and add ~3 ml more of NH_4OH.

8. Filter through #42 filter paper in a Buchner funnel and wash the precipitate with 1N NH_4OH. Discard the filtrate.

9. Dissolve the precipitate in 6N HCl and collect the solution in a filtering flask.

10. Transfer the solution to a 150 ml beaker.

11. Repeat Steps 7-10 for second precipitation of $Mg(NH_4)PO_4$.

12. Repeat Step 7 for third precipitation of $Mg(NH_4)PO_4$.

13. Filter precipitate through 47 mm millipore filter and wash with 1N NH_4OH followed by alcohol.

14. Slurry the precipitate on to a labelled SS planchet with small amount of DI water.

15. Dry the planchet at ~100° C. for ~1 hour.

16. Send the sample to the Counting room with a note to the Counting room personnel to return the sample to the lab after counting for colorimetric determination of the chemical yield.

17. When the planchet is returned from the Counting room, dissolve the precipitate in 5 ml of 1N HCl and transfer to a 100 ml volumetric flask with a few rinsings of DI water. Dilute to 100 ml with DI water.

18. Take a known aliquot V_1 (5.0 ml) to determine the phosphorus concentration by colorimetry from page 8-5

19. Calculate the phosphorus content in the precipitate as follows:

$$P_f \text{mg/ml} = \frac{Px \times 100}{V_1}$$

where Px = amount of phosphorus in mg/ml calculated from Step 12 on page .
V_1 = aliquot used in Step 18 on page .

20. Calculate the chemical yield by using the equation

$$y = \frac{P_f}{Pi}$$

where P_f = final concentration of phosphorus in mg/ml after the chemical separation;

Pi = initial or original concentration of phosphorus in mg/ml.