AB
HGC
GKY
→ Bup

HWSA-2887 Rev

THE RELATIONSHIP BETWEEN I^{131} CONCENTRATIONS IN VARIOUS ENVIRONMENTAL SAMPLES

by

J. K. Soldat

Environmental Studies and Evaluation

For Presentation to the
Annual Health Physics Society Meeting
New York, New York
June 13, 1963

RADIATION PROTECTION OPERATION
HANFORD LABORATORIES

HANFORD ATOMIC PRODUCTS OPERATION
Richland, Washington

GENERAL ELECTRIC

THE RELATIONSHIP BETWEEN I^{131} CONCENTRATIONS IN VARIOUS ENVIRONMENTAL SAMPLES

by
J. K. Soldat

ABSTRACT

A study was made of the relationship between I^{131} concentrations in air, water, vegetation, milk, and cattle thyroids in the vicinity of Hanford during the period January 1961 through April 1963. The study provides some insight to the magnitude of the parameters involved in the passage of I^{131} down the food chain to man, and illustrates the rate at which I^{131} concentrations decrease following relatively acute depositions of fallout materials. The major source of the I^{131} was fallout of debris from nuclear weapons tests. Concentrations noted during periods of testing were 10 to 100 times those found when no testing was in progress.

Fresh milk constituted the principal mode of intake of I^{131} for persons residing in the Hanford environs. Concentrations in milk samples collected from local dairy farms averaged about 50 picocuries of I^{131} per liter (pc/l) during 1961, and 40 pc/l during 1962. The potential radiation dose received by a small child (with a 2 gram thyroid) via milk consumption was estimated to be about 400 times that received via inhalation during the period under study. For an adult (with a 20 gram thyroid) the ratio of thyroid exposure via milk to that via inhalation was estimated to be about 40 to 1.

INTRODUCTION

Samples of air, water, vegetation, milk, and foodstuffs, and measurements of ambient dose rates are obtained routinely in the vicinity of the Hanford project by the Environmental Studies and Evaluation Operation. This extensive surveillance program is designed to determine the radiological status of the environs and to furnish data required for making reasonably accurate estimates of the internal and external radiation exposures received by the local residents. The program and the measurements obtained have been well documented. The present study utilized I^{131} measurements summarized in the 1961 and 1962 annual environmental reports(1,2) and in the report for the first quarter of 1963.(3) Sampling methods are described in these same periodic reports and in a recent paper by Soldat.(4) Figure 1 is a map of the Hanford environs illustrating various sampling sites for air, water, milk, and pasture grass.

The data evaluated included results of I^{131} measurements obtained on the following samples.

1. Weekly grab samples of Columbia River water collected below the Hanford project at Pasco, Washington.
2. Caustic scrubber air samplers operated at four nearby communities and changed weekly.
3. Samples of milk collected daily to weekly from five dairy farms in the vicinity of Hanford.
4. Samples of alfalfa collected periodically from one farm during 1961, and samples of pasture grass collected daily to weekly during 1962 and 1963 from the farms where the milk was purchased.

5. Cattle thyroids collected in batches of 3 to 6 several times per month from one slaughterhouse during 1961, and from five slaughterhouses in 1962 and 1963.

RESULTS

Monthly average values of I^{131} concentrations in water, air, grass, milk, and cattle thyroids are tabulated in Table I, and are illustrated in Figures 2 through 6. The relationship between the I^{131} concentrations in the various samples are tabulated in Table II.

DISCUSSION

It is obvious that the relationships are only approximations since the ratios varied widely with season of the year and with rate of influx of fresh fallout. It was impossible to separate all of the various factors which could have been affecting the relationships. The seasonal factors involved included feeding practices, weather, thyroid activity, and growth rate of the grass. In addition to these were the differing physical and chemical forms of the I^{131} arriving with fresh fallout. Such different forms probably have different rates of transfer from air to plant and perhaps even from plant to cow to milk.

Some work has been done at Hanford on the chemical form of both gaseous and particulate radioiodine in air. This work will be summarized by R. W. Perkins at the forthcoming Symposium on the Biology of Radioiodine.[5] The results of that study indicated that the percentage of I^{131} which arrived in particulate form with fallout materials was highly variable. This variation adds to the difficulty of assessing the magnitude of the various parameters.

TABLE I

AVERAGE I^{131} CONCENTRATIONS OF ENVIRONMENTAL SAMPLES COLLECTED IN THE VICINITY OF HANFORD

Month	Columbia River Water pc/liter	Air 10^{-4} pc/m^3	Pasture Grass pc/kg	Milk pc/liter	Cattle Thyroids pc/g
1961 January	14	400	-	50	14
February	19	210	-	ND	21
March	13	200	-	17	5.8
April	9	140	-	27	38
May	6	60	34*	33	4.6
June	< 3	110	-	36	-
July	< 3	80	ND*	ND	6.1
August	6	250	ND*	ND	4.2
September	5	150	550*	40	-
October	14	910	-	180	220
November	8	820	-	150	-
December	7	470	-	17	140
1962 January	9	620	-	3.4	14
February	7	530	-	3.1	3.5
March	8	320	-	2.5	4.6
April	5	540	60	10	9
May	2	350	ND	2.6	5.6
June	< 2	670	60	16	34
July	4	390	10	5.1	50
August	4	540	95	11.5	41
September	6	2420	970	62	450
October	10	1260	910	89	575
November	6	910	3800	190	510
December	6	290	100	70.5	610
1963 January	5	820	-	4.3	63
February	6	430	-	3.3	6
March	11	410	-	2.1	2.5
April	10	90	-	2.5	2

* Alfalfa samples from one farm only.

ND Not Detected.

TABLE II

RATIOS OF AVERAGE I^{131} CONCENTRATIONS OF ENVIRONMENTAL SAMPLES COLLECTED IN THE VICINITY OF HANFORD

Month	pc/kg Grass per 10^{-4} pc/m^3 Air	pc/l Milk per pc/kg Grass	pc/g Thyroid per pc/kg Grass	pc/g Thyroid per pc/l milk
1961 January	-	-	-	0.28
March	-	-	-	0.34
May	0.57	0.97	0.14	0.14
September	3.7	0.073	-	-
October	-	-	-	1.2
December	-	-	-	8.2
1962 January	-	-	-	4
February	-	-	-	1.7
March	-	-	-	1.8
April	0.11	0.17	0.15	0.90
May	-	-	-	2.2
June	0.09	0.27	0.57	2.1
July	-	-	-	9.8
August	0.18	0.12	0.43	3.6
September	0.40	0.064	0.46	7.2
October	0.72	0.098	0.63	6.5
November	4.2	0.050	0.13	2.7
December	0.34	0.070	6.1	8.6
1963 January	-	-	-	15
February	-	-	-	1.8
March	-	-	-	1.2
April	-	-	-	0.8

I^{131} in Irrigation Water

Monthly average I^{131} concentrations in Columbia River water sampled below the project at Pasco, Washington, are tabulated in Table I. This water was used for irrigation at two of the five farms where pasture grass and milk were sampled. The I^{131} content of the irrigation water was low enough so that no detectable contribution to the I^{131} content of the pasture grass should have resulted from this source. A comparison was made of the I^{131} content of grass collected from these two farms, and the grass collected from three farms where other water sources are used for irrigation. No significant difference was found between the two sets of data. Therefore, no further consideration was given to this source of I^{131}.

Ratio of Milk, Grass, and Thyroid Contents

An attempt was made to ascertain the percentage of the cows' feed provided by fresh pasture during October and November 1962. The owners of the five dairy farms indicated that fresh pasture provided from almost none up to 100 percent of their cows' feed at that time. The approximate overall average was about 50 percent for the five farms combined. If this percentage held true for the entire grazing season (it was probably higher in the spring and early summer), then the theoretical ratio of milk to grass would be 0.3 at 100 percent pasture instead of the 0.15 actually found. Also, the theoretical thyroid-to-grass ratio at 100 percent pasture would be 0.9. The thyroid-to-milk ratio should be independent of the percentage of fresh pasture provided the stable iodine content of the cows' diet is not changed significantly when the percentage pasture is changed.

<u>Time Relationships</u>

Although not readily apparent from the averages presented in the Figures 2 through 6, it is possible to deduce from the individual sample results some information related to the time sequence of events following relatively acute depositions of I^{131}. An average delay of ~6 days was found between the appearance of a peak I^{131} content in vegetation and its appearance in milk. A delay of twelve days was found between the peak concentration in grass and the peak concentration in the cow's thyroid. This latter time has been corrected for the approximately one to two days spent by the cows on dry feed at the slaughterhouse before the thyroid samples were obtained.

These time delays were somewhat longer than those estimated by the British following the Windscale incident of 1957.[6] They report a theoretical delay of only two to three days between grass and milk. Also, Bustad et al.[7] report time delays of about four days between peak I^{131} concentrations in feed and milk, and about seven days between feed and thyroid. The time delays found in the present study were undoubtedly lengthened by the continued influx of I^{131} following the peak depositions.

The effective half-life for clearance of the I^{131} from the grass following the peak concentration measured in the fall of 1962 was about six days. Effective half-life in milk and cow thyroid was about eight to nine days following the 1961 peak and about ten days following the peak observed in 1962. These relatively long effective half-lives may also reflect the continued influx of lesser amounts of I^{131} after the peak occurred.

CONCLUSIONS

Since the data were obtained under field conditions for the purpose of evaluating human exposures, many of the parameters normally controlled in laboratory experiments were either undefined or highly variable during the period under study. Therefore, any conclusions drawn from the data are applicable only to the Hanford environs and for the particular weather and feeding conditions in existence at the time of the study. Additional information required before more quantitative relationships can be established include:

1. Stable iodine and I^{131} content of all feed consumed by the cows.
2. More exact information on the relative amounts of fresh pasture and dry hay consumed.
3. Lower detection levels for I^{131} in pasture grass to match the present excellent capabilities for measurement of I^{131} in milk and thyroid samples.

For Purposes of defining approximate local field conditions, one could ignore the multitude of uncontrolled variables and calculate the average ratio for the 1961 and 1962 growing seasons. When this is done, the following relationships are obtained.

$$\frac{\text{pc/kg of Grass}}{\text{pc/m}^3\text{ of Air}} \approx 4{,}200$$

$$\frac{\text{pc/liter of Milk}}{\text{pc/kg Grass}} \approx 0.15$$

$$\frac{\text{pc/gram Thyroid}}{\text{pc/kg Grass}} \approx 0.45$$

$$\frac{\text{pc/gram Thyroid}}{\text{pc/liter Milk}} \approx 3.0$$

$$\frac{\text{pc/liter Milk}}{\text{pc/m}^3\text{ Air}} \approx 600$$

$$\frac{\text{Dose to 20-gram Thyroid from Milk}}{\text{Dose to 20-gram Thyroid from Air}} \approx 40$$

$$\frac{\text{Dose to 2-gram Thyroid from Milk}}{\text{Dose to 2-gram Thyroid from Air}} \approx 400$$

This latter relationship is based on the assumption that the doses to both the 2-gram and the 20-gram thyroid via inhalation are the same because of an almost constant ratio of breathing rate and thyroid size versus age. The data from individual sampling locations implied a time delay between peak I^{131} concentrations in grass and those in milk and cow thyroids of about six days and twelve days, respectively. Effective half-times for clearance of relatively acute depositions of I^{131} from grass, milk, and cow thyroids ranged from six to ten days following the peaks noted in both 1961 and 1962.

ACKNOWLEDGMENTS

I wish to express my thanks to the many individuals who provided necessary assistance in the preparation of this paper. They include members of the Environmental Monitoring Operation who collected the samples, Mrs. Darlene Moore who summarized the data, and J. M. Prewett who drew the figures.

REFERENCES

1. Radiological Evaluation Staff, Evaluation of Radiological Conditions in the Vicinity of Hanford for 1961, HW-71999, Unclassified. (March 1, 1962)

2. Radiological Evaluation Staff, Evaluation of Radiological Conditions in the Vicinity of Hanford for 1962, HW-76526, Unclassified. (March 1, 1963)

3. Radiological Evaluation Staff, Evaluation of Radiological Conditions in the Vicinity of Hanford, January to March 1963, HW-77533, Unclassified. (May 8, 1963)

4. Soldat, J. K., Management of Radioactive Effluent Gases at Hanford Atomic Products Operation, HWSA-2629 Rev., Unclassified. (October 24, 1962)

5. Perkins, R. W., Physical and Chemical Forms of Radioiodine in Fallout. (Presented at the Symposium on the Biology of Radioiodine, June 17-19, 1963, at Richland, Washington.)

6. Chamberlain, A. C., R. J. Gardner, and D. Williams, "Environmental Monitoring After Accidental Deposition of Radioactivity", Reactor Science and Technology, (J.N.E. Parts A and B), Vol. 14. (1961)

7. Bustad, L. K., E. E. Elefson, E. C. Watson, D. H. Wood, and H. A. Ragan, "I^{131} in the Thyroid of Sheep and in Food, Thyroid, and Milk of Dairy Cows", Hanford Biology Research Annual Report for 1962, HW-76000, Unclassified. (1963)

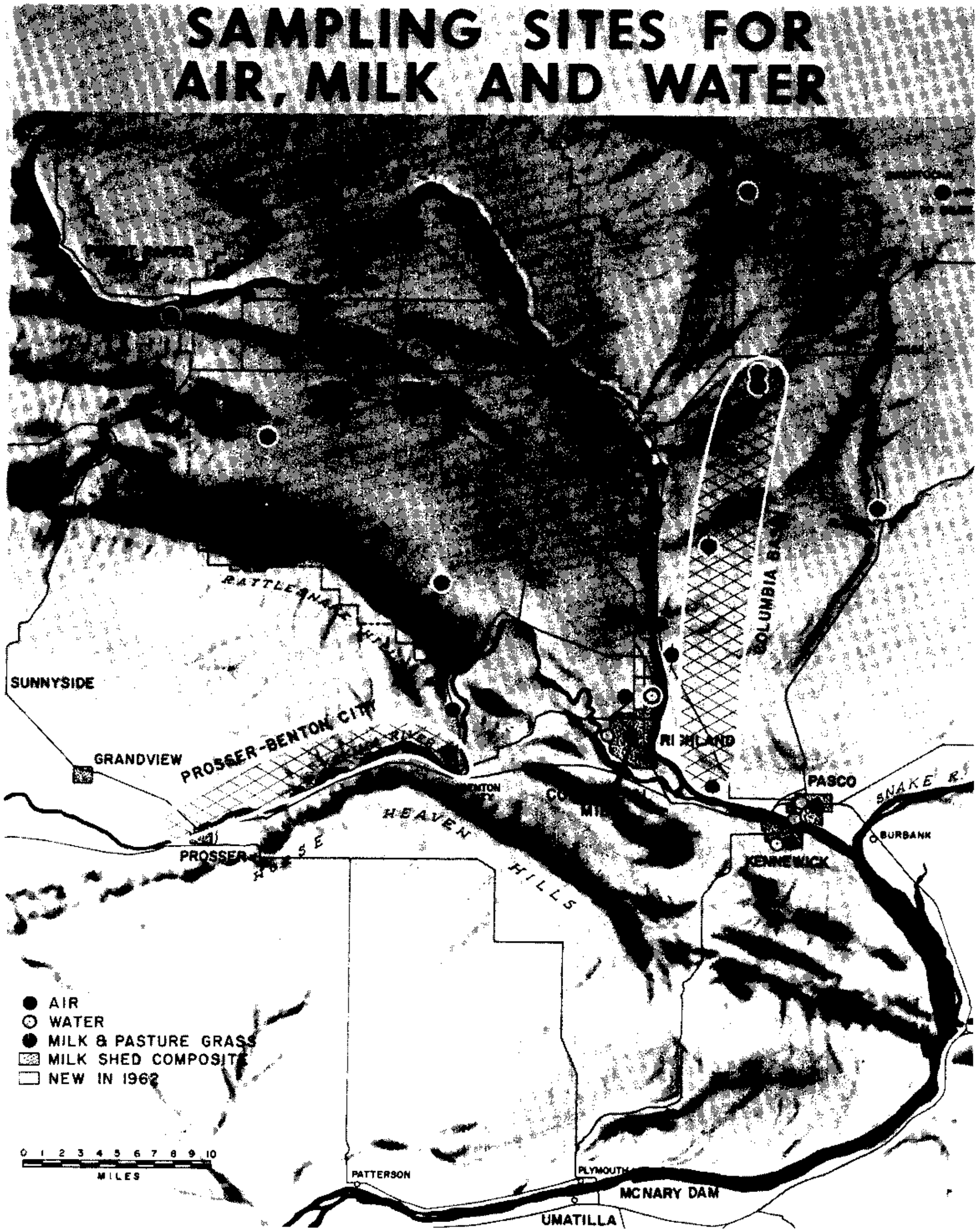

FIGURE 1

Hanford Plant Environs and Sampling Sites

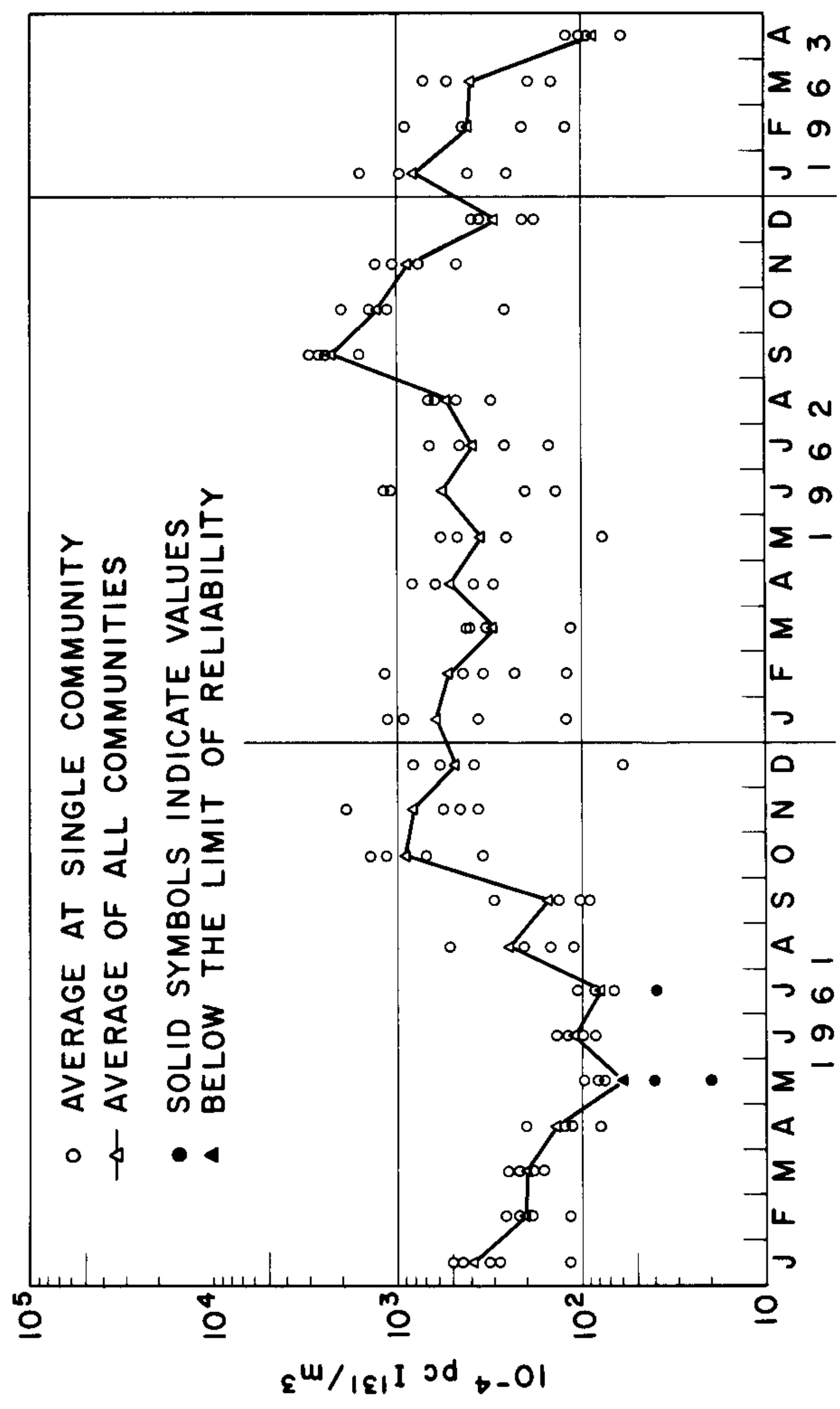

FIGURE 2

Monthly Average Concentrations of I^{131} in Air at 4 Communities

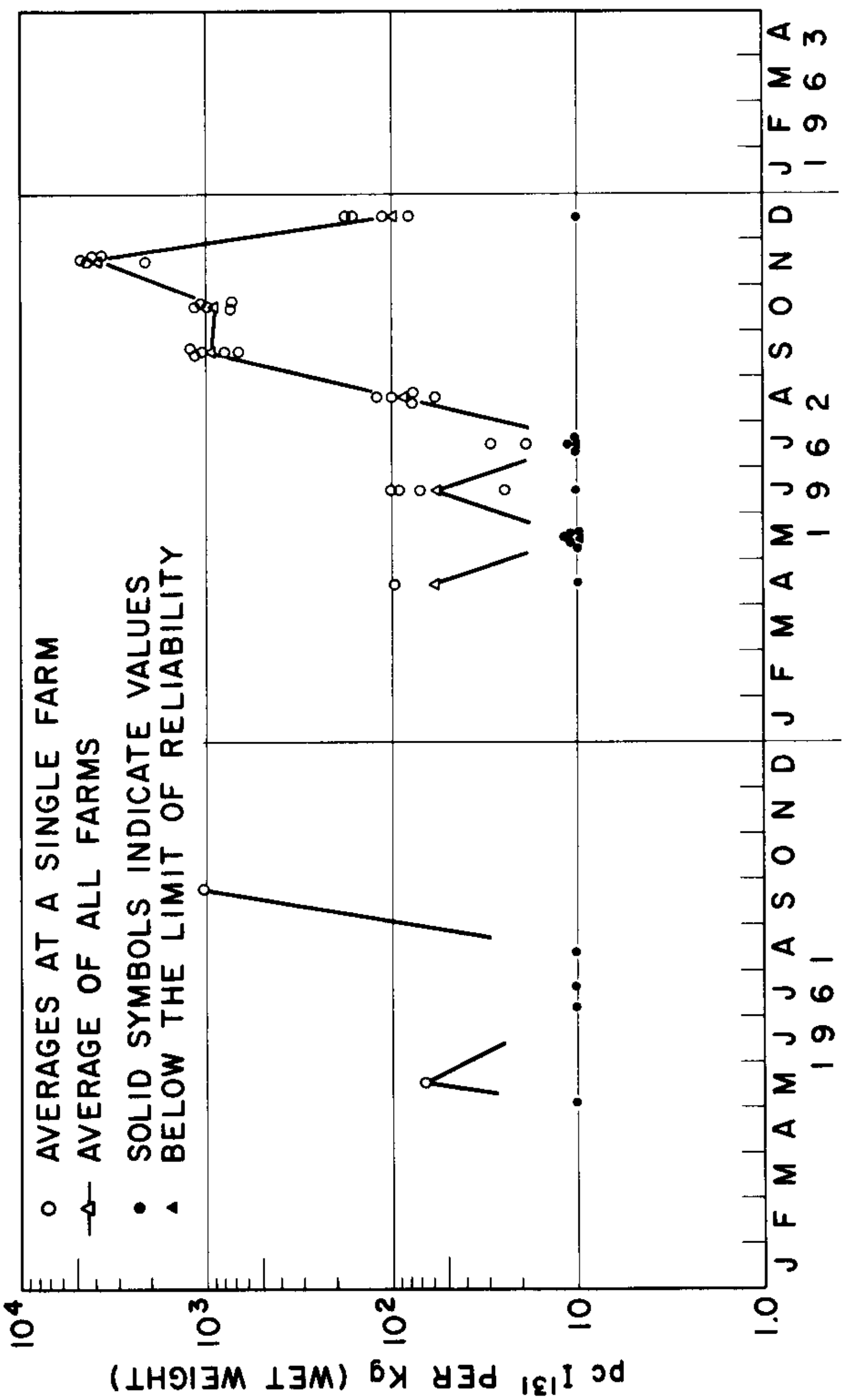

FIGURE 3

Monthly Average Concentrations of I^{131} on Pasture Grass at 5 Dairy Farms

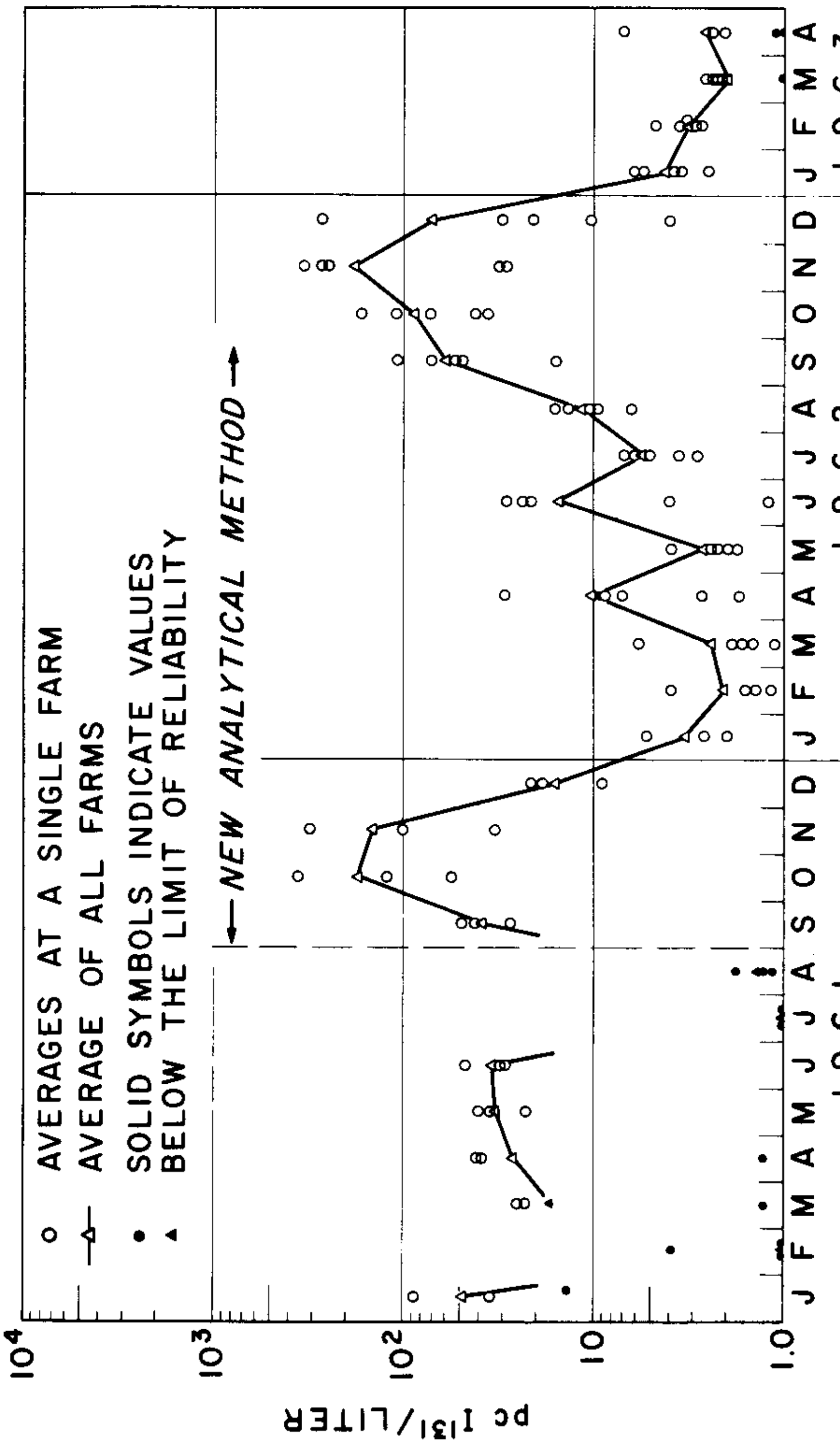

FIGURE 4

Monthly Average Concentrations of I^{131} in Milk From 5 Dairy Farms

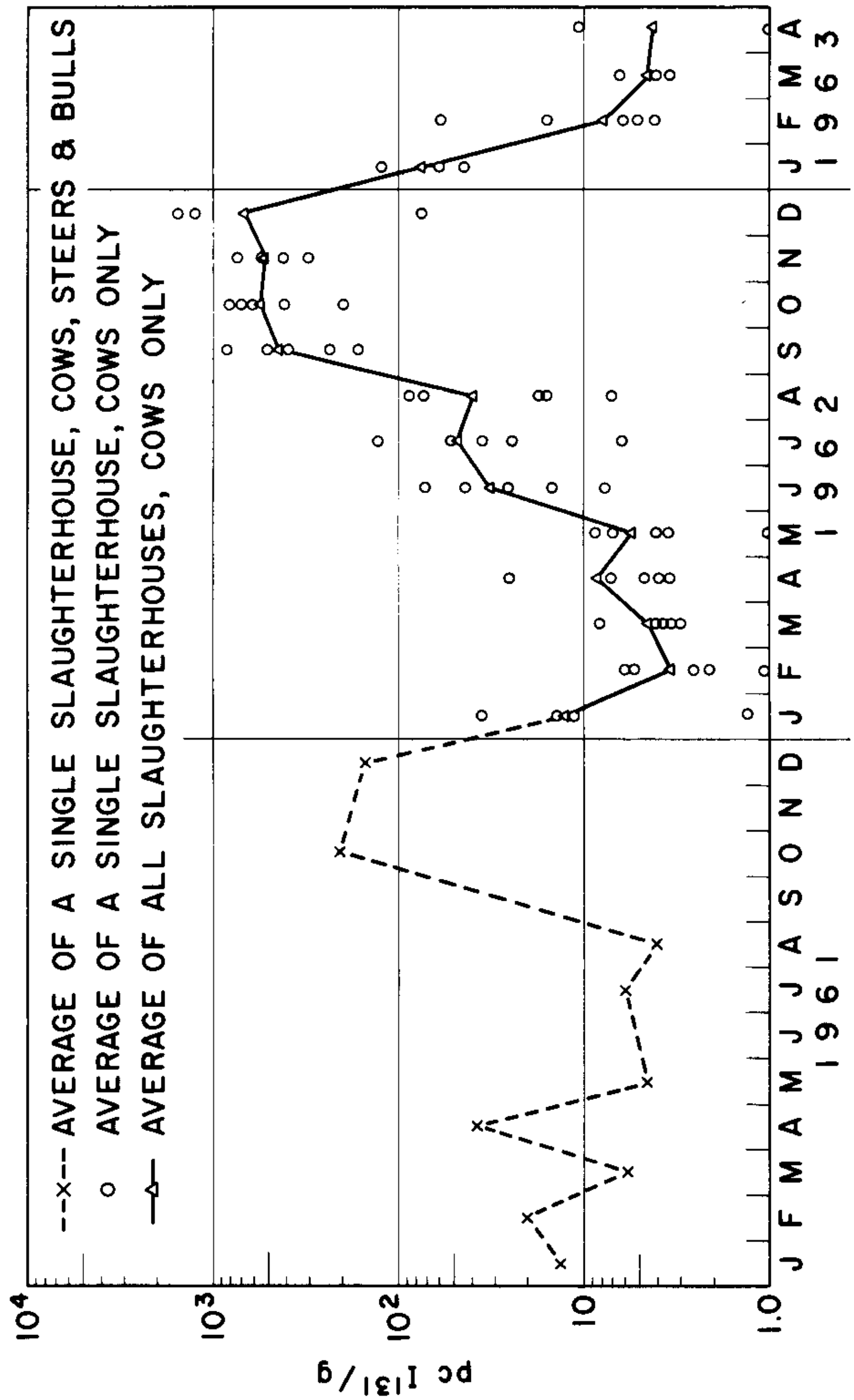

FIGURE 5

Monthly Average Concentrations of I^{131} in Cattle Thyroids at 5 Slaughterhouses

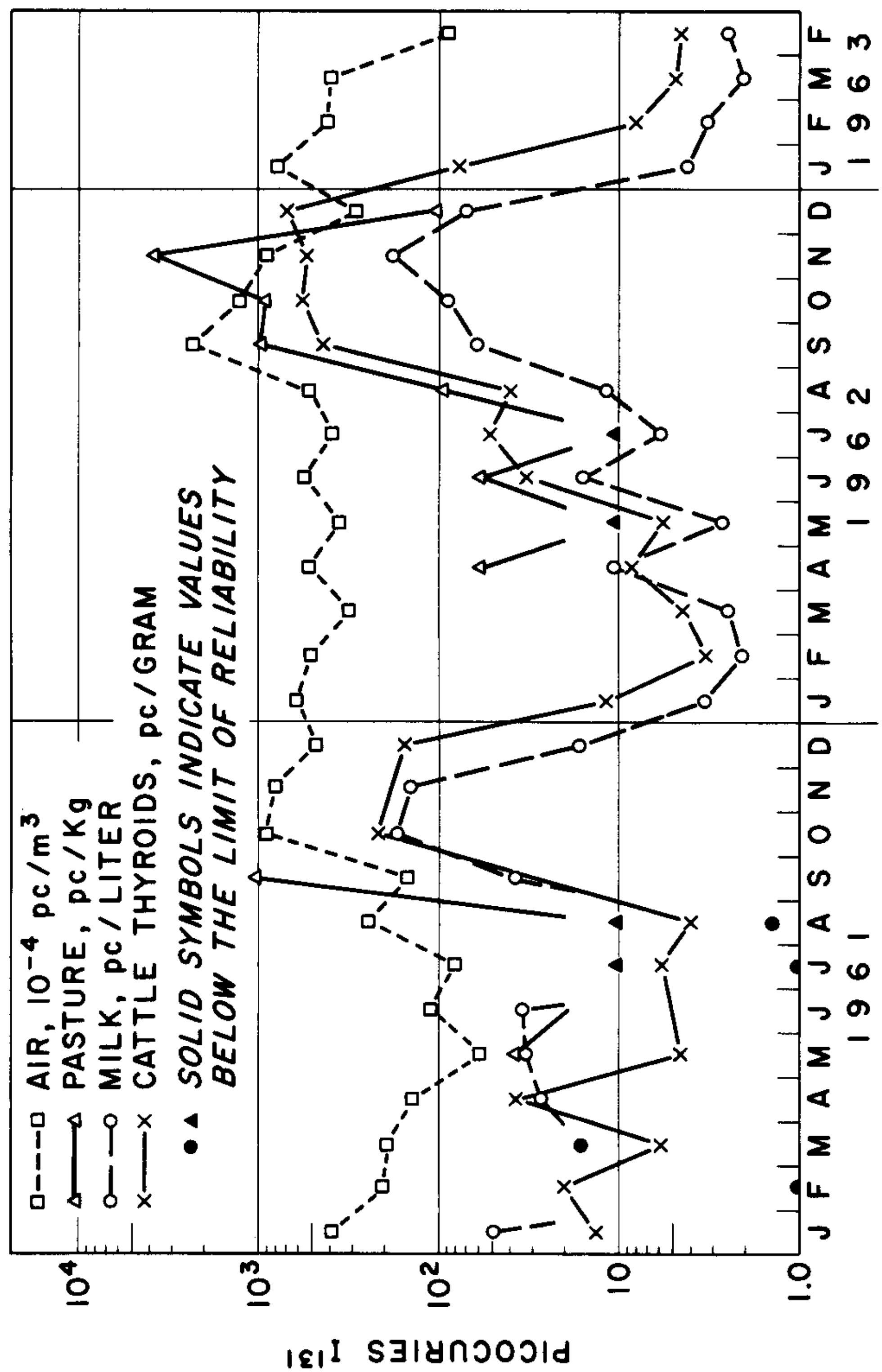

FIGURE 6

Comparison of Monthly Average Concentrations of I^{131} in Various Environmental Samples

AEC-GE RICHLAND, WASH